A Summary of the Current Forest Management Strategies for the South Puget HCP Planning Unit

Washington State
Department of Natural Resources

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Acronyms

BNR	Board of Natural Resources
cwd	Coarse woody debris
dbh	Diameter at breast height
DEIS	Draft Environmental Impact Statement
DNR	Department of Natural Resources
Ecology	Department of Ecology
HCP	Habitat Conservation Plan
MoRF	Movement, roosting, and foraging
NAP	Natural Area Preserve
NMFS	National Marine Fisheries Service
NRCA	Natural Resource Conservation Area
NRF	Nesting, roosting, and foraging (habitat)
NSO	Northern spotted owl
SEPA	State Environmental Policy Act
SOMU	Spotted Owl Management Unit
USFWS	US Fish and Wildlife Service
WAU	Watershed Administrative Unit
WRIA	Watershed Resource Inventory Area

Purpose

This document summarizes the current management strategies used in the South Puget Habitat Conservation Plan planning unit. This summary provides a background of the planning unit, the management objectives and general strategies. Also included is a brief summary of the implementation and monitoring strategies and current planning efforts. Some of the maps, charts, tables and figures can also be found in DNR's 2008 South Puget HCP Planning Unit Draft EIS.

The Planning Area

The South Puget planning area was delineated in the *Habitat Conservation Plan* (WDNR 1997) (see Map 1 p.6, DNR 2008). This planning unit, as with most others, was delineated by clustering Water Resource Inventory Areas (WRIAs), as defined by the Washington State Department of Ecology (Ecology). The counties and parts of counties in this planning unit that contain DNR-managed lands are southern King, Pierce, eastern Thurston, north-central Lewis, Kitsap, and eastern Mason. The Cedar, Green, White, Carbon, Puyallup, Nisqually, and Deschutes rivers are also included in the planning unit.

This planning unit is the most densely populated region in Washington with more than 50 percent of its area supporting urban environments. Most of the unit is located in the Puget Trough ecoregion. However, small portions are located in the neighboring West Cascades ecoregion.

- The Puget Trough includes the marine waters of the Puget Sound and the lowlands. Nearly eighty percent of the planning unit is below 3,000 feet in elevation; half — mostly the lands immediately adjacent to the Puget Sound — is less than 1,000 feet in elevation. The Olympic Mountain rain shadow strongly influences the climate and precipitation (usually in the form of rain) averages 20 to 70 inches per year. Summers are generally warm and dry, and winters are relatively mild.

  Forests in this region are dominated by Douglas-fir with western hemlock and western red cedar as primary species. The conifer forest mosaic is interspersed with hardwood species such as bigleaf maple and red alder. In addition to forests, the ecoregion contains a number of grasslands, wetlands, bogs, riparian areas and estuaries. Urbanization and fire suppression threaten rare plant species in this area because forests are more prone to catastrophic events as they become overstocked with trees and interspersed with houses.

- The highlands of the West Cascades ecoregion receive from 50 to 140 inches of precipitation every year, and higher elevations are often packed with snow. This ecoregion is very large and ecologically diverse. Many riparian areas include broadleaf species, wetlands, grassy balds, and oak woodlands. Conifer forests, consisting mainly of Douglas-fir and western hemlock mixed with red alder and bigleaf maple, cover the landscape at all elevations. Middle elevations in this area also contain Pacific silver fir and noble fir. Although the highest DNR-managed forests in this planning area are at about 5,000 feet, mountain hemlock and silver fir forests are found at about 7,000 feet, along with sub-alpine parklands.

The planning unit includes all or part of the following counties: southern King, Pierce, eastern Thurston, north-central Lewis, Kitsap, and eastern Mason. The forested state trust lands in the planning unit are commonly referred to as the Elbe Hills, Tahoma, Tahuya, Green Mountain, Sherwood, Tiger Mountain, McDonald Ridge, and Grass Mountain state forests.

DNR manages nearly 144,000 acres of forested state trust lands in this planning unit alone, and must manage them consistent with ongoing direction from the Board and the agency. Planning unit managers are expected to balance varied public expectations with achieving the maximum effective development and use of the land for the beneficiaries and meeting wildlife habitat requirements and other social-cultural and environmental values.

State forested trust land management is carried out within the framework of state and federal laws; the state constitution; the federal Enabling Act of 1889; DNR's Policy for Sustainable Forests (WDNR 2006) , Habitat Conservation Plan (WDNR 1997), and Sustainable Forest Management including the Sustainable Harvest Level (WDNR, 2004) and its 2007 addendum; and with oversight and policy direction provided by the Board of Natural Resources (the Board). DNR also follows current Washington State Forest Practices Rules (Chapter 76.09 Revised Code of Washington [RCW] and Title 222 WAC).

Forest Management Plan Objectives

The South Puget HCP planning unit has the following objectives:

1. Provide habitat conditions that support the objectives of the 1997 trust lands Habitat Conservation Plan.
    i. Specific targets are to create and maintain 50 percent of the designated spotted owl management areas in nesting, roosting foraging and dispersal habitat and to develop older stand conditions with riparian management zones.
    ii. Create older forest conditions on forested state trust forest lands within the South Puget HCP planning unit. The target is to attain at least 10 percent of the forested state trust lands within the planning unit within the niche diversification and fully functional forest stand development conditions within the life of the trust lands Habitat Conservation Plan (1997-2067).
2. Generate trust revenue through the sale of the timber. The target for SP HCP planning unit is a harvest decade level of 265 million board feet of timber to generate approximately $79 million. This decade harvest level was determined as part of the 2004 and 2007 Sustainable Harvest Calculation (see Sustainable Harvest Calculation http://www.dnr.wa.gov/BusinessPermits/Topics/SustainableHarvestImplementation/Pages/lm_sust_harvest_implement.aspx). The Department is directed by state law to readjust the acreages and calculate the sustainable harvest periodically (RCW 79.10.320). This analysis is directed by the Board of Natural Resources through the 2006 Policy for Sustainable Forests.
3. Apply all Board and agency resolutions, policies and procedures using the key principles of the trust mandate, within current budgetary and administrative constraints, and according to state and federal law.
4. Manage public access and recreation on state trust lands that provide a safe recreational experience and a quality user experience and the protection of the sustainable resource within the framework of compatibility with trust objectives.

Current Policy and Procedural Direction

The current direction is derived from implementing the existing Board policies and forest management direction contained in the *Policy for Sustainable Forests* (DNR, 2006), the1997 *Habitat Conservation Plan* (DNR, 1997), current department procedures, memoranda of understanding, and federal and state statutes.

Management includes *Implementation Procedures for the Habitat Conservation Plan Riparian Forest Restoration Strategy* (DNR, 2006). The strategy is designed to achieve restoration of high-quality aquatic habitat to support recovery efforts on behalf of federally listed salmon species, and to contribute to the conservation of other aquatic and riparian obligate (dependent) species. DNR plans to combine various types of active management with natural development of unmanaged stands to achieve these riparian objectives resulting in the restoration of structurally complex riparian forests that provide ecological functions consistent with the strategy.

The procedure *Identifying and Managing Structurally Complex Forests to Meet Older Forest Targets (Westside)* (PR14-004-046) describes how DNR will manage suitable structurally complex forests to meet older-forest targets. Older forests are represented by the niche diversification and fully functional stages of stand development. Stand structural complexity begins notably in the biomass accumulation stage and provides increasing benefit as the stand progresses into the niche diversification and fully functional stages (DNR, 2004). The goal is to achieve functional older-forest structures across 10 to 15 percent of each western Washington planning unit within 70 to 100 years. The identification and review of landscape level management strategies to achieve the 10 to 15 percent older-forest target will be completed during forest land planning.

Major Landscape Management Strategies

Economic performance

Economic performance strategies relate to product marketing and land transactions. These two topics address the range of activities and various commodities that should be considered in producing revenue from forested state trust lands where different approaches are being considered to implement issues related to financial diversification.

Financial diversification is important in meeting DNR's obligations to each trust beneficiary. Financial diversification deals with the forest asset class only and discusses both marketing and sales of forest products, as well as income from non-timber forest products and services.

Product marketing

DNR's professional region forest managers design timber sales based upon a series of considerations that include, but are not limited to: the topography of the site, the issues associated with the area (social, ecological, economic), the most cost-effective means of harvest, the road system needed to access the site, tree species composition, and the market value of the timber. Once the timber sale has been laid out, a public auction is held and the timber is sold to the highest bidder. The timber purchaser usually has two years from the time of purchase to harvest the timber and complete all contractual requirements.

There are three basic methods of selling timber: lump sum, scale sales, and log sort sales. In addition, local harvesters are granted products leases in a small but growing market share.

Under current management, DNR continues working with a timber sales program dominated by lump sum sales, but including all three different sales types (lump sum, scale sales, log sort sales) that are offered. This management offers a mix of special forest products and marketing strategies that take advantage of existing markets and market value fluctuations to improve the overall financial performance.

Land Transactions

Financial diversification among trust asset classes is guided by DNR's 1998 *Asset Stewardship Plan* and the Asset Stewardship Council. DNR strives to improve the value of trust lands, increase their income potential, and reduce financial risks to the trusts by diversifying the land base, both among the asset classes and within each asset class. Land transactions are designed to help meet these goals. DNR selectively repositions trust lands through three different processes: land exchanges, public auctions, and direct sales to public agencies (without public auction).

"Funds from trust land sales to other public agencies are deposited into the Real Property Replacement Account Fund. Funds from the sales of trust lands at public auction are either deposited in the Land Bank Account or the permanent fund. The Real Property Replacement Account and the Land Bank Account are used to purchase replacement properties to be managed to benefit the trust" (RCW 79.17.200).

DNR current approach is to acquire lands that optimize economic short- and long-term trust benefits for trust forest assets. DNR continues to proceed by transitioning out of trust lands that are isolated or have drawbacks for long-term management. DNR continues to work with local governments to ensure that local land use decisions, related to zoning and access, do not reduce trust land values or restrict management options.

Forest Ecosystem Health and Productivity

Forest health considerations specifically include insect, disease or damaging agents, and the stand conditions which influence the forests susceptibility to them. Older-forest conditions are important across DNR ownership in order to meet ecological function requirements such as life history, habitat for specific wildlife species, and clean water.

Treatments such as DNR's version of biodiversity pathways (DNR 2004) can be used to create complex, multi-aged forest stand structures. The phrase *biodiversity pathways* is used to describe management approaches used in forest stands and forested landscapes to simultaneously achieve objectives of conserving biodiversity and generating revenue. By developing stand structures typical of older forests, this approach can be used to meet the older-forest objectives of the *Habitat Conservation Plan* (DNR, 1997).

The Board has directed DNR to actively manage lands to achieve structurally complex forest conditions, especially in those suitable stands in the biomass accumulation forest development stage. This approach is intended to help achieve older-forest structures across 10 to 15 percent of each western Washington HCP planning unit within 70 to 100 years (DNR, 2006 p. 3-177). Older forests with structures that contribute to this goal are represented by stands in the fully functional and niche diversification stand development stages.

Biomass accumulation stands, under natural (unmanaged) conditions, are stands that have passed their peak density but still contain a large number of trees. These remaining trees are generally large and have enough room and resources to grow and put on woody biomass. Franklin (2002) and Carey (2003) highlight this stage as biomass accumulation, describing the principal ecological process of this stand development stage. The *Final Environmental Impact Statement on Alternatives for Sustainable Forest Management of State Trust Lands in Western Washington* (July 2004) describes this stage as botanically diverse. The biomass accumulation stage is still considered as structurally complex, but is differentiated from the niche diversification and fully functional development stages by its lack of decadence, its lack of standing deformed live trees, the presence of standing large dead trees, and the lack of large woody debris (LWD).

Through landscape assessments, DNR will identify suitable structurally complex forest stands to be managed to meet older-forest objectives. Managing stands along developmental pathways requires forest managers with a comprehensive understanding of the structures and processes in forest stands (Franklin 2002, Carey 2003). By applying innovative silviculture techniques, foresters can accelerate the development of structurally complex forest stand conditions such as snags, decadent trees, down wood, multiple tree species, and multiple ages over time. This biodiversity pathway concept is important on lands targeted to provide the most benefit to wildlife species dependent on older forests.

The current management strategies follows the procedure (PR14-004-046) *Identifying and Managing Structurally Complex Forests to Meet Older Forest Targets (Westside),* emphasizing a site-by-site analysis prior to the completion of a forest land plan. Any final harvests currently proposed in structurally complex stands must be analyzed for their role in meeting the 10 to 15 percent target for older forests. Depending upon the analysis results, the stands are either deferred or harvested.

This approach defers all stands designated for achieving older-forest conditions over the long term (70 to 100 years) from final harvest. Only harvest activities, such as thinnings, which enhance or accelerate development of older-stand conditions, would occur in these designated stands. Once the threshold is met, all additional stands meeting older-forest conditions are then available for the full range of DNR silvicultural management.

Addressing Forest Health

Maintaining and improving forest health depends upon avoiding forest conditions that are vulnerable to damage (prevention) and remedying problems as they arise (treatment). Preventive actions include growing site-appropriate tree species at stocking levels where the trees have sufficient energy to tolerate temporary stresses, defend themselves from pests, and recover from minor damage. Treatments may be used to directly suppress pest populations, improve tree vigor, and change stand structure when monitoring reveals threats are present or developing. Some of the threats include insects, disease, noxious weeds, and animal damage.

The current approach to forest health encourages pre-commercial thinning when funding is available. Invasive species are eradicated by DNR only when directed to do so by an authorized agency; and on a site-by-site basis. DNR further trains foresters to recognize the presence and impacts of root diseases, pathogens, insect infestations, and animal damage. This training results in foresters better adapting their management strategies to reduce impacts and to achieve the desired forest conditions.

Hydrologic Maturity (Watershed Systems)

DNR manages land areas that contribute water, organic matter, dissolved nutrients and sediments to a particular stream, river, lake, or ocean shoreline; these are called forested watersheds. These watersheds vary in size from small basins to groups of watersheds, or WRIA, that can include hundreds of thousands of acres. The 1997 *Habitat Conservation Plan* planning units are based on groupings of WRIA.

WRIA were formalized under WAC 173-500-040 and authorized under the Water Resources Act of 1971, RCW Chapter 90.54 RCW. Ecology was given responsibility for developing and managing these administrative and planning boundaries. These WRIA boundaries represent the administrative underpinning of Ecology’s business activities. The original WRIA boundary agreements and judgments were reached jointly in 1970 by DNR, Ecology, and the Washington Department of Fisheries and Game, now referred to as WDFW (Ecology website).

Forested watersheds are water sources for municipal water supplies, irrigation, stream and subsurface flows throughout the state. They also provide quality habitat for aquatic organisms, as well as recreational opportunities. The condition of the forest in these watersheds has a significant influence on the quality and quantity of the resource (DNR 2004). The nature of the forest cover can also influence the timing and magnitude of peak water flows. Therefore, how DNR manages the forested trust lands is an important contribution to the overall effort to controlling and mitigating probable significant adverse direct, indirect, and cumulative impacts related to water quality and quantity.

Under current management DNR implements hydrological maturity management in all rain-on-snow basins per procedure (PR 14-004-060) and in the planning unit also maintains the hydrologic maturity criteria for Lake Tahuya. A brief analysis was conducted to provide protections from perceived flooding issues as a result of harvesting activities in that area.

Northern Spotted Owl Conservation

DNR’s conservation objective for the northern spotted owl (NSO) is to provide habitat that makes a significant contribution to demographic support, maintenance of species distribution, and facilitation of dispersal. The objective is intended to provide nesting, roosting, and foraging (NRF) habitat and dispersal habitat in strategic areas in order to achieve the conservation objective. The objective is also intended to create a landscape in which active forest management plays a role in the development and maintenance of the structural characteristics that constitute such habitat.

This planning unit contains most of the designated dispersal management areas on lands managed under the HCP. Due to past timber management activities in these areas, the current ecological conditions are dominated by competitive exclusion development stage forests and young, overstocked plantations. Neither condition contributes to the life requirements of dispersing northern spotted owls.

Current management in designated dispersal management areas according to the current 1997 HCP definition of dispersal habitat, a target of maintaining at least 50 percent of each spotted owl management unit (SOMU) in dispersal condition and follows the concurrence letter between DNR and United State Fish and Wildlife Service dated September 6, 2006.

Social and Cultural Benefits

Forested state trust lands play an important role in providing opportunities for public access and recreation and preserving the visual integrity of Washington's forested landscapes. These landscapes contribute to local, regional, and state economies through the sale of forest products.

Recreation and Access

Today, the public's demand for access to forested state trust lands via trails and roads that have minimal support facilities has expanded in both type and intensity. At the same time, expectations for environmental stewardship set higher standards and impose legal obligations that were not recognized thirty-five years ago. The combination of more people, more advanced recreational technology, and heightened environmental awareness raises new questions about the long-term sustainability of the natural resources and current recreational opportunities.

DNR's primary recreation focus is to provide a primitive experience in a natural setting through trails, trailhead facilities and rustic camping facilities. DNR currently manages campgrounds and day-use facilities such as picnic areas, boat launches, and interpretive areas. In addition to trails and specific sites, DNR also manages forest roads primarily designed and maintained for forest management purposes that also provide considerable access for dispersed recreation activities such as hunting, fishing, bird watching, and sightseeing. Most recreation and access opportunities can be characterized as dispersed in nature with primitive facilities; they are most often trail-oriented and set within a managed forest.

Recreation and public access enjoyed on trust lands must be compatible with the primary purpose of their management, which is the generation of revenue to support school construction and other public institutions. Many of the substantial public expectations for public access and recreation are compatible with DNR trust objectives, and DNR therefore provides public access opportunities on forested state trust lands as directed by the Multiple Use Act (RCW 79.10.100).

The current management approach is to maintain existing uses compatible with public access and recreation goals. The goals are the provision of a safe recreational experience and a quality user experience and the protection of the sustainable resource within the framework of compatibility with trust objectives. To meet all three goals, DNR needs to determine the types and levels of recreational activities that the land can sustain, how much recreational activity can be supported without negatively affecting trust management responsibilities, and how much activity can be supported financially.

The management strategies emphasize education for recreational users, enforcement efforts to deter inappropriate uses, and engineering — using best management practices — to address resource damage issues. Additionally, strategies include developing a comprehensive inventory and assessment of public uses to determine recreation capacity and identify specific public access issues.

Visual Impacts

DNR activities can alter the visual experience of people viewing forest stands and forested landscapes. The visibility of forest management activities — mostly timber harvest — is influenced by the position and distance of the viewpoint from the activities, the topography of the land, and the type of forest management activity. Visual changes can be localized (visible only from a particular viewpoint), or regional (visible from a broader area). The observer's perspective and personal values influence whether the reaction to the visual impact is positive, negative, or neutral.

Visual impacts can be mitigated through a variety of forest management strategies such as the timing, design (including the physical layout and harvest method), and size of timber harvest areas. At the public mapping meetings, many visually sensitive areas were identified, but DNR also used modeling tools to help identify areas of potential concern. The majority of areas identified for visual management are often already mitigated through riparian and wetland buffers, protection of unstable slopes, and/or the arrangement of wildlife trees.

The current management strategies are based on current visual management procedure (PR014-0014) which provides direction for mitigation of local and regional visual issues on a site-by-site basis. The development of DNR's forest management policies included a decision to mitigate visual impacts through various land management strategies (DNR 2006).

Tiger Mountain (Specific)

Visual impacts specific to Tiger Mountain (Map 3, p.30) were addressed in the 1986 Tiger Mountain Plan. Tiger Mountain harvesting activities are regulated by area; each watershed is limited to a specified percentage of harvesting activities in the total watershed area during any 10-year period. The objective is to create a well-distributed mosaic of different age-class forest stands (DNR 1986).

Implementation strategies identified for Tiger Mountain include:

- Harvest no more than 1/6 of each Watershed Administrative Unit (WAU) per decade.
- Inventory forest stands and develop a harvest schedule to determine DNR's ability to meet the specified percentage allotted to each WAU.
- Model the harvest schedule to determine whether a mosaic of different age-class forest stands is created over time.
- Continue with a 60-year harvest rotation age.

Other Forest Management Strategies

Additional management strategy direction for planning and operations is in the DNR forestry handbook (http://sharepoint/divisions/lm/teams/forestryhandbook/default.aspx). These strategies and direction are summarizes in Table 3 p.3 of this document.

Existing Environment and Management Today

This describes the existing environmental conditions of DNR-managed forests in the South Puget Habitat Conservation Plan (HCP) Planning Unit and DNR's current management as the department fulfills its fiduciary responsibility to the trust beneficiaries and its conservation objectives. In addition to forestlands, DNR manages uplands for Natural Area Preserves, Natural Resource Conservation Areas, administrative sites, and recreation areas. References in this document are referring to tables, charts, maps and appendices in the 2008 Draft EIS for the South Puget Planning Unit.

The current environmental setting is the starting point for an examination of the potential environmental impacts of the forest management alternatives being proposed. Topics include: forest conditions and management (including forest health), watershed systems (hydrology, water quality, wetlands, riparian areas and fish), wildlife, northern spotted owls, soils, forest roads, recreation, visual management, land transactions, cultural resources, climate, air, climate change, and carbon sequestration.

DNR manages over 145,000 acres of forested state trust lands in the planning unit, including portions of the Cedar, Green, White, Carbon, Puyallup, Nisqually, and Deschutes rivers. Watersheds vary in size from small basins to Watershed Resource Inventory Areas (WRIAs) that contain hundreds of thousands of acres. As with all planning units, the delineation of this planning unit is based on groupings of WRIAs (DNR 1997). A total of 13 WRIAs, or portions thereof, are present within the planning unit (Table F-3; Map 3-1 p.45). Appendix F of the 2008 Draft EIS contains descriptions of the six major WRIAs.

Each WRIA can be further broken down into Watershed Administrative Units (WAU), and sub-basins within the larger watersheds. A watershed is the land area that drains into a particular lake, river, or ocean. Hydrology is the study of water—in this case, of its quantity, quality, and distribution. A watershed is the unit that is used to analyze hydrologic conditions.[1]

The boundaries of a WAU are defined by DNR in cooperation with the state departments of Ecology and Fish and Wildlife, affected Indian Tribes, local governments, owners of forest land, and the public. The WAU boundary dataset is intended for use at 1:24,000 scale. WAUs are used by the timber/fish/wildlife cooperators as boundaries on state and privately owned lands for analyzing watersheds and for other natural resources management purposes. WAUs are divided into 844 units whose boundaries mainly follow drainage divides (ridges), with some along rivers and other DNR management boundaries. In the forested areas of the state, the WAUs range in size from 3,822 to 297,614 acres.

Forest Conditions and Management

This section describes the condition of DNR-managed forests within the 145,000-acre planning unit, which is spread out across parts of 54 watersheds. DNR management activities have the potential to cause significant impacts, either positive or negative, to the environment in those watersheds where it manages a high percentage of the forestland. The watershed scale is convenient for assessing where impacts occur within the planning unit at different points in time. Where DNR managed trust ownership of the total watershed area is equal to or greater than 20 percent, potential impacts are compared in the context of DNR managed trust ownership within each watershed. While this threshold is somewhat arbitrary, DNR has used it in the past to determine how management actions within the 54 watersheds in the planning unit (refer to Appendix F of the 2008 Draft EIS) may influence their environments (DNR 2004). Of the 54 watersheds, DNR manages more than 20 percent of the total watershed area in eight (Table 3-1, below). Collectively, these eight watersheds represent nearly half (48 percent) of DNR-managed forestlands within the planning unit.

The forest conditions described include how DNR-managed forestlands are distributed across the planning unit by watershed, site productivity, forest species type, age class distribution, and forest stand conditions in terms of standing volume (or biomass), stand development stage, and relative density. For a description of stand development stages and relative density (RD), refer to Text Boxes 3-1 p.37 and 3-2 p.38 of the Draft EIS.

What Information Do the Current Forest Conditions Provide?

The current forest conditions of DNR-managed forests provide the starting point for examining the environmental impacts of the alternative management strategies being proposed. The environ-mental impacts include, but are not limited to:

- The amount of standing forest biomass (volume). This affects DNR's ability to sustainably produce timber, protect and create habitat resources, and sequester carbon.
- The distribution of each stand development stage. In particular, impacts can affect stand development stages that represent older or later successional forest conditions.
- Forest conditions related to stand density. Forest density influences the risk to forest health (specifically mortality and growth) which in turn can influence forest development stages.
- The amount and types of harvest activities across the forest and over time. These types of forest management activities can potentially affect visual resources, recreational access, and water quality and quantity, as well as wildlife habitat quality and quantity.

Why Is Forest Biomass (Standing Volume) Important?

Forest biomass is the total merchantable standing volume of trees, measured in thousand board feet per acre. The trend of standing forest biomass over time is an indicator of the impacts of timber harvesting across the forested landscape and a measure of sustainability for timber production. Forest biomass also provides measures for carbon sequestration, ecological functions for wildlife, riparian vegetation, and older-forest conditions.

Why Examine Stages of Stand Development?

The measureable, physical attributes of a forest stand which affect its ecological functions, such as the sizes and numbers of trees, number of vertical canopy layers, number of snags, and down woody debris can outline stand structure (Franklin et al. 2002; Carey 2007). Forest stand structure is a substitute for measuring ecosystem functions that are difficult to measure directly; forest stand structure also can be used to assess a forest's value in terms of products or services provided (Carey 2007; Franklin et al. 2002).

DNR's stand structure classification system of stand development stages is based on the physical attributes of a stand (DNR 2004, p. 4-11 and B-31, see Modeling Appendix C) and derives from various descriptions of stand development in Pacific Northwest forests (Carey 2007; Van Pelt 2007; Franklin et al. 2002; Carey et al. 1996; Oliver and Larson 1996). Text Box 3-1 describes each stand development stage.

Stand development stages are indicators of the major ecological processes occurring in the forest (Franklin et al. 2002; see Text Box 1). Each stage supports various wildlife and plant species (see Wildlife, p. 53 DNR 2008); therefore, by examining the trend in and number of stand development stages over time within forested landscapes, one can infer the ecological conditions of the landscape, the impacts on wildlife, and perhaps the aesthetic appeal of the viewsheds.

Table 3-1. Watersheds with at Least 20 Percent DNR-managed Trust Ownership

Watershed	Acres	Percent of DNR Ownership
Ashford	7,613	33%
Busy Wild	14,537	26%
Kennedy Creek	8,277	35%
Lynch Cove	10,200	27%
North Fork Mineral	12,862	80%
Pleasant Valley Dispersal	1,360	22%
Reese Creek	4,638	92%
Tiger	9,586	24%

How Do Forest Management Activities Influence Forest Conditions?

Management activities directly affect the quantity of forest biomass (volume), stand development stages, and forest density. Many studies compare harvesting activities to natural disturbance events (Carey 2007; Franklin et al. 2002; Tappeiner, Maguire and Harrington 2007). DNR's variable retention harvest frequency of between 45 and 150 years is higher than forest ecosystem disturbances expected from natural stand-replacing events in western Washington (Agee 1993; see also Franklin and Dyrness 1973).

The distribution of stand development stages shown in Chart 3-1 (p. 39, DNR 2008) demonstrates the cumulative effect of DNR's past management and natural disturbances within the planning unit. Most forest lands managed by DNR in the planning unit are second growth forests in the competitive exclusion and understory development stages.

Other potential impacts from forest management include those to water quality and quantity (p.44), visual resources (p. 70, DNR 2008), wildlife habitat (p. 53, DNR 2008), soils (p. 63, DNR 2008), roads (p. 66, DNR 2008), and northern spotted owl conservation (p. 58, DNR 2008) these pages are references to the Draft EIS for the South Puget Planning Unit.

What Young Stand Management Activities Does DNR Use and How Do They Affect Forest Structure?

Young stand management activities such as planting, managing competing vegetation, and pre-commercial thinning control the numbers and types of trees established in the newly developing forest stand. Each early management entry is an opportunity to influence the success of certain tree species rather than others in the developing stand. Species composition plays a key role in the forest structure, because over time, different species grow at different rates and develop unique foliage, bark and branch forms, contributing to a diverse forest structure (Carey 2007). Average yearly young stand management activities from 1997 to 2007 within the planning unit included about 1,500 acres of planting, 1,300 acres of vegetation management (hand-slashing or herbicide use), and 750 acres of pre-commercial thinning/spacing.

What Is the Distribution of the Land Base?

DNR's land base can be grouped into three distinct management categories: riparian and wetland areas; uplands with specific management objectives (for example, defined habitat areas or areas designated for purposes other than timber management); and uplands with general management objectives (areas managed under general policies, procedures, or Forest Practices Rules). Roughly 58,000 acres (40 percent) of the planning unit is either a riparian or upland area with specific objectives (Table 3-2). Approximately 24,000 acres (17 percent) are identified as long-term deferrals from harvest (for example, as Natural Area Preserves or Natural Resource Conservation Areas).

What Is the Standing Biomass (Volume, Growth, and Yield) in the Planning Unit?

Total standing merchantable biomass is estimated at approximately three million board feet (Table 3-2). Currently, about 30 percent of this standing biomass is contained in riparian areas, 15 percent in uplands with specific management objectives, and 54 percent in uplands with general management objectives; refer to Table 3-2.

What Is the Site Class Distribution?

The majority (46 percent) of DNR forestlands in the planning unit are classified as medium productivity forests (Site Class 3: 50-year site index from 97-118; refer to Table D-3). Another 27 percent are more productive forests (Site Class 2; 50-year site index from 118-136), and the remaining 27 percent is in the lowest productivity class (Site Class 4).

What Are the Dominant Tree Species?

Douglas-fir (*Pseudotsuga menziesii*) is the dominant tree species across most (77 percent) of the planning unit, with western hemlock (*Tsuga heterophylla*), red alder (*Alnus rubra*) and Pacific silver fir (*Abies amabilis*) occurring less frequently as dominants (15, 6, and 2 percent, respectively). Co-dominant species include Pacific silver fir and western redcedar (*Thuja plicata*). Most watersheds contain distributions of forest types that are similar to those in the overall planning unit (refer to Appendix D, Table D-2, 2008 DNR DEIS). However, the North Fork Mineral watershed contains a higher percentage of western hemlock-dominant forests (41 percent) and a higher proportion of Pacific silver fir as dominant (2 percent) or co-dominant (12 percent) types. Neither the Kennedy Creek nor the Lynch Cove watershed contains a significant proportion of western hemlock types (one and zero percent, respectively).

What Are the Age and Volume Distributions of Forest Stands?

While the forest stands range in age from zero to 220 years, most (96 percent) are 80 years old or younger. Within the eight watersheds, over 60 percent of the volume is in forest stands between 50 and 70 years of age. Most of the oldest forests (90 plus years) in the planning unit are in the Tiger and North Fork Mineral watersheds.

Table 3-2. Area and Volume by Land Class for the Planning Unit

Land Class	Acres	Long-Term Deferrals (% of Area)	Standing Volume (MBF)*
Riparian and Wetlands	39,773	8%	1,007,858
Uplands with Specific Mgt. Objectives	19,221	4%	496,520
Uplands with General Mgt. Objectives	86,355	5%	1,793,383
Total (All Classes)	**145,349**	**17%**	**3,297,761**

* MBF = Million Board Feet

How Are the Stand Development Stages Distributed?

Over the planning unit, the largest proportion of forested state trust lands (40 percent) is in the understory development stage, followed by the Ecosystem Initiation (27 percent), Competitive Exclusion (20 percent), and Biomass Accumulation (11 percent) stages (Chart 3-1 p. 39, DNR 2008). Less than two percent is in the Niche Diversification and Fully Functional stages. Chart 3-1 p. 39, DNR 2008 demonstrates the variability of stand development stages for the eight selected watersheds and compares those watersheds to the entire planning unit. Most watersheds are still dominated by the understory development stage, and less than two percent are in the Niche Diversification and Fully Functional stages.

How Does Stand Density Vary?

Table 3-3 displays the current distribution of acreage by dominant species and stocking class. Twenty-two percent of DNR-managed forests are in a dense condition, defined here as greater than 75 Curtis' RD, where mortality is generally accelerated and tree vigor is reduced when compared to lower densities.

Stands dominated by western hemlock have the highest proportion of acreage in dense stand conditions (43 percent). This is not unexpected, as western hemlock is a shade tolerant species and can grow at higher densities than shade intolerant species such as Douglas-fir.

Table 3-4 illustrates that, for the entire planning unit, the uplands with specific management objectives and riparian land classes have a slightly greater proportion of their acreage (27 and 34 percent, respectively) in forests with dense stand conditions (RD > 75) than the uplands with general management objectives (18 percent).

The current acreage by watershed and the percent of DNR area with above optimal stocking (RD>75) is displayed in Table 3-5. The watersheds with the highest percentage of over-stocking are the Reese Creek, North Fork Mineral, and Tiger watersheds.

Table 3-3. Current Acreage by Dominant Species and Stocking Class

	Stocking Class (Curtis' RD for trees greater than 4 inch diameter)*			
Forest Types Classed by Dominant Species	<50	50-75	75-100	>100
Douglas-Fir	50%	30%	18%	1%
Red Alder	15%	76%	9%	0%
Silver Fir	56%	20%	17%	7%
Western Hemlock	28%	29%	34%	9%
Total (all forest types)	**45%**	**32%**	**20%**	**2%**

* See Text Box 3-2 for an explanation of Curtis' Relative Density

Table 3-4. Current Stocking of Forests by Land Class

	Stocking Class (Curtis's RD for trees greater than 4 inch diameter class)			
Land Class	<50	50-75	75-100	>100
Riparian and wetlands	34%	39%	24%	3%
Uplands with specific objectives	36%	30%	31%	3%
Uplands with general objectives	52%	30%	16%	2%
Total (All Classes)	**45%**	**32%**	**20%**	**2%**

Where Are Old Growth and Older Forests in the Planning Unit?

DNR developed the Weighted Old Growth Habitat Index (WOGHI) to screen its inventory data for old growth (DNR 2006a). Forest stands with either a high potential (greater than or equal to 60 WOGHI score) or moderate potential (between 50 and 60 WOGHI scores) to be old growth are assumed to be old growth. They are deferred from harvest until a field assessment is conducted to determine if the stand is old growth or open for management activities in accordance with DNR's 2006 *Policy for Sustainable Forests*. Of the 820 acres identified as having a high old-growth potential, 507 have been preserved permanently within the newly created Charlie Creek Natural Resource Conservation Area in the Green Mountain watershed. An additional 191 acres are protected within the Bald Hills Natural Resource Conservation Area in the Powell Creek watershed. Remaining scattered acreage of high potential are located within Kennedy Creek (33 acres), Tiger (26 acres), North Fork Mineral (56 acres), and Middle Deschutes (10 acres) watersheds. Most of the 579 acres of moderate old-growth potential are located in Mineral Creek (374 acres) and North Fork Mineral (100 acres) watersheds.

Older-forest conditions are represented by stands in the Fully Functional or Niche Diversification stage of stand development (DNR 2006a). Currently, less than 2 percent of the land base meets older-forest conditions (Chart 3-1 p. 39, DNR 2008).

What Current DNR Policies Are Likely to Influence Forest Conditions?

DNR's forest management guidance comes from the 2006 *Policy for Sustainable Forests*. This policy document is DNR's vision of the type of forested landscapes it aims to create for the future, while recognizing DNR's fiduciary responsibility to generate revenues for the trust beneficiaries and meet DNR's contractual obligations under the 1997 *Habitat Conservation Plan* (HCP). The general silviculture policy directs DNR to manage forested landscapes actively to achieve 10 to 15 percent older-forest structures across each western Washington HCP planning unit. In addition, the policy directs the protection of existing old-growth forests and management of riparian and wildlife in accordance with the 1997 HCP. The plan sets out specific conservation strategies for the northern spotted owl and marbled murrelet in designated management areas, riparian management strategies, and more general conservation strategies. These strategies include the protection of unique habitats across the landscape, such as legacy trees, talus, balds, cliffs, caves, snags, and mineral springs. These combined forest management policies and strategies have been designed to achieve a vision of creating forested landscapes with greater levels of structurally complex forests than exist today (Chart 3-1 p.39; DNR 2004).

Table 3-5. Distribution of Currently Overstocked Acreage for Selected Watersheds

Watershed	Overstocked DNR Acres (RD>75)	Percent Overstocked (RD>75)
Ashford	852	11%
Busy Wild	2,194	15%
Kennedy Creek	1,035	12%
Lynch Cove	399	4%
North Fork Mineral	4,772	37%
Pleasant Valley Dispersal	143	11%
Reese Creek	2,201	48%
Tiger	3,812	40%
Planning Unit Total	**31,977**	**22%**

What Type of Harvest Methods Does DNR Use?

DNR's timber harvesting activities can be broadly summarized as thinning or regeneration (Modeling Appendix C). DNR uses thinning and variable retention harvests to intentionally enhance forest structures in distinctly different ways across forested landscapes that are managed for multiple objectives. Thinning and regeneration create forest stands with different structures—i.e., over time, the stands differ in how they function ecologically. For example, the water quality or habitat provided by them may differ from stand to stand. Thinnings can maintain and prolong a stand development stage, change the development pathway by adding structure (down woody debris or snags), or encourage the development of a second or third tree cohort in the understory. Thinning harvests generally maintain most of the existing overstory commercial cohort of trees. DNR's variable retention harvest activities are more comparable to variable retention harvests (described in DNR 2004) than to traditional clearcuts because of the number of trees left standing after harvest. The main objective of a variable retention harvest is to initiate a new commercial cohort (Text Box 3-3 p. 43, DNR 2008). Table 3-6 depicts the number of acres harvested over the past decade.

Table 3-6. Average Harvested Acres over the Past Decade (1997-2007) in the Planning Unit.

Completed Harvest Activity	Acres	Annual Average
Regeneration with legacies	14,469	1,447
Thinning: commercial or variable density	7,025	703
Total harvested acres	**21,496**	**2,150**

What is a Cohort?

DNR employs a cohort management system. The term cohort refers to a group of individuals with common characteristics, such as a group of trees developing after a single disturbance, commonly consisting of trees of similar age. The idea is to manage and track components (cohorts) of forest stands over time in order to achieve management objectives. Forest cohorts may be ecological components (snags, down wood, very large trees) or economic components (commercial products of a certain size, species or quality)(see *Management of Forest Stand Cohorts*, Westside PR-14-006-090 Appendix E).

Water Quantity

How Does Management Affect Water Quantity?

Land use activities such as logging, building roads, grazing, and wildfires can change vegetative cover and cause extensive soil compaction. Roads and their compacted surfaces can accelerate surface runoff and alter the natural characteristics of annual, peak, and minimum flows (Everest et al. 2004); in addition, land use activities that reduce vegetative cover can increase peak discharges and the potential for flooding as shown by paired watershed studies in western Oregon and Washington (Beschta et al. 2000; Bowling et al. 2000; Thomas and Megahan 1998).

What is Meant by Watershed Systems?

Forest management activities have the potential to affect various physical, chemical, and biological components of watersheds. The primary components addressed under watershed systems include water quantity (hydrology and hydrologic maturity), water quality, wetlands, and riparian systems. Because changes in these watershed components can cause direct and indirect effects to fish and instream fish habitat, the potential effects of the alternatives on this resource will also be discussed.

How Was the South Puget Planning Unit Delineated for Watersheds?

The planning unit includes more than 145,000 acres and takes in portions of the Cedar, Green, White, Carbon, Puyallup, Nisqually, and Deschutes rivers. Watersheds in the planning unit range from small basins to hundreds of thousands of acres. A total of 13 WRIAs, or portions thereof, are present within the planning unit (Table F-3; Map 3-1). Appendix F contains descriptions of the six major WRIAs. Each WRIA can be further broken down into WAUs, equivalent to sub-basins within the larger watersheds, and as discussed above, WAUs in this planning unit are divided into 844 units. Table F-3 in Appendix F, DNR 2008 lists the 59 watersheds that contain DNR forested state trust lands within the planning unit.

In examining the relationship between peak discharge, forest removal, and regrowth in 10 small watersheds in western Oregon, Jones (2000) concluded that with 50 years of recorded data, extreme floods and large rain-on-snow events are so rare that it is difficult to assess the statistical significance of changes in peak flow. Rain-on-snow events happen when the warmer conditions associated with large rainfalls cause snow packs to melt quickly. Ziemer and Lisle (1998) concluded that it is difficult to determine if forest practices increase the size of large floods because forest practices usually affect only a small portion of large basins.

What Are the Current Hydrologic Maturity Conditions?

Forest stands older than 25 years of age with a Curtis' relative density of greater than or equal to RD 25 are considered hydrologically mature. If hydrologically mature forest cover is reduced basin-wide, the reduction may lead to peak flows that damage streambeds during rain-on-snow events (DNR 1997, p. III.64).

Under the procedure for assessing hydrologic maturity (Procedure 14-004-060, Appendix E), 66 percent of the sub-basins in the rain-on-snow zone must remain in hydrologically mature forests before variable retention harvesting may take place.

Of the 59 watersheds in the planning unit, only five have more than one percent of their land area in hydrologically immature forest in rain-on-snow zones. Of these, only two have greater than five percent (Table F-1).

Sixty-eight percent of the 4,638-acre Reese Creek watershed is within the six rain-on-snow basins in which DNR manages the potential peak flow impacts within the watershed. The Busy-Wild watershed has 5.1 percent of its 56,966 acres in hydrologically immature forest within the rain-on-snow zone. The 12,862-acre North Fork Mineral watershed has the largest component of rain-on-snow zone (73 percent) within the planning unit, but the hydrologically immature component of the rain-on-snow zone is only 4.4 percent of the watershed.

Logging could result in increased stream flows during the summer (Ziemer and Lisle 1998). Summer water yields have been reported to increase after harvest for a few years before returning to pre-harvest levels (Everest et al. 2004). However, because increases in low summer flows from small watersheds are generally widely scattered in time and space within larger basins, these effects are difficult to detect and thus considered insignificant in larger downstream rivers.

Why Was Hydrologic Maturity a Concern around Lake Tahuya?

To validate or suggest changes to the management of the Lake Tahuya sub-basin (see Chapter 2 p.25 2008 DNR DEIS), a peer review of the hydrologic maturity analysis completed in 2002 for three sub-basins in the Tahuya Lake watershed was conducted, initially to address concerns about the lake's water level.

Estimates of potential changes in the levels of Tahuya Lake were based on estimates of changes in runoff volume with and without forest cuts in the Gold Creek, Grada Creek, and Tin Mine Creek basins. The analysis included total forested area of 3,340 acres, where 17 percent was classified as recently or assumed to have been cut, 2.9 percent was roads, and the rest was considered hydrologically mature forest.

An unpublished hydrologic analysis of the Tahuya Lake watershed (conducted by DNR) was based on standardized, tested and generally accepted approaches that provide a reasonable estimate of the magnitude of potential change to Tahuya Lake levels from the combined influence of forest roads and forest harvest. The overall analysis indicates that local flooding issues around the lake are related only in a small way to forest practice activities such as timber harvesting.

Wetlands

What Amount of Wetlands Is in DNR Ownership?

Geographic Information System (GIS) data are used to identify wetland acres which were discussed in detail in the 2004 *Final EIS on Alternnatives for Sustainable Forest Management* (p. 4-131 to 4-137). Wetlands and the associated buffers are documented within DNR's GIS data layers.

Overall, about 2.3 percent (73,327 acres) of the planning unit, approximately 3.1 million acres (considering all lands private and public), have mapped wetlands. DNR forested state trust lands account for 1,457 of these wetland acres, equivalent to about two percent of the known wetlands within the planning unit (Table 3-7), even though DNR lands account for about 4.9 percent of the planning unit. Of these wetlands, 53 percent are mapped as forested and 47 percent are mapped as non-forested.

How Are Wetlands Managed Today on Forested State Trust Lands?

The policies that govern the management of wetlands on DNR lands can be found in the 2006 *Final Environmental Impact Statement for Policies for Sustainable Forests* (p. 3-115 to 3-123). Wetlands are also managed in accordance with the 2006 *Implementation Procedures for the Habitat Conservation Plan Riparian Forest Restoration Strategy* and Forestry Handbook Procedure for *Wetland Management* (PR 14-004-150, Appendix E).

The 1997 HCP discussed above defines the objective of the wetland protection strategy as maintaining hydrologic function through:

1. Continuously maintaining a plant canopy that provides a sufficient transpiration surface and established rooting,

2. Maintaining natural water flow, and

3. Ensuring stand regeneration.

DNR timber management activities normally avoid wetland areas and their associated buffers. The 1997 HCP specifies that if ground disturbance alters the natural surface or subsurface drainage of a wetland, restoration is required. Salvage timber operations are permitted only in buffers that are not periodically flooded. The HCP also requires all forested and non-forested wetlands over 0.25 acre to be buffered.

In forested wetlands, harvesting is allowed within wetlands and their associated buffers provided a minimum basal area of 120 square feet per acre remains after harvest. Forest management in forested wetlands must minimize entry and use practices that reduce disturbance. These activities were analyzed in the 1996 *Draft EIS for the Habitat Conservation Plan,* p. 4-488 to p. 4-490.

Table 3-7. Wetlands by Ownerships in the Planning Unit

Acres					
Wetland Type	DNR Forested Trust Lands	Federal Lands	Private Lands[1]	Other [2]	Total
Forested Wetlands	766	1,770	15,509	2,047	20,092
Non-Forested Wetlands	691	4,136	42,873	5,446	53,145
Total Acres of Wetlands	1,457	5,905	58,383	7,492	73,237
Percent of Total Wetlands Acres	2%	8%	79%	11%	100%

1 The “Private Land” category includes industrial forestland, agricultural lands, residential, industrial, and commercial lands.

2 The “Other” category includes DNR-managed non-forested land, municipal lands, and water bodies (larger streams, rivers, lakes, and marine shorelines).

Riparian

Why Are Riparian Areas Important?

Riparian zones are the streamside vegetation, soils, and moisture regimes along streams (DNR 1997). Raedeke (1988) describes riparian systems as having long, linear shapes with high edge-to-area ratios and microclimates distinct from those of adjacent uplands. Distinct gradients of moisture create obvious changes in communities of plants and animals from those of adjacent uplands (Richardson et al. 2005).

Riparian areas and particularly riparian forests contribute to the ecological health of streams and plants and animals associated with them. Many authors (Karr and Schlosser 1977; Meehan et al. 1977; Raedeke 1988; Bilby 1988; Murphy and Meehan 1991; Beschta, 1991; Castelle et al. 1992) recognize the important functions of riparian areas such as recruiting LWD and leaf and needle litter, shading the stream, and providing microclimates, streambank stability, and sediment control. The analyses of these functions can be found in the 2004 *Final Environmental Impact Statement on Alternatives for Sustainable Forest Management,* p. 4-35 to 4-39; DNR 2001, p. 3-36 to 3-88 and p. B-14 to B-22.

How Have Riparian Areas Been Managed Historically?

In Washington, harvesting activities that have occurred near riparian areas over the past 33 years have been governed by *Forest Practices Rules* (DNR 2001, p. 3-40), but in 1997, DNR began managing riparian areas as prescribed in the HCP. A summary of the environmental consequences in western Washington on riparian and aquatic systems can be found in the draft and final EIS for the HCP (DNR 1996, 1997 Matrix 2a, p. 2-64 to 2-65) developed for the 1997 HCP (p. IV. 70 to IV. 79). Harvest activities dating back more than 30 years generally did not restrict harvest near riparian areas (DNR 2001, p. 3-40). The long-term changes to riparian habitat that have occurred in the past affect both forest composition and the structure of riparian forests (Knutson and Laef 1997).

How Much Riparian Area Is Managed by DNR for Trust Beneficiaries?

In 2007, an estimate using GIS found that 27 percent of the area in the planning unit was within the riparian and wetland management zones; this was an increase in acres over the 2004 estimate presented in the *Final Environmental Impact Statement on Alternatives for Sustainable Forest Management.*

What Are the Current Riparian Stand Conditions?

Forty percent of existing riparian areas are in the understory development stage, which are forests in transition from highly dense, closed conditions to forests with more complex conditions. Refer to Stand Development Stages, Text Box 3-1, p.39. In these areas, less than one percent is in the Fully Functional stage (Chart 3-2 p.40).

What Does Stream Ownership Look Like within the Planning Unit?

The length of streams varies substantially among the different watersheds (Table 3-8 and Map 3-2 p.50). Within this planning unit, about 1,183 miles of streams exist; they represent eight percent of the total stream miles on forested state trust lands.

How Does DNR's Management Activity Affect Riparian Areas?

DNR's 2006 *Implementation Procedures for the Habitat Conservation Plan Riparian Forest Restoration Strategy* (RFRS) provides the framework for how DNR now manages stands adjacent to riparian zones. DNR's riparian forest restoration strategy describes the importance of maintaining ecological functions and silvicultural treatments to achieve the goal of stand conditions with vertical and horizontal heterogeneity and structural complexity (Bigley and Deisenhofer 2006, p. 21). Implementation of the strategy is consistent with the biological opinion for the 1997 HCP (USFWS 1997, p. 16).

The long-term goal for riparian zones is based on the assumption that forests having structurally complex characteristics will support desirable aquatic habitat, and thus aid riparian obligate species and salmon habitat recovery. The long-term target for riparian management zones is older-forest conditions, while the more immediate goals are described in Table 3-9 (Bigley and Deisenhofer 2006, p.8). Currently, it is estimated that two to four percent of riparian areas are in this condition.

What Are the Key Elements for Restoring Riparian Function?

Restoring riparian function includes increasing the number of large trees to enhance stand complexity. Large trees provide strong root systems, which in turn provide critical structure for fish habitat and help prevent streambank erosion (Bigley and Deisenhofer 2006). Over time, these trees provide the LWD to the stream system that is critical for spawning, rearing, and over-wintering habitat (Bigley and Deisenhofer 2006). Stand structure and composition are vital components of riparian restoration.

Table 3-8. Stream Miles by Ownership within the Planning Unit

Stream Miles					
DNR Stream Type[1]	DNR Forested Trust Lands	Federal Lands	Private Lands[2]	Other[3]	Total
1	36	97	732	475	1,342
2	8	12	160	51	231
3[4]	321	328	2,431	321	3,400
4	818	2,137	5,468	876	9,299
Total (all Types)	**1,183**	**2,574**	**8,791**	**1,724**	**14,271**

[1] DNR and the Federal Services (U.S. Fish and Wildlife Service, and National Oceanic and Atmospheric Administration Fisheries) have agreed the Washington Forest Practices Board Emergency Rules (stream typing), November 1996 (WAC 222-16-030) meet the intent of DNR's 1997 HCP. A comparison of DNR's permanent water typing system is defined in the rules (see WAC 222-16-030) to the HCP stream typing system is discussed in Appendix B of DNR (2006b).
[2] The "Private Land" category includes industrial forestland, agricultural lands, residential, industrial, and commercial lands.
[3] The "Other" category includes DNR-managed non-forested land, municipal lands, and water bodies (larger streams, rivers, lakes, and marine shorelines).
[4] The current DNR Geographic Information System layer for streams is believed to underestimate the amount of Type 3 streams. Consequently, for the purposes of this paper, stream types in the stream layer were modified by upgrading Type 9 and Type 5 streams to Type 4, and Type 4 streams to Type 3.

Table 3-9. Riparian Desired Future Conditions (RDFC) Threshold Targets

RDFC Characteristics	RDFC Threshold Targets
Basal Area	At least 300 square feet per acre.
Quadratic Mean Diameter (QMD) (all trees greater than 7 inches diameter at breast height [DBH])	At least 21 inches.
Snags	Retain existing snags at least 20 inches DBH through no-cut zones. Maintain at least 3 snags per acre.
Large down wood	Maintain at least 2,400 cubic feet/acre. Actively create down wood (contribute 5 trees from the largest thinned DBH class) during each conifer management entry.
Vertical stand structure	Maintain at least two canopy layers (bi-modal or developing reverse J-shaped diameter distribution).
Species Diversity	Maintain at least two main canopy tree species suited to the site.

Fish

What Fish Species Are of Concern?

Fish species selected as the focus of this analysis include Chinook, sockeye (includes resident kokanee), coho, and chum salmon; steelhead (includes resident rainbow trout), coastal cutthroat, bull, and Dolly Varden trout. These species were selected because they all have commercial or sport harvest value and are known to be sensitive to forest management activities. Furthermore, the Puget Sound populations of Chinook salmon, steelhead and bull trout, and the Hood Canal population of summer chum salmon, are listed as threatened under the federal Endangered Species Act (ESA) and are present within the planning unit. Coho salmon are classified as a federal species of concern and a petition to list the Lake Sammamish population of kokanee is currently under review by the U.S. Fish and Wildlife Service. Refer to the 2001 *Final EIS for Forest Practices Rules* (p. 3-120 to 3-129) for additional details regarding these species. A thorough discussion of the life histories and habitat requirements of Pacific salmon and trout is presented in the 2001 *Final EIS for Forest Practices Rules* (p. 3-120 to 3-127) and the Final EIS on Alternatives for Sustainable Forest Management (p. 4-140 to 4-146).

What Is the Distribution of Salmonids in the Planning Unit?

Salmonids are fish belonging to a group that includes salmon, trout, and char. This group belongs to the family Salmonidae. Table 3-10 lists the overall distribution of salmonids within the planning unit, while Maps F-1, F-2, and F-3, DNR 2008 illustrate their distribution. Forested state trust lands contain approximately four percent of the anadromous salmonid distribution within the planning unit, while accounting for five percent of the resident salmonid distribution. No streams on DNR-managed land within the planning unit are known to support bull trout, although bull trout may be distributed within or adjacent to larger rivers.

Table 3-10. Salmonid Distribution by Landowner in the Planning Unit (DNR 2008)

Type of Salmonid	Stream Miles				
	On DNR Forested Trust Land	On Federal Land	On Private Land[1]	On Other[2]	Total
Anadromous	73	99	1,438	323	1,933
Resident	124	89	1,659	383	2,254
Bull Trout	2	139	268	144	552

[1] The “Private Land” category includes industrial forestland, agricultural lands, residential, industrial, and commercial lands.
[2] The “Other” category includes DNR-managed non-forested land, municipal lands, and water bodies (larger streams, rivers, lakes, and marine shorelines).

Wildlife

Why Is Wildlife Habitat Important?

One of DNR’s long-term management goals is to provide a diversity of forest structural stages so that forested state trust lands have the ability to support a broader diversity of wildlife species on a landscape or ecoregional scale. Wildlife habitat, regardless of whether it is upland, riparian, or wetland habitat, is significant because of a number of functions it performs such as food and shelter for many species.

How Is Wildlife Habitat Defined?

Under the *Policy for Sustainable Forests* (DNR 2006a, p. 3-76), wildlife habitat is defined as the combination of resources (food, water, cover, breeding habitat) and environment (climate, soils, vegetation structure) that attracts and supports a species, population, and/or assembly of species (also referred to as communities or guilds).

How Does DNR Manage Wildlife Habitat?

DNR manages for specific wildlife habitats and specific forest conditions through the combination of silviculture and landscape management strategies, as described in Appendix F of the *Final EIS for Policy for Sustainable Forests* (DNR 2006b) and the 1997 HCP. Silvicultural techniques include variable retention harvests and thinning treatments, which have been developed by DNR staff (Holmberg et al. 2007) from the forestry literature (Franklin and others 2002, Carey et al. 1996). Refer to the 2004 *Final EIS on Alternatives for Sustainable Forest Management* for more information.

Wildlife guilds can be used to examine how wildlife responds to various forest conditions under all alternatives. Guilds are assemblages of species that have similar habitat requirements for foraging, breeding (nesting/denning) and/or shelter. Guilds are defined using different types of ecological overlap, so individual species can belong to several guilds (see Table 3-11). The guilds in Table 3-11 were developed for this analysis, based largely on Brown (1985) and Johnson and O'Neil (2001), to describe species that will benefit from various forest conditions. The guilds and species listed are only examples of how different assemblages of wildlife may respond over time to forest structures and conditions used by DNR to enhance wildlife habitat on forested state trust lands within the planning unit. The 1997 HCP recognized that age class is not a sufficient indicator of stand structure, nor is it a satisfactory indicator of ecological function (DNR 1997, p. IV-180; DNR 2004). For a discussion on stand development stages refer to p. 37, DNR 2008.

Table 3-11. Wildlife Guilds and Species Benefitting from Various Forest Conditions and Structures*

Forest Structures and Conditions	Benefiting Guild	Representative Species
Retained live trees (patches and individual trees)	Feed and/or breed in large trees (generally greater than 24 inches diameter)	Chestnut-backed chickadee, brown creeper, golden-crowned kinglet, Pacific-slope flycatcher, rufus hummingbird, pileated woodpecker
	Arboreal seed eaters	Pine siskin, Douglas squirrel, Townsend's chipmunk
	Arboreal needle/bud eating	Blue grouse, Douglas squirrel, porcupine,
	Arboreal omnivores	Raccoon, Virginia opossum
	Bark probers/gleaners	Hairy woodpecker, northern flicker, red breasted nuthatch, brown creeper
	Foliage gleaning insectivores	Warbling vireo, golden-crowned kinglet, hermit warbler, western tanager
	Perching/hawking (esp. during ecosystem initiation)	Red-tailed hawk, great horned owl, Steller's jays, American crow
Retained and created snags	Primary cavity nesters	Pileated woodpecker, red breasted nuthatch
	Secondary cavity nesters	Chestnut-backed chickadee, saw-whet owl
	Arboreal insectivores (nesting)	Tree swallow, violet green swallow, Vaux's swift
	Large snag dependent	Pileated woodpecker, northern saw-whet owl, western screech owl, black bear, American marten, bats
Retained coarse woody debris, ground cover, organic soil layers	Herbivorous and fungivorous forest floor small mammal (truffles and fungi, seeds, berries, insects)	Deer mouse, Oregon creeping vole, red backed vole
	Small mammal predators	Coyote, bobcat, long-tailed weasel, red-tailed hawk, American marten
	Ground insectivores	Northern alligator lizard, western fence lizard, western toad, Northwest salamander, Pacific tree frog, shrews, moles, black bear
	Large downed wood dependant	Amphibians and reptiles (see row above), black bear, American marten, western red backed vole

Created small forest openings, diversity of tree sizes, vertical and horizontal diversity	Understory birds	Dark-eyed junco, fox sparrow, hermit thrush, orange-crowned warbler, olive-sided flycatcher, pine grosbeak, ruby-crowned kinglet, Wilson's warbler, winter wren
	Herbivorous mammals	Columbia black-tailed deer, Rocky Mountain elk, eastern cottontail, deer mice, voles
	Aerial salliers	Western tanager, olive-sided flycatcher
	Foliage gleaning insectivores	Golden-crowned kinglet, warbling vireo, hermit warbler, western tanager
	Understory-gleaning insectivores	Winter wren, song sparrow
	Edge species	Deer, elk , western screech owl, great horned owl, bats (see also Table 3-11)
	Large mammal predators	Cougar, bear
Complex forest structure: Niche-diversification and fully functional stand development stages	Late successional specialists	Northern goshawk, northern spotted owl, Townsend's warbler, red tree vole, northern flying squirrel

*Based on Brown (1985); Carey et al. (1996); Franklin (2002); Johnson & O'Neil (2001)

What Is the Relationship between Wildlife Habitat and Stand Age?

The 1997 HCP recognized that age class is not a sufficient indicator of stand structure, nor is it a satisfactory indicator of ecological function (DNR 1997, p. IV.180; DNR 2004). For a discussion of stand development stages, refer to p. 37, DNR 2008. In response, DNR developed a classification of forest stand development stages based on structural characteristics (see discussion on p. 37, DNR 2008).

What Type of Wildlife Diversity Exists in Ecosystem Initiation Stands?

Stand development begins as open, newly regenerated stands of rapidly growing young trees and shrubs. Compared to other stages, wildlife diversity is greater in this stage until stands reach structurally diverse conditions (Brown 1985; Johnson and O'Neil 2001). Many species use stands in the ecosystem initiation stage more for foraging than breeding. Brown (1985) identified 70 species in western Washington and Oregon that used Ecosystem Initiation (grass/forb stage in Brown 1985) as primary foraging habitat, compared to 26 species that use the Ecosystem Initiation stage as primary breeding habitat (refer to Table 3-12). Reptiles, such as northern alligator lizard and western fence lizard, are generally uncommon in forested landscapes, but are known to occur within variable retention harvest areas, where stumps, woody debris, and open canopies provide basking habitats believed to be important for thermoregulation (Waldien et al. 2003).

The Ecosystem Initiation stage stands create "edge" habitat that can increase wildlife use (Hunter 1990; Patton 1992; Johnson and O'Neil 2001). Adjacent stands in the Understory Development and older stages provide cover and perching habitat adjacent to possible high-quality foraging habitat of Ecosystem Initiation. Such high-contrast edges are known to be used by red-tailed hawks, accipiters (sharp-shinned and Cooper's hawks), and several species of owls (Johnsgard 1988, 1990; Table 3-13). Edges also provide escape and hiding cover, so that species that forage within the relatively open Ecosystem Initiation stands, such as deer and elk, stay near forested edges where they can more readily escape predators (Kirchhoff et al. 1983; Yahner 1988).

Table 3-12. Stand Development Stages and Vertebrate Species Closely Associated with Them*

Stand Development Stage	Species
Ecosystem Initiation	Rubber boa, terrestrial garter snake, northern alligator lizard, western fence lizard, ruffed grouse, California quail, common nighthawk, mountain bluebird, orange-crowned warbler, rufus-sided (spotted) towhee, white-crowned sparrow, dark-eyed junco, snowshoe hare, mountain beaver, deer mouse, creeping vole, Pacific jumping mouse, striped skunk, Rocky Mountain elk, Columbian black-tailed deer, black bear
Competitive Exclusion	Ruffed grouse, orange-crowned warbler, white-crowned sparrow, snowshoe hare, mountain beaver, common porcupine
Understory Development	Masked shrew, Townsend's chipmunk, western red-backed vole, common porcupine
Biomass Accumulation	Blue grouse, golden-crowned kinglet, Townsend's warbler, masked shrew, Townsend's chipmunk, Douglas' squirrel, western red-backed vole
Niche Diversification	Blue grouse, northern pygmy-owl, northern spotted owl, pileated woodpecker, Steller's jay, winter wren, varied thrush, masked shrew, long-legged myotis, silver-haired bat, big brown bat, snowshoe hare, Townsend's chipmunk, Douglas' squirrel, northern flying squirrel, western red-backed vole, red tree vole, common porcupine, Rocky Mountain elk, Columbian blacktailed deer
Fully Functional	Blue grouse, marbled murrelet, northern spotted owl, pileated woodpecker, Pacific-slope flycatcher, golden-crowned kinglet, sharp-shinned hawk, northern pygmy-owl, Vaux's swift, Steller's jay, winter wren, varied thrush, Townsend's warbler, western tanager, masked shrew, long-legged myotis, Keen's myotis, silver-haired bat, big brown bat, snowshoe hare, Townsend's chipmunk, Douglas' squirrel, northern flying squirrel, western red-backed vole, red tree vole, Rocky Mountain elk, Columbian black-tailed deer, black bear

*Based on Brown (1985); Carey et al. (1996); Franklin (2002); Johnson & O'Neil (2001)

What Type of Wildlife Diversity Exists in Competitive Exclusion Stands?

Competitive Exclusion stands represent a series of stages when overstory tree growth is reduced due to competition for direct sunlight, nutrients, water, and space (Oliver and Larson 1996; Carey 2003b). No wildlife species in western Washington are found exclusively in this stage (Carey et al. 1996) 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. For example, ruffed grouse nest within this habitat type and use it to escape from predators (Dessecker and McAuley 2001). Therefore, the presence of at least some Competitive Exclusion stage stands should contribute to overall biodiversity in terms of wildlife species abundance and distribution (refer to Table 3-12).

What Type of Wildlife Diversity Exists in Understory Development Stands?

This stage occurs when overstory tree density has declined to levels that allow sufficient light to reach the forest floor to support understory plant development. Overall wildlife use of this development stage is low. Johnson and O'Neil (2001) identified only six species closely associated with this stage (the same number as Competitive Exclusion): masked shrew, silver-haired bat, big brown bat, Townsend's chipmunk, western red-backed vole, and porcupine. The bat species use this habitat only for foraging, where they are known to fly above the tree canopy to feed on insects (Nagorsen and Brigham 1993, Brown 1985).

What Type of Wildlife Diversity Exists in the Biomass Accumulation Stands?

Biomass Accumulation stands contain relatively large diameter trees (at least 15 trees per acre over 30 inches in diameter) sufficiently spaced to allow rapid growth. This stage is often created through commercial thinning of Understory Development stage stands that have returned to high canopy closure conditions and in which a well-developed understory therefore may be lacking, at least initially. Johnson and O'Neil (2001) listed 11 species closely associated with this development stage, although many of the species require remnant snags to be present for breeding, including long-legged myotis, Vaux's swift and pileated woodpecker. Because existing stands in this stage lack large snags, these species are probably uncommon in stands currently classified in the Biomass Accumulation stage. Trees in this stage are sufficiently mature to produce large cone crops, food for seed eating wildlife such as red crossbill, Douglas' squirrel, and Townsend's chipmunk (Adkisson 1996; Chapman and Feldhammer 1982). Larger crowns and crown growth likely support the use by needle eating wildlife of this stage, including blue grouse and red tree vole (Cade and Hoffman 1990; Huff et al. 1992).

What Type of Wildlife Diversity Exists in Fully Functional and Niche Diversification Stands?

Numerous studies have shown that many species require structurally complex forests for some or all of their life history requirements (summarized in Zobrist and Hinckley 2005). Key elements of structurally complex forests include:

- Large live and dead trees (snags) and dead wood debris of various sizes and conditions (DNR 2004, p. B-32).
- Multiple canopy layers (for example hemlock, vine maple and associated vertical structure) and within-stand diversity (patches of larger trees, small openings).
- Understory species composition, size, and shape.

Table 3-13. Wildlife Species Closely Associated with High-Contrast Forest/Shrub Edges*

Meets All Habitat Requirements	Ensatina, ruffed grouse, band-tailed pigeon, great horned owl, common nighthawk, rufous hummingbird, western wood-pewee, winter wren, Townsend's solitaire, Swainson's thrush, hermit thrush, American robin, varied thrush, orange-crowed warbler, yellow-rumped warbler, western tananger, black-headed grosbeak, rufous-sided towhee, dark-eyed junco, brown-headed cowbird, purple finch, pine siskin, American goldfinch, masked shrew, vagrant shrew, mountain beaver, deer mouse, American kestrel, red-tailed hawk, common raven, Steller's jay
Meets Foraging Habitat Requirements Only	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, black-tailed deer, red fox, bobcat

*Based on Brown (1985)

More species require structurally complex forests (i.e., Fully Functional and Niche Diversification stages) for breeding than any of the other stand development stages. Brown (1985) listed 70 species that primarily use structurally complex forests for breeding in western Washington and Oregon. Based on habitat associations presented in Johnson and O'Neil (2001) and distribution maps prepared by Cassidy and others (1997), 23 species that breed within the planning unit are closely associated with Niche Diversification and 28 with Fully Functional stand development stages. Species that primarily use structurally complex forests as breeding habitat are listed in Table 3-12.

How Are Marbled Murrelets Managed Under the 1997 HCP?

The marbled murrelet (*Brachyramphus marmoratus*) was listed as a threatened species by the federal government in 1992, primarily due to the loss of older-forest habitat. The greatest identified threat to marbled murrelets in Washington, Oregon, California, British Columbia, and Alaska is the loss of quality nesting sites, primarily in older forests, and an increase of forest fragmentation, which is thought to increase predation and decrease nesting success.

The 1997 HCP required the development of a conservation strategy for the marbled murrelet; however, because of a lack of information on this species, DNR implemented an interim conservation strategy until a long-term conservation strategy could be created. The interim conservation strategy, which is included in the 1997 HCP (p. IV.39), is currently used in the planning unit. Any marbled murrelet-occupied site identified before or during any of the processes outlined in the 1997 HCP is protected until the long-term plan is developed.

Table 3-14. Sensitive Wildlife Species Known of Suspected to Occur in the Planning Unit*

Species and Status	Habitat		
	Foraging	Breeding and/or Resting	General Upland
Red-Legged Frog (FCo)	Ecosystem Initiation and structurally complex stand development stages	Requires riparian for breeding.	Moist habitats, including shrubby areas with large woody debris.
Western Toad (FCo, SC)	All	Requires riparian for breeding.	Large woody debris.
Northern Goshawk (FCo, SC)	Edges and open forest, Structurally complex.	Structurally complex	Mature and late-successional forests.
Bald Eagle (ST)	Large trees and snags near water.	All stages, but requires large trees for nesting and protected stands for roosting.	Large trees for nesting, dense and mature forest stands for winter roosts.
Great Blue Heron (SM)	May forage in Ecosystem Initiation stands.	Biomass Accumulation, Structurally complex, (Generally near large water bodies)	Mature forest stands (nesting).
Olive-Sided Flycatcher (FCo)	Ecosystem Initiation	Structurally complex	Large trees adjacent to open areas.
Osprey (SM)	Water (non-forest)	Structurally complex	Large trees for nesting, perching, roosting near large bodies of water.
Turkey Vulture (SM)	May forage in Ecosystem Initiation stands.	Structurally complex	Mature tree stands for roosting.
Vaux's Swift (FCo, SS)	Aerial foraging over all stages.	Structurally complex	Large snags for nesting.
Willow Flycatcher (FCo)	Ecosystem Initiation	Ecosystem Initiation	Shrubby habitats.
Long-Eared Myotis (FCo, SM)	Ecosystem Initiation	Structurally complex	Large trees and snags for roosting.
Long-Legged Myotis (FCo, SM)	Ecosystem Initiation	Structurally complex	Large trees and snags for roosting.
Townsend's Big-Eared Bat (FCo, SC)	Ecosystem Initiation	Structurally complex	Large trees and snags for nesting.
Yuma Myotis (FCo)	Ecosystem Initiation	Structurally complex	Large trees and snags for roosting.

FCo = Federal Species of Concern, SC = State Candidate, SE = State Endangered, SS = State Sensitive, ST = State Threatened, SM = State Monitor
*Source: Based on Brown (1985) and Johnson and O'Neil (2001)

What Is the Status of the Marbled Murrelet Interim Conservation Strategy in the Planning Unit?

In the planning unit, step one as outlined in the 1997 HCP (p. IV.39) is being implemented. All habitat blocks suitable for marbled murrelet are identified and deferred from harvest. It is estimated that approximately 8,000 to 10,000 acres of suitable habitat has been identified to date in the planning unit (DNR 2008).

Are any Sensitive Species Found in the Planning Unit?

The Endangered Species Act provides a means to protect species and their habitats to ensure their survival. Sensitive species [4] are defined as, "any wildlife native to the State of Washington that is vulnerable or declining and is likely to become endangered or threatened throughout a significant portion of its range within the state without cooperative management or removal of threats." Table 3-14 lists these species and their essential habitat elements.

Northern Spotted Owl

Why Is the Northern Spotted Owl Important to Forest Ecosystems?

The northern spotted owl (*Strix occidentalis*) is an indicator species of forest ecosystem health, reliant predominantly on northern flying squirrels (*Glaucomys sabrinus*) for food, which in turn, rely on truffles and other fungal fruiting bodies associated with late-sucessional western hemlock and Douglas-fir forests in the Pacific Northwest (Carey et al. 1992). The northern spotted owl inhabits structurally complex forests from southwest British Columbia through the Cascade Mountains and coastal ranges in Washington, Oregon, and California (Forsman et al. 1984, Guiterrez et al. 1984, Allen and Brewer 1985).

The major threats to northern spotted owls include loss of habitat from past management activities and current disturbances such as fire, and ongoing habitat loss as a result of timber harvest on non-federal lands (Courtney 2004). Recently, competition with barred owls (*Strix varia*) has been identified as a major threat (USFWS 2007; Gutierrez 2006; Olson et al. 2004).

What Is the Status of Northern Spotted Owls?

The northern spotted owl has been listed as threatened under the federal Endangered Species Act (ESA) since 1990. The U.S. Fish & Wildlife Service (USFWS) 5-year review of the ESA listing status of the northern spotted owl under the ESA, the USFWS (2004) summarized the status of owl populations as follows:

> "In general, northern spotted owl populations are exhibiting strong declines in the northern portion of their range in Canada, Washington, and parts of Oregon, while populations in the southern portions of their range are generally stable. Declines in Washington appear to be driven by decreased adult survivorship."

What Role Do Forested State Trust Lands Have in Northern Spotted Owl Recovery?

Forested state trust lands are "to provide habitat that makes a significant contribution to demographic support, maintenance of species distribution, and facilitation of dispersal" (DNR 1977). 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 et al. 1993, p. 11). Maintenance of species distribution refers to supporting the continued presence of the spotted owl population in as much of its historic range as possible (Thomas et al. 1990, p. 23; USFWS 1992, p. 56). Dispersal is the movement of juvenile, sub-adult, and adult animals (in this case, spotted owls) from one sub-population to another. For juvenile spotted owls, dispersal is the process of leaving the natal territory to establish a new territory (Thomas et al. 1990, p. 303; Forsman et al. 2002; Miller et al. 1997).

Approximately half (approximately 78,047 acres) of the forested state trust lands identified for dispersal management in the 1997 HCP are within the planning unit. There are also two areas designated as nesting, roosting and foraging management areas (NRF) (approximately 2,419 acres).

What Are DNR's Management Strategies for the Northern Spotted Owl?

The conservation strategy outlined in the 1997 HCP is intended to provide habitat for nesting, roosting, and foraging, as well as dispersal, in strategic areas referred to as dispersal management areas. The strategy is also intended to create a landscape in which active forest management plays a role in the development and maintenance of the structural characteristics that constitute such habitat (DNR 1997).

Does the Northern Spotted Owl Recovery Plan Affect DNR Lands?

Federal recovery plans are not regulatory documents and do not impose any restrictions on management activities on non-federal lands. The northern spotted owl final recovery plan (USFWS 2007) relies on federal lands to provide the major contribution for spotted owl recovery. Non-federal lands are expected to provide demographic support to core owl populations or to ensure connectivity with federal lands. In western Washington, the recovery plan identifies several areas outside federal lands, called conservation support areas (CSA), which "are expected to increase the likelihood that spotted owl recovery is achieved, shorten the time needed to achieve recovery, and/or reduce management risks associated with the Recovery Strategy and Actions" (USFWS 2007 p. 90). Two CSAs are delineated in the planning unit (WCSA-04 "Mineral" and WCSA-05 "I-90"). All forested state trust lands within or adjacent to these CSAs are designated as NRF or dispersal management areas under the 1997 HCP.

How Does DNR Track the Amount of Spotted Owl Habitat?

Each forest stand is classified based on its structural characteristics into one of the northern spotted owl habitat types: high quality nesting habitat, Type A, Type B, sub-mature, young forest marginal, dispersal, and non-habitat (DNR 1997). Within in each designated dispersal management area, a spotted owl management unit (SOMU) is defined and used to track the current amount of owl habitat. (SOMUs replaced the previously used Watershed Administrative Units (WAUs) which were difficult to track because the boundaries were regularly updated. The WAUs were renamed to avoid confusion and throughout the remainder of this section will be referred to as SOMU/WAU). Table 3-15 lists the SOMU/WAUs and the estimated percentages of suitable habitat in each.

Table 3-15. Estimated Current Dispersal or Higher Quality Owl Habitat as a Percentage of Designated Forested State Trust Lands in Each SOMU/WAU*

SOMU/WAU Name	Dispersal or Higher Habitat	
	DNR Forest Inventory Data Estimate	Yield Table Estimate
Ashford	43%	47%
Busy Wild	52%	57%
Big Catt	37%	48%
Grass Mountain	40%	40%
Mineral Creek	30%	34%
North Fork Green	48%	52%
North Fork Mineral	40%	56%
Pleasant Valley Dispersal	29%	32%
Reese Creek	63%	64%

*Source: DNR 2007

The reason for the overestimation when using yield tables is due to two factors: assignment of forested stands to forest strata and inventory updating methods to reflect recent past activities. Stratification of the forestland base tends to simplify the forest inventory and lends to an overestimation of the amount of habitat (refer to Appendix C). These differences have been explored and will likely be improved for the Final EIS.

What Is the Status of Management Areas in terms of Providing Dispersal Habitat for Northern Spotted Owls?

As previously stated, past timber management activities in the planning unit have resulted in conditions dominated by competitive exclusion and understory development stages. These overly stocked and structurally simplified stands are difficult for owls to fly through and contribute little to foraging and roosting habitat.

The current definition for northern spotted owl habitat for dispersal (Text Box 3-7) under the 1997 HCP does not target stand conditions that provide roosting or foraging opportunities for dispersing owls (no snag or down wood requirements). In addition, there is no upper threshold for trees per acre, which may result in stands too dense for owls to fly through. Buchanan (2004) compared existing habitat conservation plans (HCPs) that were negotiated for managing dispersal habitat (including DNR's 1997 HCP). He concluded that the proposed strategies implemented in the short and long term may not produce the conditions owls prefer, resulting in mortality due to starvation or predation.

Over-stocked forest stands offer little benefit to wildlife (Johnson and O'Neil 2001). Stand development stages do not change quickly; they remain constant for extended periods before moving to the next stage. Carey (1995) and Carey and Johnson (1995) found these closed-canopy stands devoid of exploitable prey populations due to the lack of legacy trees. Entering these closed-canopy stands and removing some competition between trees accelerates the creation of the structural complexity needed by owls and their prey (Carey 2003b) (Chart 3-1).

What Elements Need to be Present to Benefit Dispersing Northern Spotted Owls?

Buchanan (2004) identified five habitat elements previously hypothesized by Carey (1985) that northern spotted owls need to disperse: amelioration of heat stress, prey abundance, prey availability, predation risk, and ecological adaptation. These five habitat elements are described by three dispersing activities in the life history of spotted owls:

1. **Movement** - Can an owl travel from one patch of habitat to another without being predated upon? (Forsman 2002; Miller et al. 1997)

2. **Roosting** - Is an owl able to perch for resting, heat regulation, and hunting? (Forsman 1976, 1980; Barrows and Barrows 1978; Barrows 1981; Forsman et al. 1984)

3. **Foraging** - Can an owl exhibit hunting behavior—i.e., are prey species abundant and available? (Forsman et al. 1984, 2004; Gutiérrez et al. 1995; Solis and Gutiérrez 1990).

What Elements Are Needed at the Stand Level to Benefit Dispersing Northern Spotted Owls?

The forest stands should provide for the three life history requirements (see above) of dispersing northern spotted owls: movement, roosting, and foraging. All three elements allow fly space and protection from predators, which is achieved by adequate forest species composition and canopy closure.

- Stands that benefit movement must have canopies closed enough to allow the northern spotted owls to be protected from predation. Stands must also have adequate fly space achieved by canopy lift and tree densities low enough to not impede flight (Appendix G – EMDS -DAT Workshop).

- Stands that benefit roosting must have adequate tree height for roosting opportunities, multiple layers for owls to move up and down in the canopy, and a canopy depth that provides a larger thermal buffer (more insulation) and greater possibilities for avoiding predation (Appendix G – EMDS-DAT Workshop).

• Stands that benefit foraging must have adequate prey abundance, which depends on the amount of snags and down wood. Multiple canopy layers make prey more available to owls by providing hunting perches and stem densities that would not exclude owls from catching prey (Appendix G – EMDS-DAT Workshop).

How Do Dispersing Northern Spotted Owls Move through the Forest?

When owls disperse from their natal territories, they experience a transience phase that is characterized by extensive and rapid movement through an area (Greenwood 1980; Miller et al. 1997). Miller (1989) observed that juveniles moved an average of 0.75 mile (1.6 kilometer) per day. Forsman et al. (2002) estimated average daily movements during transience at between 0.44 to 0.87 mile (0.7 and 1.4 kilometers).

After a few months of transience, most northern spotted owls have a colonization period. During this time, they settle for a short while in areas over winter before trying to establish a territory (Miller et al. 1997; Forsman et al. 2002). During the colonization period, Forsman and others (2002) estimated average daily movements to be between 0.25 to 0.37 mile (0.4 and 0.6 kilometer).

Is Habitat Fragmentation an Issue?

Natal and breeding habitats are likely impacted by forest fragmentation once a certain amount of forested habitat is lost (Courtney et al. 2004). Forsman and others (2002) did not report that juvenile or adult dispersing owls cross large segments of unsuitable habitat such as the non-forested Willamette, Rogue, and Umpqua valleys, or large bodies of water. Courtney and others (2004) suggest that fragmentation could impact the rates of recolonization, reduce dispersal opportunities, and create a lower gene pool flow within and between populations.

The 1997 HCP states that dispersal habitat should be maintained on 50 percent of DNR-managed lands selected for a dispersal role. The 50 percent goal is measured at the SOMU/WAU level to ensure there is an adequate distribution of habitat across all dispersal landscape management areas.

What Are the Existing Habitat Conditions for Nesting, Roosting, and Foraging Management Areas?

There are currently two Nesting, Roosting and Foraging Management areas in the planning unit (refer to Map 3-3, p. 59 DNR 2008).

The 1,743-acre Pleasant Valley Nesting, Roosting and Foraging Management area (see Map 3-3, p. 59 DNR 2008) adjoins a U.S. Forest Service land designated as a late successional reserve.

The 618-acre Green Mountain (Far Out) NRF management area (see Map 3-3, p.59) is surrounded by US Forest Service and City of Tacoma lands and is managed by City-owned Tacoma Water for northern spotted owl habitat. The SOMU/WAU is currently at 23 percent suitable habitat. Approximations of the levels of sub-mature habitat using the yield tables in the landscape model overestimate the current levels at 29 percent.

How Will Creation of Older-Forest Conditions Affect Northern Spotted Owls?

A policy adopted by the Board of Natural Resources in the 2006 *Policy for Sustainable Forests* targets the creation of 10 to 15 percent of each HCP planning unit in older-forest conditions. The creation of older-forest conditions in each planning unit would have a positive effect on northern spotted owls. Research indicates that northern spotted owls are strongly associated with late successional and old-growth forest habitats (DNR 2007, p.III 1). Potentially, increasing these conditions could increase the quantity and quality of habitat available for owls, especially if the increase is targeted for northern spotted owl management areas.

Soils

How Does Forest Management Affect Soil Compaction?

Soil compaction occurs when heavy machinery or objects such as logs fall on or move over the soil. It can also result from mineral soil being exposed to the impact of raindrops. Compaction can be detrimental because it changes the hydraulic properties and productivity of soil (Cafferata 1992; Grier et al. 1989). Because macropore space is reduced after compaction, soil drainage and aeration properties are changed. Soil infiltration rates are reduced, and overland flow can occur when compaction is severe. Reduced drainage rates, coupled with reduced aeration and increased soil strength, can lower productivity.

Table 3-16. Erosion, Compaction and Wet Displacement Potential by WAU (Percent of Area)*

Soil Characteristics Potentials (% of Area)									
WAU	Erosion			Compaction			Wet Displacement		
	Low	*Med.*	*High*	*Low*	*Med.*	*High*	*Low*	*Med.*	*High*
Ashford	25	72	03	35	08	57	15	34	51
Busy Wild	15	85	0	03	17	80	19	38	43
Kennedy Creek	42	38	20	05	59	36	53	27	20
Lynch Cove	88	02	10	16	82	02	88	02	10
N. Fork Mineral	18	73	09	81	14	05	01	04	95
Pleasant Valley	11	89	0	02	0	98	06	87	07
Reese	41	56	03	72	06	22	15	13	72
Tiger	40	54	06	04	42	54	21	55	24

*Source: DNR 2007

Variable retention harvests usually have the most severe impacts because of the number of trees felled and the proportion of harvest site disturbed. However, the severity of the impact varies depending on the method of harvesting used. Ground-based harvesting has a greater potential for impacts than cable methods. Full-suspension cable yarding causes less impact than high-lead methods. Thinnings often use ground-based equipment but usually have a lower impact in terms of soil compaction than variable retention harvests (Cafferata 1992).

Road construction, road maintenance, and creating log landings have the greatest impacts in terms of soil compaction. Often, the upper soil horizons are removed and a compacted, firm surface is established and maintained. Most DNR roads are covered with a rock surface. Roads that are constructed on slopes require uphill cuts where soil is exposed to compaction by raindrops. For further discussion on roads, refer to DNR 2004, p. 4-44 to 4-52 and DNR 2001, p. B-13.

Some recreational activities have the potential to cause significant soil compaction. Generally, areas that experience repeated use by vehicle, horse, and foot traffic have compacted soils. These areas include trails, trailheads, campground parking areas, and established campgrounds. For further discussion refer to Recreation p. 68, DNR 2008.

How Is Surface Erosion Affected by Forest Management?

Surface erosion is the movement of soil particles from the soil surface (Megahan 1991). Surface erosion involves the processes of particle detachment, transport and deposition. The forms of surface erosion include rainsplash, sheet, rill, gully, and dry ravel. Rainsplash erosion occurs when exposed mineral soil is impacted by raindrops and particles are detached and moved. Sheet erosion transports soil particles by sheet flow over the soil surface. The particles are detached by the sheet flow or rainsplash. Rill and gully erosion occurs when sheet or overland flow is concentrated into rills and gullies. Detachment of soil particles is caused by flowing water. On a volume basis, rill and gully erosion is most significant on forestlands (Brown 1988). Exposed soils with little or no cohesion on steep slopes are subject to dry ravel. With this form of surface erosion, gravity moves small aggregates and soil particles downslope.

It is possible for timber production activities to increase surface erosion. However, most forest soils within the planning unit have high infiltration capacities relative to the precipitation intensities that occur. Modern methods of harvesting tend to minimize soil compaction. Therefore, it is unlikely that sheet erosion and rill and gully erosion would be increased significantly unless the soil disturbance is severe and the soil is highly susceptible to compaction. Both timber harvesting and thinning will remove some of the ground cover and expose mineral soil, causing a greater potential for increasing rainsplash erosion.

Of all forest management activities, road construction and maintenance have the greatest potential for causing significant increases to surface erosion. The nearly impermeable road surfaces create sheet and rill flow of water that erodes the road surface. Road use during wet weather can move fine particles from the surfacing material. Depending on the road drainage design, all or some of the road surface runoff is directed into ditches where it is further concentrated. The ditch water is drained by relief culverts. There is a potential for the outflow from relief culverts to cause rill and gully erosion depending on culvert spacing and placement. Spacing culverts too far apart has the greatest potential for high erosion. Road cuts into non-cohesive soils increase the potential for dry ravel by exposing the soil and increasing the slope. Sediment from dry ravel collects in the ditches to be carried off during precipitation or snowmelt events.

Soil displacement is considered here in the context of soil's susceptibility to rutting when disturbed. Ruts created by harvest machinery or motorized vehicles can affect soil drainage and concentrate overland flow. Concentration of overland flow can lead to the more severe forms of surface, rill, or gully erosion. Most soil displacement is associated with activities that compact the soil.

Because of the potential force and volume of sediment involved in the transport and deposition processes, mass wasting has the potential to affect capital improvements negatively. Roads, utility structures, and buildings can be damaged severely or destroyed. In addition to sediment, mass wasting often transports large organic debris that can exacerbate damage to bridges and other downstream structures.

How Is Soil Productivity Affected by Forest Management?

Soil productivity refers to the soil's fertility or capacity to grow vegetation. Management activities can impact productivity in many ways. Soil productivity is reduced when its physical properties are changed by compaction and particle removal by surface erosion and mass wasting. Another means of impacting soil productivity is affecting the soil nutrient pool and nutrient recycling processes. Timber harvest has the greatest potential for impacting soil nutrients, with the exception of directly adding nutrients through fertilization (Raison and Crane 1986). Variable retention harvests and commercial thinning remove some of the nutrients stored in trees. Undisturbed, these nutrients would have been recycled into the soil through decay. The amount of nutrient extraction is proportional to the volume removed at a given time and the frequency of re-entry (Powers et al. 1990). After harvest, the microclimate of the site is often changed to favor accelerated decomposition of residual slash and other organic material causing an influx of nutrients into the mineral soil (Boyle 1976). Opening the canopy and reducing evapotranspiration through harvest techniques causes higher soil water levels. Percolation of this water through the soil profile can accelerate the leaching of mobile nutrients such a nitrates (Blackburn and Wood 1990). The degree of loss through this process varies with soil characteristics, local climate and the timing of revegetation.

Roads (Forest Roads, including Public Utilities and Services)

What Are Forest Roads?

The composition and effects of forest roads not only differ by geographic location, but also locally. Location on the landscape, steepness, topography, aspect, parent material, interaction with stream network, slope stability, and surrounding vegetation can all determine the success or failure of a road and the road network to which it is connected (USDA 2001). Vehicular access is controlled by gates, large rocks, rip rap, stumps, LWD, ecology blocks, concrete barriers, and other pre-approved materials.

How Are DNR Roads Used?

DNR management activities such as timber harvesting, fire control, and recreation activities require the use of forest roads. Residents with in-holdings also generate traffic. While DNR's largest single source of traffic is associated with land management activities, recreational access may be the source of the highest use in some areas (DNR 2006b).

How Many Forest Roads Are in the Planning Unit?

The current method of road inventory utilizes the forest practices transportation layer in DNR's GIS. DNR estimates that approximately 850 miles (DNR 2007 dataset) of forest road exist on forested state trust lands within the planning unit, including additional miles associated with easements on other lands. Since timber generally may be extracted within 800 feet of an existing road (refer to Table H-1, the current road system now allows access to approximately 62 percent of the planning unit. Additional roads or road sections would have to be built to access the remaining approximately 38 percent of the planning unit.

The average road density for the entire planning unit is 3.2 miles per square mile, but can vary from 1.6 to 4.9 miles per square mile (Table 3-17) in the watersheds where DNR manages 20 percent of more of the land base. DNR has abandoned or eliminated roads no longer needed for management purposes consistent with state *Forest Practices Rules* and the 1997 *Habitat Conservation Plan*.

It is anticipated that 12 miles of additional roads will be built every year for the next decade to access more of the forestland base. In steep terrain, reducing road densities may require longer cable yarding distances, which raises costs, especially for thinnings (Hochrein and Kellogg 1988). Forest roads are important means of access for timber harvesting, fire control, recreation and in-holdings for other owners.

What Are the Risks Associated with Forest Roads?

This section uses information from the Final Environmental Impact Statement for the Policy for Sustainable Forests (DNR 2006) contains a more comprehensive discussion of the bulleted points below:

- Roads can affect the surface water hydraulics by intercepting, concentrating, and rerouting normal runoff patterns causing surface erosion, sedimentation (p. 65, DNR 2008), and ultimately decreased water quality (p. 46, DNR 2008).

- Landslides or mass wasting associated with roads may be a major sediment source to watershed systems as well as their riparian buffers (Bescheta 1978; Swanson & Dyrness 1975).

- Forest roads can affect site productivity by removing and displacing topsoil, altering soil properties, changing microclimates, and accelerating erosion (USDA 2001).

• Roads and the stream-crossing structures they incorporate can affect fish (p. 110, DNR 2008), mammals, riparian obligate species, and migration corridors, and to a limited extent, disturb and displace species through introduction of human activity and habitat fragmentation (p. 113, DNR 2008).

• Road building can affect soil productivity (p. 64, DNR 2008). Factors involved include road location relative to sensitive soils and soil moisture, type, area, and the frequency of disturbance, e.g., skid roads.

• Noxious and invasive plant species can be introduced into the forest environment by access roads (Lonsdale et al. 1994; USDA 2001).

• Roads can have visual impacts (p. 71, DNR 2008), which are amplified when large contiguous harvest units are visible from locations on state and local highways that have high road densities.

• Roads produce dust, which is emitted into the atmosphere by vehicles moving on unpaved roads; reducing visibility and suspending particulates into the air that can pose health hazards (USDA 2001). Refer to Air Quality on p. 86, DNR 2008 for additional information.

How Are Forest Roads Managed Today?

Almost all roads present benefits, problems, and risks. If not properly managed, roads have the potential to increase costs, damage the environment, or provide opportunities for illegal activities. When deciding how to manage roads, DNR carefully weighs the impacts of forest roads with regard to environmental protection, public use, and forestland management needs.

Timber harvesting, fire control, and recreation put a certain pressure on forest roads through the amount of traffic, the types of traffic (vehicle types, weights, sizes, purposes), and the road mileage they require. Although in most areas, the largest single source of traffic is associated with DNR's management of forested state trust lands, recreation is a competing source of traffic in some areas (DNR 2006a). Recreational activities can be affected by any changes to the road system because it provides access for recreation. DNR limits entry to forested state trust lands when public access results (or may result in) damage to the environment or the road system or interferes with a contractor lessee (McClelland, pers. comm. 2007).

DNR complies with forest practices rules related to road maintenance and abandonment.[5] Compliance with the rules includes having all forest roads inventoried and environmental issues assessed with maintenance and abandonment activities prioritized by December 2005 and fixed by July 2016 (DNR 2006a). The prioritization was completed in December 2005. Refer to Appendix H for road maintenance accomplishments to date.

Table 3-17. Road Density by Watershed (Road Miles per Square Mile)*

Watershed	Road Density (mi./mi^2)
Ashford	4.5
Busy Wild	2.8
Kennedy Creek	3.7
Lynch Cove	3.5
North Fork Mineral	4.9
Pleasant Valley Dispersal	4.2
Reese Creek	2.4
Tiger	1.6
Planning Unit Average	**3.2**

*Source: DNR 2007

Recreation

What Are the Existing Recreational Opportunities?

The planning unit has 30 developed recreation sites, over 450 miles of trails, and many acres of dispersed recreation lands used for hunting, fishing, and sightseeing. DNR identified the region's main recreational attractions as trails and environmental education. The primary recreational niche for the planning unit is day-use and trail-oriented activities (unpublished 2004 Inventory and Assessment). Day-use recreational activities are varied and include hiking, horseback riding, off-road vehicle (ORV) use, skiing, mountain biking, hunting, sightseeing, fishing, food and vegetation gathering, and paragliding.

The breadth of the types of uses and user groups that access DNR-managed lands in the planning unit indicates the region's range of recreational opportunities and variety of terrain. Managing the various recreation user groups' interests and needs while still meeting the primary responsibilities of fiscal and conservation support of forested state trust lands complicates DNR's regional management responsibilities. Table J-1 summarizes the recreational setting and available facilities for each administrative unit and state forest block. As the population continues to increase, the current levels of use and recreational impacts, as seen in Table 3-18, are expected to increase as well.

What Guides Recreation on DNR Lands?

DNR provides public access opportunities on forested state trust lands as directed by the multiple use concept[6], as long as these opportunities are consistent with trust objectives to provide financial support for schools and other state institutions, while ensuring long-term protection of the environment. Where recreational activities can coincide with these primary purposes, DNR provides trails, trailhead facilities, and a primitive experience in a natural setting (DNR 2006b).

Chapter 79.10 RCW directs DNR to allow multiple uses of the trust lands it manages, including recreation areas and trails, education and scientific studies, special events, hunting and fishing, and maintenance of scenic areas and historic sites, when such uses are compatible with trust land management. Chapter 79.10.120 RCW also states,

> "If such additional uses are not compatible with the financial obligations in the management of trust land, they may be permitted only if there is compensation from such uses satisfying the financial obligations."

Chapter 46.09 RCW applies to all lands of the state and sets standards for the permitting and use of off-road and non-highway vehicles. It does not apply to the use of snowmobiles or any vehicle designed primarily for travel on, over, or in water. Chapter 332-52 WAC, Managed Lands and Roads-Use Of, controls public use activities that occur on all lands under DNR jurisdiction. The rules are aimed at protecting recreational, economic, and industrial activities on lands and roads.

Table 3-18. Estimated Annual Recreational Use in the Planning Unit*

Visit Location	Visits Per Year
Tiger Mountain	375,000
Tahuya	250,000
Green Mountain	50,000
Elbe Hills	45,000
Tahoma	15,000
McDonald Ridge & Grass Mountain	5,000

*Source: McClelland, personal communication 2008

Visual Management

Why Is Visual Management Important to DNR?

The visual quality of the American landscape has been a subject of discussion throughout the nation's history, but has become an increasingly prominent public issue in the past several decades due to the increased rate and scale of development (Zube 1986). Washington's growth management policies have slowed but not eliminated development in rural portions of the Puget Sound region. Approximately 13 percent of growth in King, Kitsap, Pierce, and Snohomish counties targets rural areas (PSRC 2005). Such rural development places homes, businesses, and roads within view of forested state trust lands. The popularity of outdoor recreation is also increasing the number of viewers, with the state estimating a 20 percent increase in hiking and off-road vehicle use between 2003 and 2023 (IAC 2003).

Such a steady increase in forestland visibility can be problematic, since input solicited by DNR regarding current management of forested state trust lands indicates public concern about visual quality. A 2002 focus group study found the subject of forestland management was strongly associated with the issue of clear-cutting and with negative visual connotations (Connections Group 2003). More recently, during stakeholder meetings and formal scoping meetings held in 2005 and 2006, visual quality was among the issues of concern identified by attendees, with specific comments about the visual impacts of communications towers, harvest activities, and large harvest units.

What Are DNR's Visual Management Concerns?

Visual management concerns must be balanced with DNR's other obligations and concerns. As discussed in Chapter 2, visual impacts can be mitigated by managing the timing, design, and size of harvested areas strategically. The alternatives differ in the numbers of harvesting techniques used and, consequently, the placement of leave trees. The observer's perspective and personal values influence whether the visual impact is positive, negative, or neutral. In addition to visual sensitivities that arise from DNR's management activities, concerns arise from issues related to forest health and forest roads.

Land Transactions

Why Are Population Dynamics Important?

Washington's population grew by 10.1 percent between 2000 and 2007, reaching an estimated 6.5 million people. About two-thirds of the state's population growth is driven by people moving into Washington (Office of Financial Management 2007a). The portions of seven counties represented in the unit grew by 9.7 percent during the same period (Table 3-23). The 2007 population in these counties was 3.9 million. Three of the five largest municipalities in the state – Seattle, Tacoma and Bellevue – are located within the planning unit and these cities were all in the top ten fastest growing municipalities in the state. Olympia ranks 21st in population and 46th in population change among 279 municipalities (OFM 2007b). As the population continues to grow (see Appendix L, DNR 2008), the pressure to convert forestland to other uses will continue. An active land transaction program can help DNR make appropriate choices in the future to address conversion concerns.

Table 3-23. Population Statistics for Washington and Counties within DNR's South Puget Sound Region*

County	2000 Population	2007 Population	Change 2000-2007	
			Difference	Percent
King	1,737,046	1,861,300	124,254	+7.2
Kitsap	231,969	244,800	12,831	+5.5
Lewis	68,600	74,100	5,500	+8.0
Mason	49,405	54,600	5,195	+10.5
Pierce	700,818	790,500	89,682	+12.8
Snohomish	606,024	686,300	80,276	+13.3
Thurston	207,355	238,000	30,645	+14.8
Total, all South Puget Sound Region Counties	3,601,217	3,949,600	348,383	+9.7
State of Washington	5,894,143	6,488,000	593,857	+10.1

*Source: Office of Financial Management (2007)

What Is the Rate of Forestland Conversion?

Washington's forestland is being converted to other uses at a higher rate than elsewhere in the Pacific Northwest and the nation. A recent study by McClinton and Lassiter (2002) of forestland use conversion estimates that Washington has lost approximately 2 million acres of private forestland to non-forest uses since the 1930s. Much of this conversion has taken place in the low elevation forests of western Washington.

A recent study by Alig and White (2007) projects an eight percent further reduction in forestland area in western Washington from 1997 to 2027. Other projections have suggested forestland losses ranging from four percent to 13 percent over a similar period (Adams et al. 1994; Alig and Plantinga 2004).

Population growth, personal income growth, and economic expansion are the leading causes of forest conversions (McClinton and Lassiter 2002; Alig and White 2007). Population and economic growth require buildable land and shift the value of forestland away from timber production to development. Areas with the fastest growing populations near forests are likely to experience the most rapid conversion of forestlands. According to forest industry experts, land conservation organizations, and county resource managers, forests along the I-5 corridor likely will experience the most conversion pressure in the short term (DNR 2007). Clark, King, Pierce, Snohomish, and Thurston counties are those likely to have the greatest change. Grays Harbor, Jefferson, Kitsap, and Mason counties also are expected to undergo increasing rates of conversion (DNR 2007). This planning unit is located in the center of this area of impact.

What Are the Other Impacts of Population Growth on Working Forests?

The impacts of population growth and urbanization are not limited to land use conversion; these factors impact forestland indirectly.

Fragmentation and parcelization are often an intermediate step on the pathway from working forests to urban or suburban development (DNR 2007; Egan and Luloff 2000; Sampson and DeCoster 2000). Both have impacts on social and environmental values.

Typically, a large tract of industrial working forest is sold in smaller lots for rural residential use when the value of the property for these uses exceeds the value for continued timber production (Alig and White 2007). Prospective returns from growing timber cannot outweigh land development as land values for developed uses can be 80 to 100 times greater than forestlands (Alig and White 2007).

Forested state trust lands are not immune to the pressures of an increasingly urbanized environment. In order to uphold its fiduciary responsibility to trust beneficiaries, DNR is motivated to preserve the interests of the trusts by strategically repositioning timberland assets where they can continue to be managed for timber revenue production as well as environmental values.

Cultural Resources

What Is a Cultural Resource?

The WAC defines cultural resources as “archaeological and historic sites and artifacts and traditional religious, ceremonial and social uses and activities of affected Indian Tribes”.[2]

DNR (Stilson pers. comm. 2007) defines cultural resources as objects, sites, structures, buildings, and districts, containing evidence of past human activities or playing an active role in maintaining traditional cultures of the state.

DNR recognizes the significance of cultural properties, current cultural uses, and historic and archaeological sites. DNR also acknowledges the importance of government-to-government communications and collaboration with the Tribes, as discussed in the Commissioner’s Order on Tribal Relations (refer to DNR 2006b, Appendix B), as well as with interested stakeholders.

Because physical components and management strategies may vary, cultural resources on DNR lands are divided into four general types:

Historic Sites—Sites 50 or more years of age associated with activities of any of Washington’s peoples after the arrival of Euro-Americans, which have aboveground components.[7, 8] In exceptional cases, the 50-year threshold may be disregarded if a site is associated with an important person or event. Examples of historic sites include buildings, roads or trails, railroads, logging camps, dumps, and military installations.

Archaeological Sites—Sites more than 50 years in age that lack any standing structure; these may be surface scatters of artifacts, buried deposits, or both. Archaeological sites may be associated with any people who have occupied Washington, and can range from a single artifact (an “isolate”) to sites with large numbers of artifacts, ecofacts (unmodified materials such as shells or animal bones that reflect food debris), and features (modifications to the landscape such as hearths, pits, and stacked cairns).[8]

Traditional Cultural Places (TCP)—Identified by Tribes and play a significant role in a community’s historically rooted beliefs, customs and practices. These places range from the location of a secret ceremony to prominent natural features of the landscape such as ceremonial bathing areas, gear storage areas, spirit quest sites, traditional song and named places. All sites must have long-standing cultural significance to one or more Tribes, although their location may not be shared publicly (Timber/Fish/Wildlife Cultural Resources Committee; FFR Addendum; 2003 Cultural Resources and Protection Management Plan).[9] Often, to remain functional, a TCP must maintain the characteristics of purity, privacy, isolation, and permanence (from The Lummi Nation Business Council Management Concept for Cultural Resources).

Traditional Materials—Products of the landscape that continue to have significance to Tribes. Examples may include plants, animals, and minerals used for food, medicine, or raw materials used for artifacts (Timber/Fish/Wildlife Cultural Resources Committee; FFR Addendum; 2003 Cultural Resources and Protection Management Plan).[9] These property types are not mutually exclusiveand often overlap.

What Types of Cultural Resources Are Located in the Planning Unit?

All of the classes mentioned above have been found in and around the planning unit. Archaeological and historic sites have been documented in greater quantity, but DNR will continue to identify cultural resources of all classes in the course of managing forested state trust lands.

The Department of Archaeological and Historic Preservation (DAHP) database was queried November 9, 2007 and seven sites were identified within the planning unit. These sites include campsites, lithic scatter, and railroad camps as listed in Table 3-24.

Table 3-24. Current Archaeological and Historical Site Counts and Contents in the Planning Unit*

Site Type	Count	Site Contents
Historic Bridges	1	
Historic Logging Properties	4	Lumber mills, logging camps, lumber processing features—log chutes, flumes, dumps, holdings, railroads
Historic Outlooks	1	
Historic Objects	4	Historic markers, benchmarks, wagon frames, car parts, machinery
Historic Railroad Properties	2	Tracks, shelters, campsites, stations, trestles, berms, grades, cars, and materials (railroad ties and spikes)
Historic Structures – Not Specified	1	Foundations, function unknown
Pre-Contact Camp, Pre-Contact Culturally Modified	18	Short-term occupation sites
Trees	2	Culturally modified trees, including blazed and peeled trees
Pre-Contact Lithic Material	1	Lithic scatter, quarry, misc. tools and debitage
Pre-Contact Shell Midden	2	Matrix of shell, bone and lithics

*Source: Department of Archaeological and Historic Preservation (2007)

Climate

What Is the Climate of Western Washington?

The area of Washington west of the Cascade Mountains is predominantly a marine type of climate, obvious by its mildness when compared to other climates at similar latitudes (46° to 49°) (Map 3-4 p.81) Average Air Temperature). Three environmental factors—terrain, the Pacific, and semi-permanent high and low pressure systems over the northern Pacific—combine to create drastic changes over relatively short distances (Bach 2004; NOAA 1985).

There are two large mountain chains in the western part of Washington, the Olympics and the Cascades. The large Cascade Range divides the wetter western side of the state from a dramatically drier east side. Moisture-laden clouds form over the Pacific and are first intercepted by the coastal range (NOAA 1985). As the clouds move over the land and up in elevation, condensation occurs as the temperature drops, releasing precipitation as it moves up the windward mountain slopes (Agee 1993). This process is called orographic lifting and occurs in all mountainous regions; therefore, where the Cascade foothills meet the Puget lowlands, large amounts of precipitation fall every year. The profiles (Figure 3-1, p.81 DNR 2008) below compare the winter and summer flow of prevailing winds for the region.

Proximity to the Pacific Ocean is very important to the climate of western Washington. The temperature of the Pacific Ocean changes very little throughout the year (though according to the Intergovernmental

Panel on Climate Change (2001) ocean temperatures may be on the rise overall); in the winter, the water is warmer than the adjoining land mass and in the summer is slightly cooler. The air over the water is often the same temperature as the water and so nearness to the Pacific Ocean and the Puget Sound translates to similar temperatures for the surrounding land surfaces (Bach 2004). Both rainfall and snowfall increase with a slight increase in elevation and distance from the water. In addition, variations in temperature and length of growing season and fog can also be related to relative distance from these bodies of water (NOAA 1985).

There are semi-permanent high and low pressure systems over the Pacific Ocean that strongly influence the seasonal changes in Washington. The low pressure system (Aleutian Low) is strongest in the late fall, peaks in the winter, and loses strength and moves northward in the spring. The jet stream brings many cold fronts into the region which are slowed as they ascend the Cascades, bringing low intensity, long duration precipitation events (Bach 2004). As the low pressure system weakens, the high pressure system (Pacific High) gains strength, bringing westerly and northwesterly air that is dry, cool and stable (Agee 1993). The dry season begins with the movement of this air mass over the Pacific Northwest in late spring and peaks with the warmest days in July and August (refer to Figure 3-2, p.82 DNR 2008).

Nearly every winter, especially those associated with La Niña, the polar jet stream will mix with the tropical jet stream in a phenomenon called the pineapple express. This event results in exceptionally heavy precipitation, often accompanied by warm westerly winds resulting in premature snow melting (rain-on-snow events) (Bach 2004).

Winter in western Washington is cloudy and wet but the summers are generally cool and comparatively dry. December and January are the wettest months of the year, unlike July and August, where several weeks may pass with only light showers. The graph in Figure 3-2, p.81 DNR 2008 shows the monthly precipitation distribution for a 70-year period at Sea-Tac in western Washington. This graph shows the greatest precipitation levels occurring in November, December, and January with the least precipitation falling in June, July, and August. Annual precipitation averages 40 to 60 inches a year in the Puget Sound area and increases with elevation, with up to 180 inches falling annually along the west slopes of the Cascades (Bach 2004) (refer to Map 3-5p. 83, DNR 2008). Historically, Mount Rainier and other peaks in the Cascade Range have had record-breaking snow accumulations.

Six of the 10 warmest years recorded in Washington since 1918 occurred between 1996 and 2007 (NOAA 2008), which may surprise locals, since many of those years also had above-average rainfall partnered with severe flooding in western Washington and other parts of the western coastal states. For example, in 2 weeks spanning December 1996 and January 1997, 10 to 40 inches (near the annual average) of rain fell in western Washington, melting snow and causing severe flooding (NOAA 2008).

Clouds are more prevalent than sun during the winter months in western Washington, where the possible monthly sunshine is only around 25 percent but during the summer, the sun can shine up to 60 percent in any given month. The region receives one of the lowest percentages of shortwave radiation in the entire nation on average (refer to Map 3-6, p.83 DNR 2008), meaning general solar exposure is very low. The growing season ranges from April to early November, when the ground is typically frost-free (NOAA 1985).

What Role Does Wind Play in Climate Conditions?

Wind is a common component of the western Washington climate but notable disturbances from these winds generally occur only one to two times annually. During winter months, prevailing winds are generally southwesterly (Map 3-7, DNR 2008), although wind commonly flows in areas of least resistance as seen on the directional map where winds are shown flowing into the Puget Sound from the north, near Seattle, and also through small elevation gaps near the Columbia River Gorge and the Chehalis River Valley. Wind speeds are generally below 10 miles per hour in the lowlands and foothills, but can range from 50 to 70 miles per hour along the coast and have been observed at a consistent 50 to 60 miles per hour during storms with higher gusts in inland areas. Wind speeds generally increase with elevation and ridge tops have the highest and least predictable winds, as seen in Map 3-7, p.84 DNR 2008. Map 3-8, p.85 DNR 2008 depicts the higher ridges of the Cascades, especially Mount Rainier, having very high wind speeds compared to the rest of the planning unit. Wind shapes the forest structure of western Washington more than any other natural disturbance event.

While western Washington generally does not experience dry lightning storms, the area does experience 10 to 12 lightning storms per year, usually in the western foothills of the Cascades (NOAA 1985).

Air Quality

What Is Air Quality?

Air quality is the status of the atmosphere in respect to potential pollutants such as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), suspended particulates, and ground-level ozone (O_3)(Government of Alberta 2007).

What Are Sources of Air Contamination?

There are many sources of air contamination. As noted in Chapter 1, the planning unit is the most highly populated area of the state with over 50 percent of the landscape supporting urban environments. With such a high density of people in the region, it should be no surprise that the most common form of air contamination comes from motor vehicle fumes (EPA 2007) and that as much as 50 percent of the overall greenhouse gas emissions are from transportation (Ecology 2008b). This pollution is mostly composed of hydrocarbons, an organic compound of hydrogen and carbon which is commonly found in petroleum products, coal, and natural gas (National Safety Council 2005). In addition to this major contributor, industrial process losses, industrial fuel use, home heating, and refuse disposal add to air degradation (EPA 2007; DNR 2004).

What Natural Factors Affect Air Quality?

In Washington, west of the Cascade Mountains, the most common effects to air quality are caused by topography and climate. The Puget Sound is especially susceptible to natural conditions that can periodically accumulate air pollutants. High moisture levels, stable atmospheric conditions, and fog all contribute to the ability of the air to hold contaminants in the lower part of the atmosphere (DNR 2004). Although higher moisture levels in the air can hold larger amounts of particulates, precipitation and the air turbulence it causes can dissipate these contaminants. Peculiar local and regional wind patterns allow these contaminants to move relatively long distances, although they are often rapidly dispersed.

Cold weather in the late fall and winter is the most common time to notice higher levels of contaminants in the air, when a layer of warm air traps pollution closer to the surface in an inversion layer. When the air is relatively stable, contaminants are generally very concentrated near the source. Under clear skies, light wind, and sharp temperature inversions, these conditions are most obvious. Pollution is usually removed within a few days by either wind or rain (Parsons and Brinckerhoff 2005).

What Are the Adverse Effects of Forest Management on Air Quality?

There are three primary adverse effects of forest management to the quality of air on a local and regional basis, including smoke from prescribed burning, airborne dust from logging and hauling, and the sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) from trucks, logging equipment, and forest product manufacturing. These effects are commonly linked to climate change and are further discussed in the section below.

What Effect Does Prescribed Burning Have on Air Quality?

Traditionally, prescribed burning was a common method of forest site preparation used to remove unwanted vegetation, add nutrients to soil, and germinate seeds. These planned fires were also used to reduce wildfire risk. In recent years, as air quality concerns have increased, prescribed burning has become less and less common and now is allowed to take place only in very specific conditions. It has been replaced with mechanical and herbicidal vegetation management. Researchers (Holsapple and Snell 1996; Running 2006) have found that prescribed burning releases large amounts of smoke and particulates into the air, but compared to wildfire, its effects seem relatively insignificant. Nearly every year since the mid-1980s, the number of acres lost to wildfire has increased, and with three to four times the particulate emissions as prescribed burning, the latter seems to be the better option (Westerling et al. 2006).

DNR may burn 500 to 1,000 acres per decade for site preparation and 300 to 1,000 for wildfire risk reduction in Washington (DNR 1997), although in the past, it was rarely used in this planning unit. Several factors contribute to the lack of prescribed fire in this area: fear of escape, high moisture levels, and reluctance to put smoke into the Puget Sound Basin. For these reasons, an estimated value of less than one percent of the listed acres burned by DNR would be located in this area (Keeley, pers. comm. 2008).

How Can Logging and Hauling Affect Air Quality?

In general, the adverse impacts of airborne dust and particulate matter caused from driving on forest roads as well as skidding logs are localized and short term. Forest roads produce the greatest amount of airborne dust, which is generally a function of road quantity, quality, and use. In the early 1990s, DNR adopted a policy limiting the size of harvest units. Although the smaller unit size has many benefits, it has caused an increase in road mileage (DNR 2004).

What Pollutants Are Generated by Trucks, Logging Equipment, and Forest Product Manufacturing?

Trucks, skidders, loaders, splitters, booms, trailers, tractors, and even chainsaws use fuels that release high amounts of sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) into the air, contributing to elevated levels of greenhouse gases. In addition, the facilities that manufacture forest products are often run by burning wood waste fuels. More than releasing SO_2 and NO_2 into the atmosphere, burning woodchips releases carbon in the form of hydrocarbons and CO_2, increasing the probability of smog and global warming.

As of 2003, 2,796 logging trucks were registered in Washington and operated on both forest roads and highways (Lyons 2003). Trucks that travel on both paved and unpaved roads are often considered more heavy duty and are built for higher performance than many other on-road vehicles. Their engines do not use fuel as efficiently as other vehicles and are likely to have a longer life span (Ecology 2006).

Ecology (2006) is pushing for a major movement to improve air quality by reducing diesel exhaust in the air and sulfur content in current fuels. Diesel releases large amounts of macroscopic particulate matter into the air and no reported oxidation catalysts and diesel particulate filters are available that could be retrofitted to these vehicles to reduce air pollution (Lyons 2003). Other methods to reduce diesel exhaust would require that trucks be properly maintained; use low sulfur fuels, and not idle for extended periods. Access to low sulfur fuels should not be a problem for logging trucks that haul logs on paved roads, but off-road vehicles used at more remote sites may have limited access to these fuel types (Lyons 2003). Newer equipment and engines are built to burn fuel using cleaner methods and so, if possible, old equipment should be replaced or new equipment should be used more frequently (Ecology 2006).

How Can DNR Reduce Potential Impacts of Management on Air Quality?

- More intensive road management
- Reduce public access to forest roads in order to maintain high quality roads

The proposed alternatives' use of these management techniques does not differ.

Global Climate Change

What Is Climate Change?

Climate change (also called global warming) is a regional or global-scale alteration in average temperature and weather patterns, especially storm activity over a time scale ranging from decades to centuries. The term refers to both natural- and human-caused differences in climate over a long period. Current science indicates a link between climate change over the last century and human activity, particularly the burning of fossil fuels (Karl et al. 2006; Intergovernmental Panel on Climate Change 2007; PBS 2008).

Why Is Climate Change a Concern?

Since the late 1980s, scientists have suggested a worldwide trend toward global warming, demonstrated through climatic occurrences such as El Niño and La Niña, typhoons, tsunamis, and disturbances like forest fires (Ecology 2008a).

Warming in the western mountains is projected to cause decreased snowpack, more winter flooding, and reduced summer flows (Intergovernmental Panel on Climate Change 2007). The panel also reported the "warming of the climate system is unequivocal" and it is more than 90 percent likely that the accelerated warming trends of the past half-century are due to human contributions.

Researchers (Oregon Wild 2007; McNulty and Aber 2000; EPA 1998) predict that a warmer climate means more rain during winter months in Washington and less available water, typically stored in high elevation snowpack, to be released during summer. Increased rainfall during winter months may also contribute to greater flooding and soil erosion. Warmer, drier summers in combination with these effects can increase stresses to forests such as fire, pests, and disease (EPA 1998). In addition to losing water in streams and lakes, drier weather could mean drier soils as an additional threat to ecosystem health.

Climate change could move current plant and animal communities toward the poles and up to higher elevations. These drifts potentially could change relationships between pollinators, predators, and prey as well as other important species interactions (Sherry et al. 2007).

Scientists (Sherry et al. 2007; Hanson et al. 2001) have seen species' shifts on a global scale over the past century in both plants and wildlife. As climates have changed slowly, species have migrated or adapted. Many species are not able to move fast enough and are overtaken by more adaptable non-native species (EPA 1998). Although many species can adapt to a wide range of conditions, some depend on very specific habitats to survive. For example, the northern spotted owl has different life history requirements for nesting, roosting, and foraging within a very small range. If any change occurs, these special conditions may be lost and the species may be at risk.

Forest fires threaten thousands of acres of DNR land annually and contribute greenhouse gases into the atmosphere. However, very few acres burn annually within this planning unit due to high fuel moisture. Steve 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. Fire is an essential component of recycling dead biomass, and a benefit where these rates are traditionally extremely low. However, these benefits are far exceeded by fire expenses and the addition of nearly 40 percent of fossil fuel carbon emissions (Running 2006). If annual temperatures continue to increase, plant and soil moisture levels may decrease and vegetation composition may change to drier species. Through this process, an increased frequency of disturbances (such as forest fires) in this planning unit could become a reality.

What Factors Affect Climate Change?

Several factors dramatically affect climate change. The most widely discussed reason is increased greenhouse gases in the atmosphere, mostly caused by humans. Scientists continue to debate whether climatic variability is the primary cause of climate change and if the change is a cycle in the earth's life similar to former ice ages. For now, they have settled on the fact that a number of methods are available to mediate the effects of climate change and perhaps even prevent it.

What Are Washington State Officials Doing to Address Climate Change?

Washington and other western states are participating in a federal grant to examine how the 2.1 million acres of forested state trust lands and 8.5 million acres of private forestland could be used to offset greenhouse gas that comes from vehicles, electric power generated by fossil fuels, and other CO_2 sources.

This project is part of the Global Climate Change Initiative (signed by President Bush, February 14, 2002) studying carbon sequestration, where trees remove carbon from the air as part of their natural biological respiration process and store the carbon in the wood as standing trees or in the structural lumber. As part of this initiative, greenhouse gas emitters would then purchase carbon credits from owners of forest land. The carbon balance for current management of forested state trust lands is thought to be positive (more carbon is fixed than is lost) considering the carbon in the forest and in structural wood products produced from the forest. This is especially true when accounting for the reduction of structural materials with more carbon-intensive production, such as steel or concrete (DNR 2004).

In March 2008, Washington Governor Christine Gregoire signed the Climate Change Framework/Green-Collar Jobs Act, which calls for the state's transportation sector, Washington's largest contributor to greenhouse gas emissions, to cut vehicle miles traveled by 18 percent by 2020, 30 percent by 2035, and 50 percent by 2050 (News Release 2008). Refer to Air Quality p. 85, DNR 2008 for more information on this subject.

How Do Forestlands Counteract the Negative Influences of Climate Change?

Forest management is one of few human activities that can create biological carbon sinks to help mitigate the accumulation of CO_2 in the atmosphere (Kurz et al. 2002). Photosynthesis and respiration trap carbon dioxide and release oxygen into the atmosphere. The two ways to increase this carbon catching would be to increase the forest area or to increase carbon density through management. Long-term terrestrial storage of carbon dioxide through carbon sequestration has been hypothesized to reduce the effects of climate change. Additional ways forests may counteract effects include regulating localized microclimates by reducing wind and limiting surface cooling.

Carbon Sequestration

What is Carbon Sequestration?

Carbon sequestration is the annual rate of carbon storage in above- and below-ground biomass over the course of one growing season, as carbon is biologically converted from a gas (CO_2) to organic compounds in a tree.

Carbon dioxide is exchanged between the atmosphere and forests in several ways. Through photosynthesis and respiration, it is absorbed into the plants and during decomposition and fire, CO_2 is released again into the atmosphere (Kurz et al. 2002).

How Does Carbon Move into Plants?

During photosynthesis, atmospheric CO_2 enters the plant leaves through surface pores, called stomata. Within the plant, a chemical reaction catalyzed by sunlight takes place: CO_2 combines with water and creates cellulose, sugars, and other materials. Therefore, carbon from the atmosphere is trappedin new chemical forms in terrestrial plants (Britannica 2008).

How Is that Carbon Stored?

In general, forest trees store most carbon, up to fifty-one percent, in their trunks. The second largest storehouse of carbon in trees is the branches and stems at thirty percent, followed by the below-ground root biomass which holds 18 to 24 percent of the carbon and is usually left when trees are harvested. Three percent is stored in the foliage (leaves or needles), and there can be a net carbon loss when leaves are shed by the tree (McPherson and Simpson 1999).

Carbon can be stored in standing wood, lumber products, soil humus, and decomposing organisms. Therefore, removing biomass from a site for a use such as building materials prevents the carbon from being recycled back into the atmosphere through decomposition or other means (McPherson and Simpson 1999).

How Long Does Carbon Stay in the Environment?

The amount of sequestered carbon remaining in a system depends on factors that include but are not limited to tree growth, mortality, species composition, age distribution, structure class, period before next harvest and overall forest health.

Smaller pieces of debris return carbon to the atmosphere faster than large ones. Mulching, chipping, and burning return carbon to the atmosphere rapidly, especially in moist environments. Carbon can be held in wood after it is cut down so long as it does not decompose; most down wood can survive for around 50 years (on average) before gradually decomposing (Norse 1990).

What Is the Best Carbon Sequestration Environment?

Healthy, vigorous growing trees will absorb more CO_2 than diseased or otherwise stressed ones (McPherson and Simpson 1999). In recent years, scientists have debated whether fast-growing, short-lived trees or slow-growing, long-lived trees could sequester and maintain more carbon (Kurz et al. 2002). Although rapidly growing trees sequester more CO_2 initially than slower growing ones, the advantage can be lost if the fast growing trees die at younger ages.

McPherson and Simpson (1999) reported that, as long as trees were growing, their rate of photosynthesis CO_2 uptake would be higher than their level of respiration. Therefore, more carbon can be sequestered by an actively growing tree than at other stages.

How Is Carbon Released Again into the Atmosphere?

Carbon is released into the atmosphere from standing forests in two ways. Burning is the most rapid method for carbon to return to the atmosphere. Decomposition occurs much more slowly and is a second primary means of returning carbon to the air (McPherson and Simpson 1999).

How Can We Measure the Benefits of Carbon Sequestration?

The Canadian Forest Service Carbon Accounting Team (Kurz et al. 2002) has been working since the late 1990s to create a tool to model the carbon budget in Canada. DNR is currently exploring the possibility of employing this modeling system to improve its decision-making. In 2002, the team began developing a more localized version of the model to create values for smaller tracts of land and morphing their research tool into a user-friendly decision support tool. This carbon model can now be used with input from forest models (such as the one used in this assessment) to estimate landscape level forest carbon stocks and carbon stock changes (Kurz et al. 2002).

Does DNR Have a Carbon Sequestration Program?

There is no local carbon program in place, but at a national level, there are tax credits and additional benefits to private landowners who increase their carbon sinks.

End Notes

1 Chapter 222-22-020 Washington Administrative Code [WAC]
2 Chapter 222-16-010 Washington Administrative Code [WAC]
3 Chapter 230.41a (1) Code of Federal Regulations
4 Chapter 232-12-297 Washington Administrative Code [WAC]
5 Chapter 222-24 Washington Administrative Code [WAC]
6 Chapter 79.10.100 Revised Code of Washington [RCW]
7 Chapter 27.34.020 Revised Code of Washington [RCW]
8 Chapter 27.53.030 Revised Code of Washington [RCW]
9 Executive Order 0505
10 36 CFR Part 61

Implementation

Silvicultural Prescriptions

Silvicultural prescriptions are developed in the planning are through general guidance (Holmberg and Aulds, 2007). An Inter-Active Self-Study and Reference Pamphlet By Pete Holmberg and Bob Aulds (2007) describes a silvicultural prescription as the optimal regime to attain rotational forest management unit (FMU) objectives. The intent of rotational silvicultural prescriptions is two-fold: (1) to develop and demonstrate that present activity prescriptions are the best course to attain rotational FMU objectives, and (2) to schedule key future activities. Thus, future foresters will be alerted to key entries and to prescription intent. The silvicultural pamphlet's purpose is to provide a concise, effective, and easy process and method to assist field foresters in devising silvicultural prescriptions for forest management units (FMUs).

The process guides the development of silvicultural prescriptions that optimally attain Social, Ecological, and Economic FMU objectives in concert with site-specific ecological pre-disposition. The process generates sequences of FMU activities to be entered in Planning & Tracking (P&T) database through final harvest of the rotation. The process allows for modification of prescriptions at future stand density-related decision nodes.

The pamphlet utilizes a plant association-based decision tree that leads to initial prescriptions for whole rotations that attain standard FMU objectives. These prescriptions are in a standard prescription format that spans the entire rotation. Initial prescriptions may become final prescriptions with, often minor, adjustments to site-specific conditions. The process described in this pamphlet is also used for partial rotation prescriptions.

The dominant silvicultural system implemented in the planning area in the uplands is cohort management (per procedure Westside - Management of Forest Stand Cohorts). Forest stand "cohorts" are statistically distinct forest stand components whose management objectives make them important. For example, legacy cohorts such as live wildlife reserve trees, snags, and down dead logs, are important because statutes, regulations, and the Department's HCP require their management and retention beyond a single rotation. These multi-rotational cohorts co-exist with one or more rotations, within the same forest management unit (FMU). Legacy cohorts are managed to achieve environmental FMU objectives (such as wildlife and mycorrhizal habitats). One or more commercial cohorts within the same FMU are managed to achieve economic FMU objectives by generating revenue for the trusts.

Environmental Review

The State Environmental Policy Act (SEPA) in conducted when actions are expected to result in changes to the natural environment, the purpose of the Environmental Impact Statement (EIS) is more than just disclosure or justification of a particular action. It must be used by decision makers when making decisions on proposed actions to ensure environmentally sound solutions.
Environmental Impact Statement (EIS) are expected to result in; a complete impartial inquiry into the environmental impacts of a proposal. Encourage public participation in the discussion and development of a range of reasonable alternatives, and provide decision makers with enough information on the environmental impacts of a proposal to make a decision.

At the strategic level, DNR state lands has used the EIS process for the 1997 Habitat Conservation Plan, 2004 Sustainable Harvest Calculation and 2007 addendum, 2006 Policy for Sustainable Forests. An EIS must include all *probable significant* adverse environmental impacts (RCW 43.21C.031-110 (1)). An EIS may identify beneficial or other impacts (e.g., social, economic), but this is not required. Discussion of insignificant impacts is not required. If included, discussion of such impacts must be brief and limited to noting why further study is not warranted (WAC 197-11-402(3)).

Forest land planning, which are tactical plans, not only specify and adapt forest management strategies for local conditions, but also identify where and what activities will most likely produce the Board's desired outcomes. Through feedback and communication opportunities, including reporting progress toward desired outcomes to the Board and providing for stakeholder and public participation, the forest land planning process can help refine strategies and outcomes as appropriate.

Environmental review requirements of the State Environmental Policy Act (SEPA) provide a mechanism to not only identify the impacts of forest land planning, but to also bring that information to the Board and the public.

Monitoring the Current Plan

Silviculture

Each quarter new silvicultural prescriptions are entered into the planning and tracking system by region foresters. These prescriptions are monitored to ensure agency performance measures are met which includes appropriate harvesting methods.

State of the Forest Reports

The Board of Natural Resources directs the Department, in its annual report to the Board, to give a general accounting of the activities and investments made to reach the objectives and outcomes modeled in the Sustainable Harvest Calculation and the status of the current and anticipated results of those activities and investments, including any indication that the Board should consider an adjustment of the decadal harvest level.

The report contains the following timber topics: volume sold, value earned, acres transferred, silviculture using biodiversity pathways, inventing in forest stands, and new markets.

The report also contains other topics with include: contributions to forest ecosystem health, social and cultural benefits, forest land planning, forest lands, non-timber programs, and total revenue earned.

HCP Implementation Monitoring and Reporting

Implementation monitoring, also known as compliance monitoring, determines whether our habitat conservation strategies are being implemented as written. It is one of three major types of monitoring required under our trust lands HCP. The data we gather from this monitoring is used to help us determine how well we are doing, as well as to help us modify our management strategies as needed to better protect and enhance habitat. The implementation monitoring team is responsible for the following activities:
Documenting the types, amounts, and locations of forest management activities in each HCP planning unit on a yearly basis. This helps us decide what and how to monitor, while also providing a record of our activities.
Monitoring and reporting on selected conservation strategies or components each year. We use what we learn to modify and improve our monitoring and reporting methods as well as our strategy implementation.
Producing annual reports on forest management activities on lands managed under the HCP.
Providing periodic comprehensive reviews on implementation of the HCP (e.g. the HCP 5-Year Comprehensive Review).

Monitoring harvest levels

The Planning and Tracking database is used to monitor activities statewide. The purpose of Activity Monitoring Reporting is to identify what activities are scheduled or completed during a specified time period. This report is also designed to assist with budget, time management and contract preparation. The report contains scheduled, completed or canceled activity information and summarizes acres treated. Activity information can be sorted by county, trust, DNR administrative area, activity type, technique, crew type, Forest Management Unit (FMU) or many additional combinations which you chose. Activities reported include those activities associated with current and historical FMUs

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Forest Resource Inventory System

The forest resource inventory systems provides consistent and reliable site specific vegetation information to allow managers, planners, and field foresters to make operational and planning decisions. The information is used to:

- Identify and describe the vegetative component of forest ecosystems
- Conduct silvicultural operations
- Conduct planning efforts
- Calculate sustainable harvest levels
- Support marketing of timber resources

The Forest Resource Inventory System is a multi-vegetative inventory system. Data is collected on trees, understory vegetation, down woody debris and land surface composition according to various sampling protocols. The measurements collected are useful to evaluate commercial forest products, wildlife habitat conditions, and forest health risks. The inventory is updated periodically using a Forest Vegetation Simulator (FVS) model to project growth and mortality. New sampling records are included as lands are acquired. DNR also conducts long-term monitoring of stands through cooperative agreements with Stand Management Cooperative, and the US Forest Service Research Station

Table 2 South Puget HCP unit Harvest levels - from the 2007 Sustainable Harvest adjustment

DATA	DECADE	Harvest Treatments: Regeneration	Heavy thinning	Light thinning	TOTAL
Harvest Volume (MMBF)	1	191.4	44.9	29.4	265.7
	2	218.0	77.3	46.8	342.1
	3	192.8	98.6	73.4	364.8
	4	619.5	113.1	42.0	774.6
	5	323.5	34.1	35.1	392.7
	6	241.0	32.7	50.9	324.6
	7	341.3	47.1	63.2	451.5
	8	439.9	41.8	43.1	524.9
	9	488.2	49.5	62.1	599.8
	10	600.3	69.5	65.0	734.8
Harvest Area (thousand-acres)	1	7.0	3.4	3.8	14.2
	2	9.1	6.0	6.2	21.2
	3	7.0	6.1	7.2	20.4
	4	13.8	6.7	3.7	24.1
	5	7.4	2.8	3.1	13.3
	6	7.0	3.4	4.3	14.7
	7	10.2	3.3	5.3	18.8
	8	11.6	2.0	3.8	17.4
	9	12.0	3.0	5.5	20.5
	10	13.9	4.6	7.5	26.0
Gross Revenue ($million)	1	64.9	10.2	4.0	79.1
	2	71.4	18.5	6.5	96.4
	3	63.3	23.8	10.9	98.0
	4	194.2	26.0	6.0	226.3
	5	110.4	8.3	5.0	123.7
	6	82.6	7.1	6.5	96.2
	7	115.3	10.0	8.0	133.3
	8	149.1	9.8	5.7	164.6
	9	170.2	11.1	8.3	189.6
	10	207.7	16.2	8.8	232.8
Total Harvest Volume (MMBF)		3,656.0	608.6	510.9	4,775.5
Total Harvest Area (thousand-acres)		99.0	41.2	50.5	190.7
Total Gross Revenue ($million)		1,229.2	141.1	69.8	1,440.1

Note: Harvest Treatments: Variable retention harvest includes variable retention harvest; heavy thinning is 40 percent of the harvest unit is retained; Light thinning is where 70 percent of the harvest unit is retained.

Forest Land Planning

The *Policy for Sustainable Forests* (DNR, 2006) directs DNR to implement Board of Natural Resources (the Board) policy goals through forest land plans at geographic scales similar to DNR's Habitat Conservation Plan planning units. The Board uses planning efforts such as the sustainable harvest, a strategic planning process, to establish general direction and goals for the Department which form the basis of further planning efforts.

Forest land planning, which are tactical plans, not only specify and adapt forest management strategies for local conditions, but also identify where and what activities will most likely produce the Board's desired outcomes. Through feedback and communication opportunities, including reporting progress toward desired outcomes to the Board and providing for stakeholder and public participation, the forest land planning process can help refine strategies and outcomes as appropriate.

Environmental review requirements of the State Environmental Policy Act (SEPA) provide a mechanism to not only identify the impacts of forest land planning, but to also bring that information to the Board and the public.

The DNR is developing a forest land plan for the South Puget HCP planning unit. A draft environmental impact statement, which includes analysis of the alternative landscape management strategies under consideration for the planning unit is due out in the summer of 2008. Table 1 presents a summary of the alternative strategies under consideration. Figures present some primary results in terms of harvest levels, cash-flow, net present value, forest structure and northern spotted owl habitat.

Table 1. Summary of the Alternative Management Strategies being considered as part of the Forest Land Planning Process.

	Alternative A (No Action)	Alternative B (Preferred Alternative)	Alternative C (Other Options)	Related Management Goal
Forest Condition and Management				
Average harvested area (acres) per decade	20,446 acres	22,553 acres	26,791 acres	Manage the land base to meet multiple objectives
Harvest Volume (million board feet MMBF)	273 MMBF	353 MMBF	489 MMBF	265 MMBF
Harvest Types: Thinning (thin) or Regeneration (regen)	65 % thin	67 % thin	68 % thin	Achievement of plan objectives (no set limit on harvesting types)
	35 % regen	33% regen	32 % regen	
Older Forest Conditions [1] by 2067	16 %	26 %	26 %	10 to 15 percent of the planning unit in older forest conditions
Watershed Systems				
Hydrologic maturity (water quantity) criteria for Lake Tahuya	Continue with existing Lake Tahuya prescription of maintaining 40 to 42 percent of each WAU with trees over 25	Review prescription	Same as Alternative A	Flexibility to conduct harvest activities

[1] Niche Diversification and Fully Functional stand development stages

	Alternative A (No Action)	Alternative B (Preferred Alternative)	Alternative C (Other Options)	Related Management Goal
	years old			
Average riparian area harvested by decade	7 %	7 %	8 %	Improve forest stand conditions, increase stand structure
Wildlife				
Habitat	Produces less foraging habitat-(deer, elk, shrub birds), less than 6% in Ecosystem Initiation. Results in 34 % structurally complex[2] land cover over planning horizon.	More consistent levels of foraging habitat, results in 38 % in structurally complex land cover over planning horizon.	Maintains greatest amount of Ecosystem Initiation Stages, results in 36 % in structurally complex land cover over planning horizon.	Contribute to the demographic support of populations of unlisted species and; facilitate the dispersal of wide-ranging species among and between federal forest reserves.
Northern Spotted Owl (NSO)				
Percent and type of dispersal habitat over the planning horizon (See Chapter 2 and MoRF definition p.28 under Alternative B)	MoRF and higher quality habitat (20%)	MoRF and higher quality habitat (48%)	MoRF and higher quality habitat (39%),	Demographic support for northern spotted owls through the provision of dispersal habitat
Harvest Activities in Status One Owl Circles (2007-2017)	Regen-25 ac. Thinning-884 ac. Variable Density Thinning[3]-0 ac.	Regen-0 ac. Thinning- 218 ac. Variable Density Thinning- 294 ac.	Regen-64 ac. Thinning- 290 ac. Variable Density Thinning- 2,024 ac.	Increase structural diversity to enhance the spotted owls ability to disperse across the landscape.
Roads				
Use and road density	Starting with the lowest level of road use and ending with the highest; with a steady increase in road usage for decade six to the end of the planning horizon.	Lowest level of road use over the first six decades.	Highest level of road use due to the level of thinning harvests, specifically in decades one and four.	Maintain roads while selling timber, allowing for public access where compatible, road miles are expected to be similar
Recreation				
Motorized and Non-Motorized	Assess recreation activities	Evaluate resource issues to determine where, what type, and how much recreation is appropriate	Include expanded contract services to provide more opportunities	Safe, sustainable recreational compatible with trust management obligations
Visual Management				
Modeled projections of Thinning vs. Regeneration acres	Thinning 119,210 ac. Regeneration 92,214 ac.	Change from Alternative A Thinning +21% Regeneration -6%	Change from Alternative A Thinning +43% Regeneration	Manage visually sensitive areas while generating revenue for the trust beneficiaries

[2] Biomass Accumulation, Niche Diversification, Fully Functional stand development stages
[3] Type A, MoRF and Sub-Mature Thinnings

	Alternative A (No Action)	Alternative B (Preferred Alternative)	Alternative C (Other Options)	Related Management Goal
			+25%	

Additional details related to the alternative Northern Spotted Owl dispersal management strategies

Figure 1 Current Spotted Owl Management units

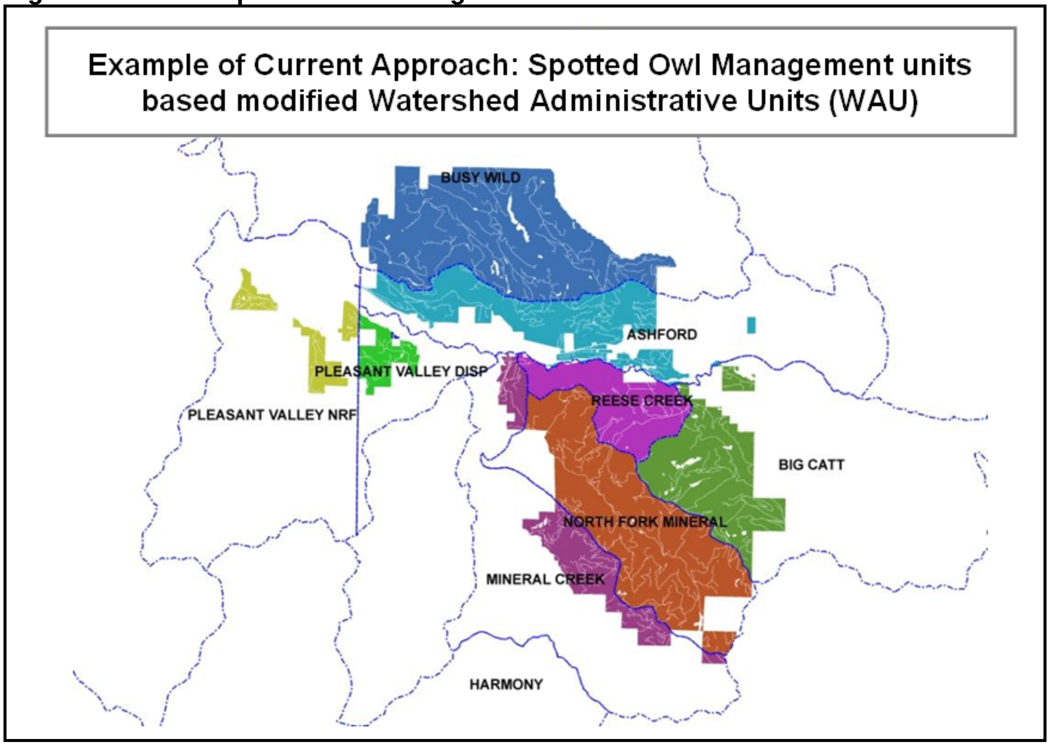


Figure 2 Proposed Spotted Owl Management Units

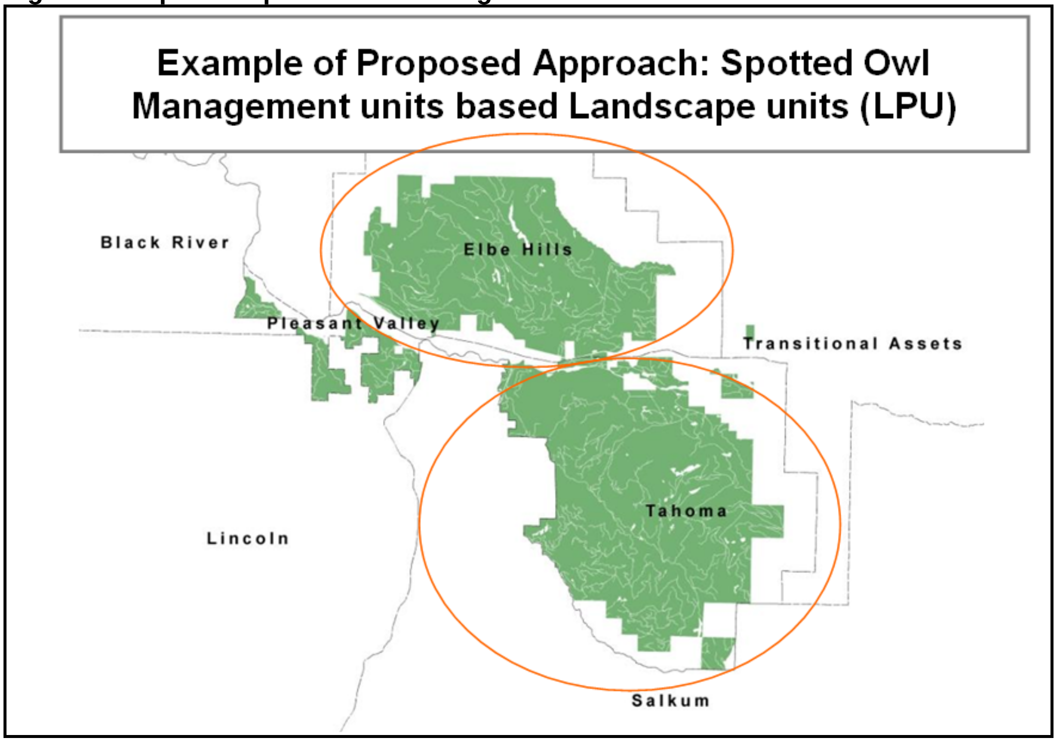


Figure 3 Examples of draft modeling results for northern spotted owl habitat in the Elbe landscape

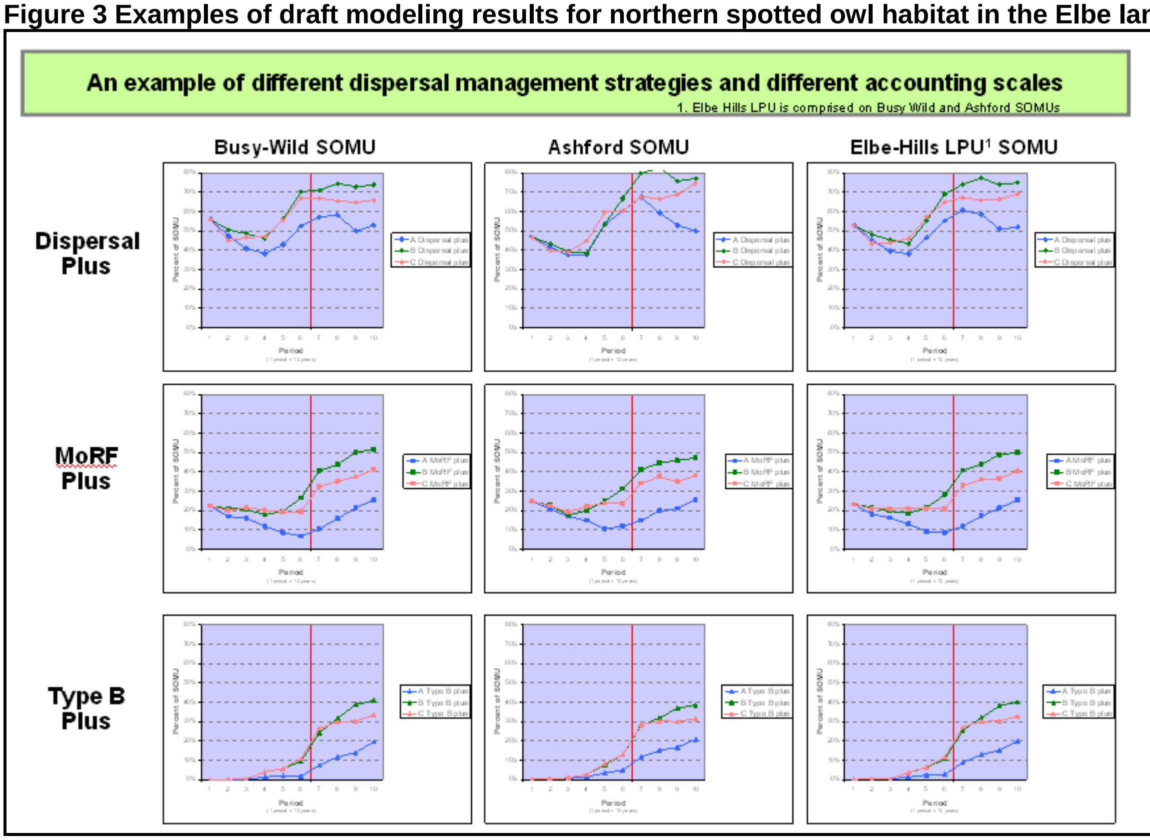


Figure 4 Examples of the draft spatial distribution of northern spotted owl habitat under different management alternatives in the Elbe landscape

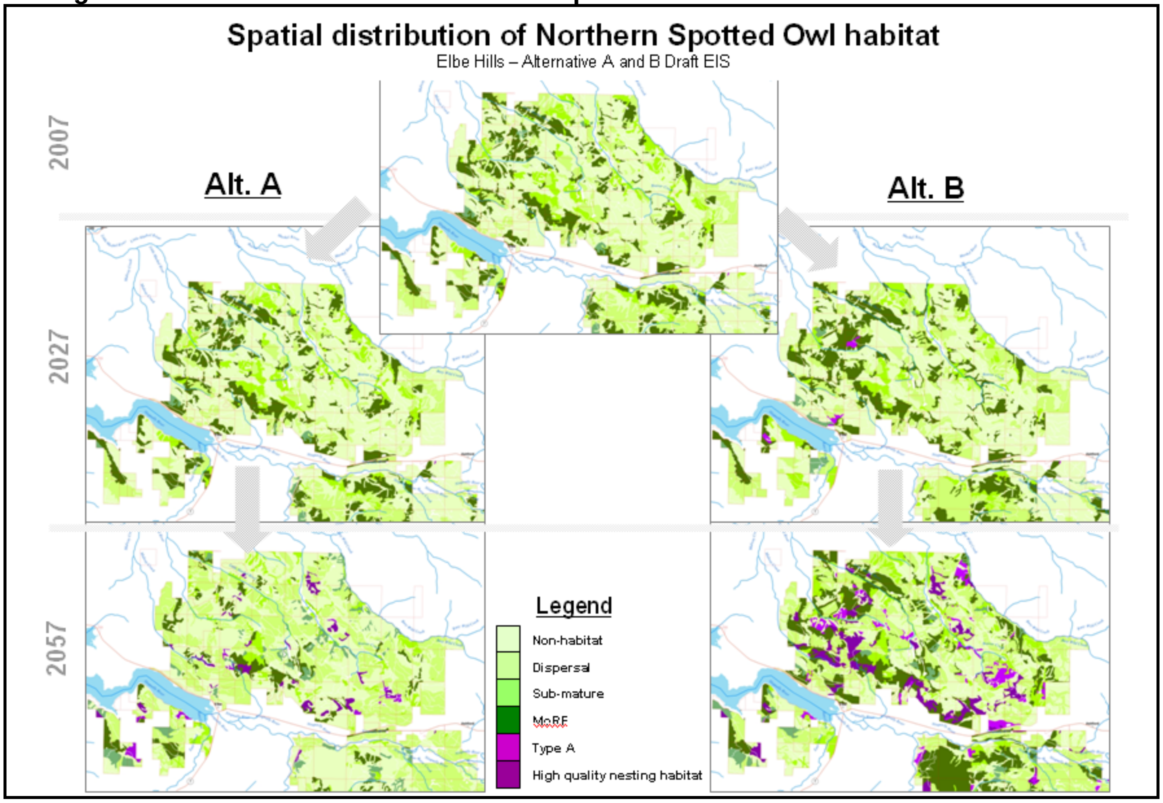
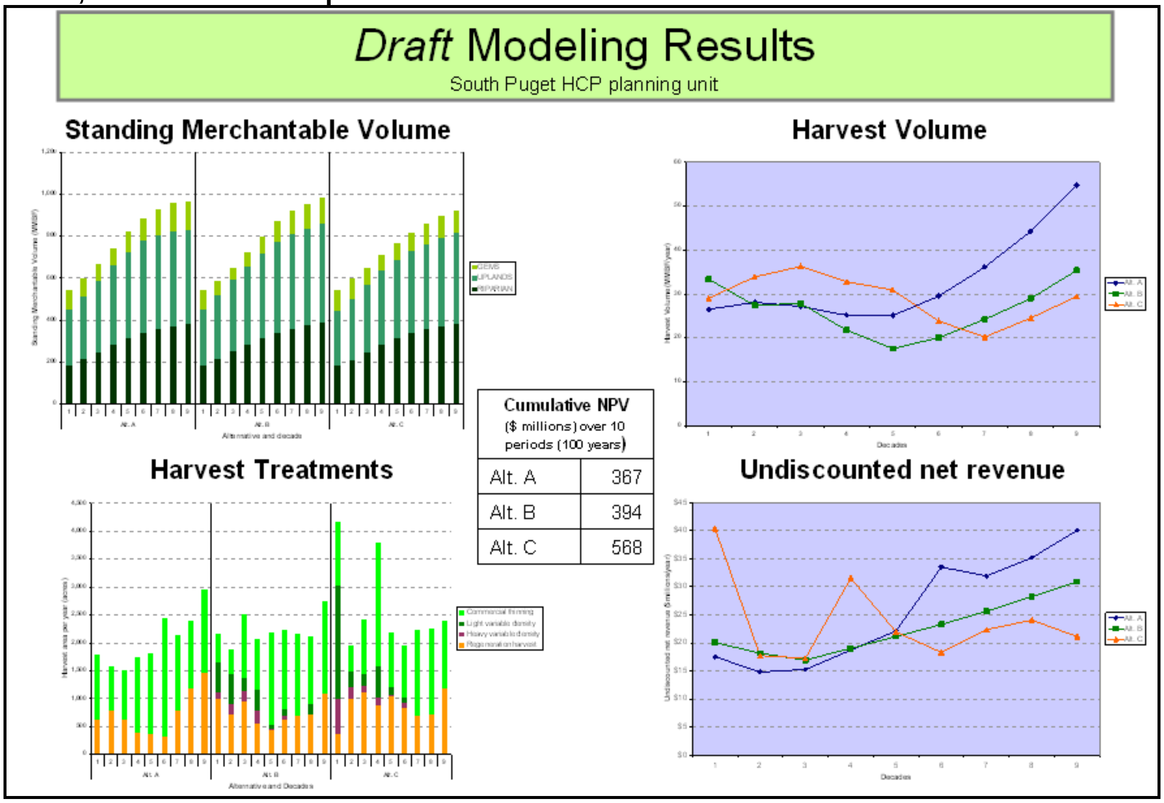


Figure 5 Examples of draft modeling results of the alternative management strategies on harvest levels, cash-flow and net present value



References

Adams, D.M., R.J. Alig, and J. Stevens. 1994. An Analysis of Future Softwood Timber Supply in Western Washington. Western Journal of Applied Forestry 9(3):81-7.

Adkisson, C.S. 1996. Red Crossbill (*Loxia curvirostra*). *In*: A. Poole (ed.). The Birds of North America Online. Cornell Lab of Ornithology, Ithica, New York. Available online at: http://bna.birds.cornell.edu/bna/species/256.

Agee, J.K. 1993. Fire Ecology of Pacific Northwest Forests. Island Press, Washington D.C.

Alig, R.J. and A.J. Plantinga. 2004. Future Forestland Area: Impacts from Population Growth and Other Factors that Affect Land Values. Journal of Forestry 102(8):19-24.

Alig, R.J. and E. White. 2007. Projections of Forestland and Developed Land Areas in Western Washington. Western Journal of Applied Forestry 22(1):29-35.

Allen, H.L. and L.W. Brewer. 1985. A Review of Current Northern Spotted Owl (*Strix occidentalis caurina*) Research in Washington State. USDA Forest Service General Technical Report PNW-GTR-185. Pacific Northwest Research Station, Olympia, Washington.

Bach, A. 2004. Northwest Washington Climate. Explorations in Environmental Studies, Western Washington University, Bellingham, Washington. Available online at: http://myweb.facstaff.wwu.edu/wallin/esci301/NWclimate.doc.

Barrows, C. and K. Barrows. 1978. Roost Characteristics and Behavioral Thermoregulation in the Spotted Owl. Western Birds 9:1-8.

Barrows, C.W. 1981. Roost Selection by Spotted Owls: An Adaptation to Heat Stress. The Condor 83:302-309.

Beschta, R.L. 1978. Long-term Patterns of Sediment Production following Road Construction and Logging in the Oregon Coast Range. Water Resources Research 14(6):1011-1016.

Beschta, R.L. 1991. Stream habitat management for fish in the northwestern United States: The role of riparian vegetation. American Fisheries Society Symposium.

Beschta, R.L., M.R. Pyles, A.E. Skaugset, and C.G. Surfleet. 2000. Peakflow Responses to Forest Practices in the Western Cascades of Oregon. Journal of Hydrology 233:102-120.

Bigley, R. and F. Deisenhofer. 2006. Implementation Procedures for the Habitat Conservation Plan Riparian Forest Restoration Strategy. Washington State Department of Natural Resources, Olympia, Washington.

Bilby, R. E. 1988. Interactions Between Aquatic and Terrestrial Systems. Pages 13-30 *In*: K.J. Raedeke (ed.). Streamside Management: Riparian Wildlife and Forestry Interactions, Contribution No. 59. University of Washington, Seattle, Washington.

Blackburn, W.H. and J.C. Wood. 1990. Nutrient Export in Stormflow following Forest Harvesting and Site-preparation in East Texas. Journal of Environmental Quality 19(3):402-408.

Bowling, L.C., P. Storck, and D.P. Lettenmaier. 2000. Hydrologic Effects of Logging in Western Washington, United States. Water Resources Research 36(11):3223-3240.

Boyle, J.R. 1976. A System for Evaluating Potential Impacts of Whole-tree Harvesting on Site Quality. Tappi 59(7):79-81.

Brown, E.R. (tech. ed.). 1985. Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington (2 Parts). USDA Forest Service Publication R6-F&WL-192-1985. Pacific Northwest Region, Portland, Oregon.

Buchanan, J.B. 2004. In My Opinion: Managing Habitat for Dispersing Northern Spotted Owls—Are the Current Management Strategies Adequate? Wildlife Society Bulletin 32(4):1333–1345

Cade, B. S and R.W. Hoffman. 1990. Winter Use of Douglas-fir Forests by Blue Grouse in Colorado. Journal of Wildlife Management 54:471-479.

Cafferata, P. 1992. Soil Compaction Research. Pages 8-22 *In*: A. Skaugset (ed.) Forest Soils and Riparian Zone Management: The Contributions of Dr. Henry A. Froehlich to Forestry. Oregon State University, Corvallis, Oregon.

Carey, A. B. 1985. The scientific basis for spotted owl management. In: Gutierrez, RJ; Carey, A. B., eds. Ecology and management of the spotted owl in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-185. Portland, OR; USDA Forest Service, Pacific Northwest Res. Sta. 100-114.

Carey, A.B. 1995. Sciurids in Pacific Northwest Managed and Old-growth Forests. Ecological Applications 5:648-661.

Carey, A.B. 2003b. Managing for Wildlife: A Key Component for Social Acceptance of Compatible Forest Management. Pages 401-425 In: R.A. Monserud, R.W. Haynes and A.C. Johnson (eds.). Compatible Forest Management. Kluwell Academic Publishers, Norwell, Massachusetts.

Carey, A.B. 2007. Aiming for Healthy Forests: Active, Intentional Management for Multiple Values. USDA Forest Service General Technical Report PNW-GTR-721. Pacific Northwest Research Station, Portland, Oregon.

Carey, A.B., C. Elliott, B.R. Lippke, R. Bruce, J. Sessions, C.J. Chambers, C.D. Oliver, J.F. Franklin, and M.G. Raphael. 1996. Washington Forest Landscape Management Project – A Pragmatic, Ecological Approach to Small-landscape Management, Report No. 2. Washington State Department of Natural Resources, Olympia, Washington.

Carey, A.B., S.P. Horton, and B.L. Biswell. 1992. Northern Spotted Owls: Influence of Prey Base and Landscape Character. Ecological Monographs 62(2):223-250.

Carey, A.B. and M.L. Johnson. 1995. Small Mammals in Managed, Naturally Young, and Old-growth Forests. Ecological Applications 5:336–352.

Cassidy, K.M., C.E. Grue, M.R. Smith, and K.M. Dvornich (eds.). 1997. Washington State Gap Analysis Project Final Report (5 Volumes). Washington Cooperative Fish and Wildlife Research Unit, University of Washington, Seattle, Washington.

Castelle, A.J., C. Conolly, M. Emers, E.D. Metz, S. Meyer, M. Witter, S. Mauermann, T. Erickson, and S.S. Cooke. 1992. Wetland Buffers: Use and Effectiveness. Adolfson Associates, Inc. and Washington Department of Ecology, Olympia, Washington.

Chapman, J.A. and C.A. Feldhammer (eds.). 1982. Wild Mammals of North America. John Hopkins University Press, Baltimore, Maryland.

Connections Group, The. 2003. Sustainable Harvest Focus Groups. Washington State Department of Natural Resources, Olympia, Washington. Available online at: http://www.dnr.wa.gov/Publications/lm_sh_focusgrp_report.pdf.

Courtney, S.P., J.A. Blakesley, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fleischer, A.B. Franklin, J.F. Franklin, R.J. Gutiérrez, J.M. Marzluff, and L. Sztukowski. 2004. Scientific Evaluation of the Status of the Northern Spotted Owl. Sustainable Ecosystems Institute, Portland, Oregon.

Dessecker, D.R. and D.G. McAuley. 2001. Importance of Early Successional Habitat to Ruffed Grouse and American Woodcock. Wildlife Society Bulletin 29(2):456-465.

DNR *See* Washington State Department of Natural Resources

Ecology *See* Washington State Department of Ecology

Egan, A.F. and A.E. Luloff. 2000. The Exurbanization of America's Forests. Journal of Forestry 98(3):26-30.

Encyclopedia Britannica. 2008. Carbon Dioxide. Available online at: http://www.britannica.com/eb/article-9020249/carbon-dioxide.

EPA *See* United States Environmental Protection Agency

Everest, F.H., D.J. Stouder, C. Kakoyannis, L. Houston, G. Stankey, J. Kline, and R. Alig. 2004. A Review of Scientific Information on Issues Related to the Use and Management of Water Resources in the Pacific Northwest. USDA Forest Service General Technical Report PNW-GTR-595. Pacific Northwest Research Station, Portland, Oregon.

Forsman, E.D. 1976. A Preliminary Investigation of the Spotted Owl in Oregon. M.S. Thesis. Oregon State University, Corvallis, Oregon.

Forsman, E.D. 1980. Habitat Utilization by Spotted Owls in the West-central Cascades of Oregon. Ph.D. Thesis. Oregon State University, Corvallis, Oregon.

Forsman, E.D., R.G. Anthony, C.E. Meslow, and C.J. Zabel. 2004. Diets and Foraging Behavior of Northern Spotted Owls in Oregon. Journal of Raptor Research 38(3):214-230.

Forsman, E.D., R.G. Anthony, J.A. Reid, P.J. Loschl, S.G. Sovern, M. Taylor, B.L. Biswell, A. Ellingson, E.C. Meslow, G.S. Miller, K.A. Swindle, J.A. Thrailkill, F.F. Wagner, and D.E. Seaman. 2002. Natal and Breeding Dispersal of Northern Spotted Owls. Wildlife Monographs 149:1-35.

Forsman, E.D., E.C. Meslow, and H.M. Wight. 1984. Distribution and Biology of the Spotted Owl in Oregon. Wildlife Monographs 87:1-64.

Franklin, J.F. and C.T. Dyrness. 1973. Natural Vegetation of Oregon and Washington. USDA Forest Service General Technical Report PNW-GTR-8. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Franklin, J.F., T.A. Spies, R. Van Pelt, A.B. Carey, D.A. Thornberg, D.R. Berg, D.B. Lindenmayer, M.E. Harmon, W.S. Keeton, D.C. Shaw, K. Bible and J. Chen. 2002. Disturbances and Structural Development of Natural Forest Ecosystems with Silvicultural Implications, Using Douglas-fir Forests as an Example. Forest Ecology and Management 155:399-423.

Government of Alberta. 2007. Glossary. Available online at: http://environment.alberta.ca/ETG_Glossary.aspx.

Greenwood, P.J. 1980. Mating Systems, Philopatry and Dispersal in Birds and Mammals. Animal Behaviour 28(4):1140-1162.

Grier, C.C., K.M. Lee, N.M. Nadkarni, G.O. Klock, and P.J. Edgerton. 1989. Productivity of Forests of the United States and its Relation to Soil and Site Factors and Management Practices: A Review.

USDA Forest Service General Technical Report PNW-GTR-222. Pacific Northwest Research Station, Portland, Oregon.

Gutiérrez, R.J., M. Cody, S. Courtney, and A.B. Franklin. 2006. The Invasion of Barred Owls and its Potential Effect on the Spotted Owl: A Conservation Conundrum. Biological Invasion 9(2):181-196.

Gutiérrez, R.J., A.B. Franklin, and W.S. LaHaye. 1995. Spotted Owl: *Strix occidentalis*. *In*: F. Gill (ed.). American Ornithologists' Union. The Academy of Natural Sciences, Philadelphia, Pennsylvania.

Gutiérrez, R.J., D.M. Solis and C. Sisco. 1984. Habitat Ecology of the Spotted Owl in Northwestern California: Implication for Management. Pages 368-373 *In*: Proceedings of the Society of American Foresters National Convention, October 16-20, 1983, Bethesda, Maryland.

Hanson, E., D. Hays, L. Hicks, L. Young and J. Buchanan. 1993. Spotted Owl Habitat in Washington: A Report to the Washington Forest Practices Board. Washington Forest Practices Board, Olympia, Washington.

Hanson, A.J., R.P. Nielson, V.H. Dale, C.H. Flather, L.R. Iverson, D.J. Currie, S. Shafer, R. Cook and P.J. Bartlien. 2001. Global Change in Forests: Responses of Species, Communities, and Biomes. BioScience 51(9):765-779.

Hochrein, P.H. and L.D. Kellogg. 1988. Production and Cost Comparison for Three Skyline Thinning Systems. Western Journal of Applied Forestry 3(4):120-123.

Holmberg, P. (compiler). 2007. Thinning Forest Stands, East- and Westside: An Inter-active Self-Study and Reference Pamphlet. Washington State Department of Natural Resources, Olympia, Washington.

Holsapple, L.J. and K. Snell. 1996. Wildfire and Prescribed Fire Scenarios in the Columbia River Basin in Relationship to Particulate Matter and Visibility. *In*: R.E. Keane, J.L. Jones, L.S. Riley, and W.J. Hann (tech. eds.). Compilation of Administrative Reports: Multi-scale Landscape Dynamics in the Basin and Portions of the Klamath and Great Basins. USDA Forest Service, Bureau of Land Management, and Interior Columbia Basin Ecosystem Management Project, Walla Walla, Washington.

Huff, M.H., R.S. Holthausen, and K.B. Aubry (tech. cords.). 1992. Biology and Management of Old-growth Forests Habitat Management for Red Tree Voles in Douglas-fir Forests. USDA Forest Service General Technical Report PNW-GTR-302. Pacific Northwest Research Station, Portland, Oregon.

Hunter, M.L. 1990. Wildlife, Forests, and Forestry: Principles of Managing Forests for Biological Diversity. Prentice Hall, Englewood Cliffs, New Jersey.

IAC *See* Washington State Interagency Committee for Outdoor Recreation

Intergovernmental Panel on Climate Change. 2007. Climate Change 2007: Synthesis Report. Summary for Policy Makers. Available online at: www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf.

Johnsgard, P.A. 1988. North American Owls: Biology and Natural History. Smithsonian Institution Press, Washington D.C.

Johnsgard, P.A. 1990. Hawks, Eagles and Falcons of North America: Biology and Natural History. Smithsonian Institution Press, Washington D.C.

Johnson, D.H. and T.A. O'Neil (eds.). 2001. Wildlife Habitat Relationships in Oregon and Washington. Oregon State University Press, Corvallis, Oregon.

Jones, J.A. 2000. Hydrologic Processes and Peak Discharge Response to Forest Removal, Regrowth and Roads in 10 Small Experimental Basins, Western Cascades, Oregon. Water Resources Research 36(9):2621-2642.

Karl, T.R., S.J. Hassol, C.D. Miller, and W.L. Murray (eds.). 2006. Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, D.C.

Karr, J.R. and I.J. Schlosser. 1977. Impact of Nearstream Vegetation and Stream Morphology on Water Quality and Stream Biota. U.S. Environmental Protection Agency, Athens, Georgia.

Kirchhoff, M.D., J.W. Schoen, and O.C. Wallmo. 1983. Black-tailed Deer Use in Relation to Forest Clear-cut Edges in Southeastern Alaska. The Journal of Wildlife Management 47(2):497-501.

Knutson, K.L. and V.L. Naef. 1997. Management Recommendations for Washington's Priority Habitats: Riparian. Washington Department of Fish and Wildlife, Olympia, Washington.

Kurz, W.A., M. Apps, E. Banfield and G. Stinson. 2002. Forest Carbon Accounting at the Operational Scale. The Forestry Chronicle 78(5):672-679.

Lonsdale W.M. and A.M. Laine. 1994. Tourist Vehicles as Vectors of Weed Seeds in Kakadu National Park, Northern Australia. Biological Conservation 69(3):277-283.

Lyons, K. 2003. Assessment of Potential Strategies to Reduce Emissions from Diesel Engines in Washington State. Publication Number 05-02-005. Washington State Department of Ecology, Olympia, Washington.

McClinton, J.F. and S.R. Lassiter. 2002. Prime Forestland or Urban Development: Must We Choose? USDA Natural Resources Conservation Service, Spokane, Washington. Available online at: ftp://ftp-fc.sc.egov.usda.gov/WA/NRI_PDF/fs_pdfs/Final_Revised_2000_Summit.pdf

McNulty, S.G. and J.D. Aber. 2000. Climate Change Impacts on Forest Ecosystems. Acclimations March/April 2000. U.S. Climate Change Science Program, Washington, D.C. Available online at: http://www.usgcrp.gov/usgcrp/Library/nationalassessment/newsletter/2000.04/Frsts.html

McPherson, E.G. and J.R. Simpson. 1999. Carbon Dioxide Reduction through Urban Forestry: Guidelines for Professional and Volunteer Tree Planters. USDA Forest Service General Technical Report PSW-GTR-171. Pacific Southwest Research Station, Albany, California. Available online at: http://www.fs.fed.us/psw/publications/documents/gtr-171/gtr-171-cover.pdf

Meehan, W.R., F.J. Swanson, and J.R. Sedell. 1977. Influences of Riparian Vegetation on Aquatic Ecosystems with Particular Reference to Salmonid Fishes and their Food Supply. Pages 137-145 *In*: R.R. Johnson and D.A. Jones (eds.). Importance, Preservation, and Management of Riparian Habitat: A Symposium. USDA Forest Service General Technical Report RM-GTR-43. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Megahan, W.F. 1991. Erosion and Site Productivity in Western-montane Forest Ecosystems. Pages 146-159 *In*: A.E. Harvey and L. F. Neuenschwander (eds.). Proceedings – Management and Productivity of Western-montane Forest Soils. USDA Forest Service General Technical Report GTR-INT-280. Intermountain Research Station, Ogden, Utah.

Miller, G.S. 1989. Dispersal of Juvenile Northern Spotted Owls in Western Oregon. M.S. Thesis. Oregon State University, Corvallis, Oregon.

Miller, G.S., R.J. Small, and E.C. Meslow. 1997. Habitat Selection by Spotted Owls during Natal Dispersal in Western Oregon. Journal of Wildlife Management 61:140–150.

Murphy, M.L. and W.R. Meehan. 1991. Stream Ecosystems. Pages 17-46 *In*: W.R. Meehan (ed.). Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society Special Publication 19, Bethesda, Maryland.

Nagorsen, D. and M. Brigham. 1993. Royal British Columbia Museum Handbook: Bats of British Columbia. University of British Columbia Press, Vancouver, Canada.

National Oceanic and Atmospheric Administration. 1985. Climates of the States: Narrative Summaries, Tables and Maps for Each State with Overview of State Climatologist Programs (3rd ed.), Volume 2. Gale Research Company, New York, New York. Available online at: www.wrcc.dri.edu/narratives/WASHINGTON.htm.

National Oceanic and Atmospheric Administration. 2008. 2007 was Tenth Warmest for U.S., Fifth Warmest Worldwide. National Oceanic and Atmospheric Administration, Washington, D.C. Available online at: http://www.noaanews.noaa.gov/stories2008/20080115_warmest.html.

NOAA *See* National Oceanic and Atmospheric Administration

Norse, E.A. 1990. Ancient Forests of the Pacific Northwest. Island Press, Washington, D.C.

OFM *See* Washington State Office of Financial Management

Oliver, C.D. and B.C. Larson. 1996. Forest Stand Dynamics. John Wiley & Sons, New York, New York.

Oregon Wild. 2007. The Straight Facts on Forests, Carbon, and Global Warming, Version 1.4. Oregon Wild, Eugene, Oregon. Available online at: http://www.oregonwild.org/.

Olson, G.S., Glenn, E.M., Anthony, R.G., Forsman, E.D., Reid J.A., Loschl P. J. and William J. Ripple. Modeling Demographic Performance of Northern Spotted Owls Relative to Forest Habitat in Oregon. Journal of Wildlife Management. Vol. 68, No. 4, pp. 1039-1053.

Parsons Brinckerhoff. 2005. Air Quality. Pages 3.13-1 to 3.13-9 *In*: Tukwila South Project Draft Environmental Impact Statement. City of Tukwila, Tukwila, Washington. Available online at: www.ci.tukwila.wa.us/dcd/tuksouth/TukSouth-3.13AirQuality.pdf.

Patton, D.R. 1992. Wildlife Habitat Relationships in Forested Ecosystems. Timber Press, Portland, Oregon.

PBS *See* Public Broadcasting System

Powers, R.F., D.H. Alban, R.E. Miller, A.E. Tiarks, C.G. Wells, P.E. Avers, R.G. Cline, R.O. Fitzgerald, and N.S. Loftus, Jr. 1990. Sustaining Site Productivity in North American Forests: Problems and Prospects. Pages 49-79 *In*: S.P. Gessel, D.S. Lacate, G.F. Weetman, and R.F. Powers (eds.). Sustained Productivity of Forest Soils: Proceedings of the 7th North American Forest Soils Conference. University of British Columbia, Vancouver, Canada.

PSRC *See* Puget Sound Regional Council

Public Broadcasting System. 2008. Glossary: National Geographic's Strange Days on Planet Earth. Vulcan Productions and National Geographic Television and Film. Available online at: http://www.pbs.org/strangedays/glossary/C.html.

Puget Sound Regional Council. 2005. Growth Management by the Numbers: Population, Household, and Employment Growth Targets in the Central Puget Sound Region. Puget Sound Regional Council, Seattle, Washington.

Raedeke, K.J. 1988. Introduction. Pages xiii-xvi *In*: K.J. Raedeke (ed.). Streamside Management: Riparian Wildlife and Forestry Interactions, Contribution No.59. University of Washington, Institute of Forest Resources, Seattle, Washington.

Raison, R.J. and W.J.B. Crane. 1986. Nutritional Costs of Shortened Rotations in Plantation Forestry. Martinus Nijhoff, Dordrecht, Netherlands.

Richardson, J.S., R.J. Naiman, F.J. Swanson, and D.E. Hibbs. 2005. Riparian Communities Associated With Pacific Northwest Headwater Streams: Assemblages, Processes, and Uniqueness. Journal of the American Water Resources Association 41(4):935–947.

Running, S.W. 2006. Is Global Warming Causing More, Larger Wildfires? Science 313:927-928.

Sampson, N. and L. DeCoster. 2000. Forest Fragmentation: Implications for Sustainable Private Forests. Journal of Forestry 98(3):4-8.

Sherry, R.A., X. Zhou, S. Gu, J. Arnone III, D.S. Schimel, P.S. Verburg, L.L. Wallace and Y. Luo, 2007. Divergence of Reproductive Phenology under Climate Warming. Proceedings of the National Academy of Sciences of the United States of America 104(1):198-202.

Swanson F.J. and C.T. Dyrness. 1975. Impact of Clear-cutting and Road Construction on Soil Erosion by Landslides in the Western Cascade Range, Oregon. Geology 3(7):393-396.

Tappeiner, J.C., D.A. Maguire, and T.B. Harrington. 2007. Silviculture and Ecology of Western U.S. Forests. Oregon State University Press, Corvallis, Oregon.

Thomas, J.W., E. D. Forsman, J. B. Lint, E.C. Winslow, B.B. Noon, and J. Verner. 1990. A Conservation Strategy for the Northern Spotted Owl: Report of the Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl. USDA Forest Service, USDI Bureau of Land Management, USDI Fish and Wildlife Service, and USDI National Park Service, Portland, Oregon.

Thomas, R.B. and W.F. Megahan. 1998. Peak Flow Responses to Clearcutting and Roads in Small and Large Basins, Western Cascades, Oregon: A Second Opinion. Water Resources Research 34(12):3393-3403.

United States Department of the Interior Fish and Wildlife Service. 1997. Intra-service Concurrence Memorandum and Biological Opinion for the Washington Department of Natural Resources' Habitat Conservation Plan. Fish and Wildlife Service, Olympia, Washington.

United States Environmental Protection Agency. 1998. Climate Change and Oregon. EPA 236-F-98-007u. U.S. Environmental Protection Agency, Climate and Policy Division, Washington, D.C.

United States Environmental Protection Agency. 2007. CO: What is It? Where Does It Come From? Available online at: http://www.epa.gov/air/urbanair/co/what1.html.

United States Fish and Wildlife Service. 1992. Protocol for Surveying Proposed Management Activities that May Impact Northern Spotted Owls (Revised). U.S. Fish and Wildlife Service, Portland, Oregon.

United States Fish and Wildlife Service. 2004. Northern Spotted Owl Five-year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Portland, Oregon.

United States Fish and Wildlife Service. 2007. 2007 Draft Recovery Plan for the Northern Spotted Owl, *Strix occidentalis caurina*: Merged Options 1 and 2. U.S. Fish and Wildlife Service, Portland, Oregon.

USDA *See* United States Department of Agriculture

USFS *See* USDA Forest Service

USFWS *See* United States Fish and Wildlife Service

Waldien, D., J. Hayes, and B. Wright. 2003. Use of Conifer Stumps in Clearcuts by Bats and Other Vertebrates. Northwest Science 77(1):64-71.

Washington State Department of Ecology. 2006. Focus on Reducing Diesel Exhaust. Washington State Department of Ecology, Air Quality Program. Available online at: http://www.ecy.wa.gov/programs/air/cars/DieselEmissionPage.htm.

Washington State Department of Ecology. 2008a. Extreme Weather. Available online at: www.ecy.wa.gov/climatechange/extremeweather_more.htm.

Washington State Department of Ecology. 2008b. Surface Water Quality Standards. Available online at: http://www.ecy.wa.gov/programs/wq/swqs/index.html.

Washington State Department of Natural Resources. 1996. Forest Practices Board Emergency Rules (Stream Typing). Forest Practices Board, Olympia, Washington.

Washington State Department of Natural Resources. 1996. Draft Habitat Conservation Plan. Washington State Department of Natural Resources, Olympia, Washington.

Washington State Department of Natural Resources. 1997. Final Habitat Conservation Plan. Washington State Department of Natural Resources, Olympia, Washington.

Washington State Department of Natural Resources 2001. Final Environmental Impact Statement on Alternatives for Forest Practices Rules. Washington State Department of Natural Resources, Olympia, Washington.

Washington State Department of Natural Resources. 2004. Final Environmental Impact Statement on Alternatives for Sustainable Forest Management of State Trust Lands in Western Washington and for Determining the Sustainable Harvest Level. Washington State Department of Natural Resources, Olympia, Washington.

Washington State Department of Natural Resources. 2006a. Final Environmental Impact Statement on the Policy for Sustainable Forests. Washington State Department of Natural Resources, Olympia, Washington.

Washington State Department of Natural Resources. 2006b. Policy for Sustainable Forests. Washington State Department of Natural Resources, Olympia, Washington.

Washington State Interagency Committee for Outdoor Recreation. 2003. Estimates of Future Participation in Outdoor Recreation in Washington State. Interagency Committee for Outdoor Recreation, Olympia, Washington

Washington State Office of Financial Management. 2007a. 2007 Population Trends. Office of Financial Management Forecasting Division, Olympia, Washington. Available online at: http://www.ofm.wa.gov/pop/poptrends/poptrends_07.pdf.

Washington State Office of Financial Management. 2007b. Official April 1, 2007 population estimates. Office of Financial Management, Olympia, Washington.

Westerling, A.L., H.G. Hidalgo, D.R. Cayan and T.W. Swetnam. 2006. Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity. Science 313:940-943.

Yahner, R.H. 1988. Changes in Wildlife Communities near Edges. Conservation Biology 2(4):333-339.

Ziemer, R.R. and T.E. Lisle. 1998. Hydrology. Pages 43-68 *In*: R.J. Naiman and R.E. Bilby (eds.). River Ecology and Management: Lessons from the Pacific Coastal Ecoregion. Springer Verlag, New York, New York.

Zobrist K.W. and T.M. Hinckley 2005. A Literature Review of Management Practices to Support Increased Biodiversity in Intensively Managed Douglas-fir Plantations. Final Technical Report to the National Commission on Science for Sustainable Forestry (NCSSF). University of Washington, Seattle, Washington.

Zube, E.H. 1986. Landscape Values: History, Concepts, and Applications. Pages 3-19 *In*: R.C. Smardon, J.F. Palmer, and J.P. Felleman (eds.). Foundations for Visual Project Analysis. John Wiley & Sons, New York, New York.