United States Department of Agriculture

Forest Service

Pacific Northwest Region

The Okanogan-Wenatchee National Forest Restoration Strategy: a process for guiding restoration projects within the context of ecosystem management

DRAFT

Okanogan-Wenatchee National Forest

March 9, 2010

Contents

OKANOGAN-WENATCHEE NATIONAL FOREST ECOSYSTEM RESTORATION VISION 1

INTRODUCTION 2

DOCUMENT ORGANIZATION 3
NEW SCIENCE AND OTHER RELEVANT INFORMATION 4

PART I: BACKGROUND 8

MANAGEMENT DIRECTION AND POLICY 8
SETTING THE STAGE FOR THE NEXT STEPS - KEY CONCEPTS 9
Ecosystem Management 9
Forest Restoration 10
Aquatic Disturbance 10
Historical Range of Variability 11
Future Range of Variability 11
Ecological Subregions 11
Spatial and Temporal Scales 11
Classification of Forest Vegetation 12
Biological Legacies 15
A REVIEW OF NEW SCIENCE AND INFORMATION 15
Climate Change 15
Landscape Ecology 16
Aquatic Ecology 17
Fire Ecology 20
Forest Ecology 21
Wildlife ecology 24
SUMMARY OF NEW SCIENCE FINDINGS 30

PART II: INTEGRATED LANDSCAPE EVALUATION AND PROJECT DEVELOPMENT 33

TIMELINE FOR COMPLETION OF LANDSCAPE EVALUATION AND PROJECT PLANNING 36
LANDSCAPE EVALUATION 36
Steps to an integrated process for completing a landscape evaluation 37
PROJECT (PROPOSED ACTION) DEVELOPMENT AND ASSESSMENT 51

PART III: ADAPTIVE ECOSYSTEM MANAGEMENT 58

OPERATIONAL GOALS AND PRINCIPLES 60
Goals 60
Principles for the Practice of Adaptive Management 60
IMPORTANT STEPS TO MAKING ADAPTIVE ECOSYSTEM MANAGEMENT HAPPEN ON THE OKANOGAN-WENATCHEE NATIONAL FOREST 62

LITERATURE CITATIONS 65

APPENDIX A - CONSIDERATIONS FOR IMPLEMENTING FOREST RESTORATION WITHIN LAND ALLOCATIONS 80

APPENDIX B - SILVICULTURAL CONSIDERATIONS FOR RESTORATION TREATMENTS 82

APPENDIX C - WEAK RATIONALE FOR "THINNING" OLD TREES 83

APPENDIX D – PRESCRIPTIONS THAT ADDRESS OLD AND LARGE TREES AND SPATIAL PATTERNING 85

GLOSSARY 89

Okanogan-Wenatchee National Forest Ecosystem Restoration Vision

We are recognized as leaders in forest landscape restoration, which improves the health, resiliency, and sustainability of natural systems. We believe restored landscapes provide improved terrestrial and aquatic systems, minimize risk of uncharacteristically severe wildfire, sustain local communities and economies, and contribute to the quality of life.

- Through our efforts, landscapes will become more resilient to changing climates and disturbances and will behave in a manner that restores natural processes, patterns, and functions.
- We will work collaboratively and strategically across landscapes to double our restoration footprint within the next 10 years.
- We will focus on desired restoration outcomes and measure our success with landscapes that are restored and resilient.
- We continue to adapt strategies based on new science, changed conditions, and monitoring.

1

INTRODUCTION

A concerted effort is needed to restore the sustainability and resiliency of forested ecosystems on the Okanogan-Wenatchee National Forest (OWNF). Numerous assessments that provided a long list of peer-reviewed publications have identified that our forests are more susceptible to uncharacteristically high severity fires and epidemic levels of insects and disease, and habitats are declining for late-successional and old forest associated species (Lehmkuhl et al. 1994, Hessburg et al. 1999, Franklin et al. 2007). While our aging forest road network provides needed access for recreation and restoration treatments, it also affects the condition of aquatic ecosystems, requiring expensive repairs and untimely closures when slopes fail. These conditions are likely to be exacerbated by climate change (Franklin et al. 2007, Littell et al. 2009, Vano et al. 2009) adding an even greater sense of urgency. To be successful, the OWNF needs to significantly increase its restoration footprint, reach across boundaries through collaborative efforts, better integrate across disciplines to accomplish multiple objectives, and adapt to changing conditions and new science. This won't be easy. However, with a vision and a focused and scientifically credible strategy, we believe it will be possible.

The Okanogan-Wenatchee National Forest Restoration Strategy (Forest Restoration Strategy) described in this document provides a starting point for how to implement the "Vision" (described on the first page of this document). It outlines a process for an integrated evaluation of forest landscapes that set the context and priorities for restoration treatments evaluated in project level planning (*figure 3*). In addition, key ecological features that are important to restore stand level sustainability and resiliency are described. It also provides much needed definitions, based on current science, of important components of forest restoration (e.g., what is a "large" and "old" tree).

The Forest Restoration Strategy has undergone significant input and review. Initially, ideas were gathered from a series of district meeting and phone interviews held during the spring and early summer of 2009 to identify key issues and concepts that the strategy could be built around. The pages of flip chart notes and phone interviews were collated into a list of topics that were expanded on in the strategy (*Hot Box 1: Incorporation of District Input into the Forest Restoration Strategy*).

Once the strategy was drafted, a scientific peer review was conducted during the winter of 2009/2010. A group of ten scientists representing expertise in wildlife ecology, aquatic ecology, fire ecology, forest pathology and entomology, and forest ecology spent six weeks reviewing the document. They provided many important comments that were addressed and greatly improved the scientific foundation of the strategy.

Following the science review, an additional review was completed by District and Forest staff who are involved in the planning and implementation of restoration projects. The review was completed during the month of February, 2010 and included 25 specialists in the field of silviculture, fire and fuels, wildlife, fish and hydrology, engineering, recreation, and public affairs. They provided comments that facilitated the application of the strategy in project level planning and communication within and outside the agency.

Finally, the Forest Restoration Strategy is based on a long standing, committed, and collaborative relationship between the OWNF and the Wenatchee Forestry Sciences lab (WFSL). This long and productive relationship has resulted in several significant efforts

that are culminating in the development and implementation of this strategy. Particularly important milestones include the East-side Forest Health Assessment, peer review of the Dry Forest Strategy, Interior Columbia Basin Assessment, peer review of the Okanogan-Wenatchee Forest Health Assessment, peer reviewed publications from the Fire and Fire Surrogate Study and the Birds and Burns study, and the Okanogan-Wenatchee-Colville Climate Change Case study. Each of these efforts built upon each other, filled key information gaps in our understanding of east-side forest ecology, from how landscapes have changed over time to understanding how restoration treatments at the stand-level affect birds and small mammals. The collaboration will continue throughout the development, implementation, and monitoring of the Forest Restoration Strategy.

This document outlines a new forest restoration strategy that relies on principles of landscape and stand-level restoration ecology. The objectives of the Okanogan-Wenatchee National Forest Restoration Strategy are as follows:

1) Address new science and management direction including the incorporation of climate change and the final spotted owl recovery plan
2) This strategy will form the basis for the Okanogan-Wenatchee Land and Resource Management Plan (LRMP)
3) Provide a consistent definition and approach to forest restoration
4) Increase the restoration footprint through a process that identifies high priority, strategic treatment areas
5) Improve integration and planning and implementation efficiency
6) Improve monitoring and adaptive management

Document Organization

This document is organized into three parts:

Part I	Provides important background information such as a summary of management direction, descriptions of key concepts, a review of relevant science, and lessons learned from over a decade of implementation of the forest restoration strategy.
Part II	Presents a process for integrated landscape evaluation and project development that would be used to determine the need, priority, and location for restoration treatments. Specific issues addressed include how to develop a “landscape prescription,” how to integrate wildlife habitat, fuels reduction and forest restoration; and management of large and old trees and snags within stand spatial variability and stand density.
Part III	Presents an overview of adaptive ecosystem management and identifies specific steps that would move the Okanogan-Wenatchee towards using this approach to guide forest restoration efforts.

Hot Boxes

Throughout the document are "hot boxes" that highlight key issues and important information. These represent lessons learned since the implementation of the Dry Forest Strategy and represent significant advances in our thinking and understanding about forest restoration.

New Science and Other Relevant Information

Many new science publications have become available since the first strategy was developed. Of particular interest are the *Mission Creek Fire and Fire Surrogate* study (Agee and Lehmkuhl 2009), the *Birds and Burn* study (Saab 2007), and other studies in dry forest landscape ecology, spotted owl prey base, barred owls, and riparian-upslope fire continuity. Each of these studies has produced local science published in reputable journals within the last six years. Research in climate change has advanced the understanding of likely future trends in forest conditions and interactions with disturbance processes, forest sustainability, ecosystem processes, and the existing road infrastructure.

Other relevant information now available includes the final recovery plan for the northern spotted owl (USFWS 2008). This plan presents a significant shift in the management of spotted owl habitat in fire-prone east-side forests that better incorporates disturbance ecology and habitat sustainability. Implementation of the plan requires a landscape view and the use of fire models to design and evaluate treatment options.

The Washington Department of Natural Resources recently completed another important body of work. Franklin et al. (2008) summarized dry forest science and outlined a forest restoration strategy (similar to the OWNF for state lands in eastern Washington). Van Pelt (2008) published a useful guide to identify old trees and forests in eastern Washington. The importance of dry forest is further illustrated by a similar publication by the Wilderness Society on the restoration of dry forests of the northern Rocky Mountains (Crist et al. 2009).

Aquatic habitat maintenance and restoration in the western United States (and on the OWNF) are often perceived as being in conflict with forest restoration (Rieman et al. 2000). Some researchers suggest that short-term negative effects of fuel treatment on aquatic habitat might often be outweighed by the potential long-term benefits of the treatment (Rieman et al. 2000). However, not treating to avoid short-term effects may inadvertently lead to conditions favorable to uncharacteristic, high -severity disturbances (O'Laughlin 2005). Other researchers reported findings suggesting that, over various time scales from a few years to over a century, the aquatic habitat resulting from disturbances caused by fire (sometimes even high severity fire) is more productive than similar habitats where the fire events were suppressed or altered by human influences (Reeves et al. 1995, Dunham et al. 2003, Benda et al. 2003, Rieman et al. 2005).

Agencies and many scientists interested in interactions between fire and the aquatic environment recognize that vegetation treatments will need to take place in some altered ecosystems of the northwestern U.S. (Bisson et al. 2003, Finney et al. 2007, Noss et al. 2006, Reeves et al. 1995, Rieman and Clayton 1997, USDA and USDI 2006). For example, small gila trout populations in southwestern U.S. forests are currently threatened by both management activities and degraded habitat resulting from fire exclusion (Rieman

and Clayton 1997). When developing fuel treatments that consider the aquatic environment, the potential for success may be greater when particularly damaging roads are obliterated (Rieman and Clayton 1997). Where habitat is less degraded, researchers suggest mimicking natural disturbances, avoiding simplistic treatments, proceeding with caution, and maintaining a strong focus on experimentation and monitoring (Reeves et al. 1995, Rieman and Clayton 1997, Gresswell 1999, Bisson et al. 2003, Luce and Rieman 2005).

In summary, a new strategy is needed because of new science, local monitoring results, and planning inefficiencies. The Okanogan-Wenatchee National Forest Restoration Strategy emphasizes a restoration paradigm where defined ecological outcomes drive the development and implementation of projects. This contrasts with the existing paradigm in which project design is often driven more by production targets than restoration needs. The strategy describes more efficient project area identification and planning that increase the size of the restoration footprint. Integration among resource disciplines is critical to successful implementation of the Forest Restoration Strategy.

The Okanogan-Wenatchee National Forest Restoration Strategy needs to be adaptive and molded by additional information as it becomes available. It is important to implement the adaptive management approach described in this document in order to incorporate new information into the strategy.

HOTBOX 1
Incorporation of District Input Into the Forest Restoration Strategy

During May-August of 2009, district meetings and phone interviews were conducted across the Okanogan-Wenatchee National Forest to gather input and identify key issues and approaches to include in the Forest Restoration Strategy. This information, compiled from many pages of flip-chart notes, was collated into the following comments that were addressed in detail in the Strategy.

Comment	Response
Concerned about being able to treat enough of the landscape to make a difference	The Vision Statement includes a goal of significantly increasing our restoration footprint. To accomplish this, the landscape evaluation will help to identify the amount of area that needs to be treated. In addition, the process should help us be more strategic and efficient with our limited resources.
Concerned about using diameter limits to restore “big” trees	Instead of diameter limits, the strategy proposes desired outcomes and objectives for old and large trees. The desired outcomes and objectives are informed by information generated by the landscape evaluation and local stand reconstructions.
Need to factor in climate change	The strategy incorporates the concept of “future range of variability” that provides information to the landscape evaluation on a likely climate change scenario. In addition, the road network evaluation provides an opportunity to evaluate the interactions

HOTBOX 1 Incorporation of District Input Into the Forest Restoration Strategy	
	between roads and changing hydrologic regimes. These represent innovative ways to bring climate change and forest resiliency concepts into project level planning (also see Climate Change and the Forest Restoration Strategy Hot Box).
The strategy should address the kinds of treatments and how much treatment should occur in riparian zones	The strategy discusses the current science relative to interaction between riparian and upslope fire disturbances. Riparian objectives are then discussed with condition described under which treatments within riparian zones are appropriate. The landscape evaluation will set the context that determines how important treatments within riparian zones are to achieving restoration objectives. This topic was also identified as an important monitoring item.
Need to address access (roads) in the strategy	The landscape evaluation includes a process called the road network evaluation in order to identify the most at-risk road segments and identify restoration opportunities and priorities. In addition, it will likely be linked to the Minimum Roads Analysis process that will be required.
There is a conflict between doing “restoration” and meeting the “timber target”	The strategy is focused on outcomes and the landscape evaluation will allow better estimation of potential outputs. The Regional Forester, Deputy Regional Forester, Forest Supervisor, Deputy Forest Supervisor, and Forest Leadership Team are working to develop more meaningful measures of restoration accomplishment. This will likely be something like “restoration acres” and it will be implemented along with the forest restoration strategy and informed by Landscape Evaluations.
How will support be provided for districts to implement the strategy? Training will be important for district teams to implement the strategy	The Strategy development team has and will continue to work with district teams throughout all phases of implementation. In addition, the Wenatchee Forestry Sciences lab continues to provide needed expertise until it is developed across the Forest. This will allow roll-out of the strategy that will not leave any planning teams with a lack of expertise nor interrupt on-going planning efforts.
Key players were left out of the development of the strategy – specifically implementers	Because of this comment, a review by district personnel involved in the planning and implementation of the Strategy will take place in February of 2010, immediately following the science review.
The dry forest video needs to be updated but cannot become too long. In addition, there is a need for another source of information that can be provided to audiences that have an in-depth understanding of forest ecology and forest restoration	The dry forest video is being updated and revised into a Forest Restoration video. It will likely be somewhat shorter but still targeted for the same level of understanding as the dry forest video. In addition, a Power Point presentation is being developed that can be easily updated and used for more technical audiences.
Implementation monitoring needs to occur and a network of monitoring sites needs to be identified for long-term monitoring	A chapter in the strategy is devoted to monitoring, especially implementation monitoring. Once the strategy is being implemented, two projects per year

HOTBOX 1 Incorporation of District Input Into the Forest Restoration Strategy	
	would be monitored, similar to the ongoing fuels review process. One Forest Leadership Team meeting per year would be devoted to reporting of monitoring results and making adjustment to the strategy as needed.

133

PART I: BACKGROUND

Management Direction and Policy

In 1992, Forest Service Chief Dale Robertson issued direction that ecosystem management is the model by which the National Forests and Grasslands would be managed in order to meet their multiple-use objectives. In addition to acknowledging the need for collaboration among land managers, scientists, and the public, he explicitly directed the restoration of biological diversity and ecological processes leading to productive and sustainable ecosystems. The Northwest Forest Plan (1994) brought that direction a step closer to the ground. Its Record of Decision (ROD) included a discussion of the statutory basis for ecosystem management and a discussion of ecological process, pattern, and composition as important management principles. It also included direction that, "Except as otherwise noted…the standards and guidelines of existing plans apply where they are more restrictive or provide greater benefits to late-successional forest-related species (than those of the ROD)."

Chief Jack Ward Thomas reaffirmed the ecosystem management paradigm when, in 1994, he issued the *Forest Service Ethics and Course to the Future,* stating that diverse composition, structure, and function were key elements of healthy and productive ecosystems. According to Doug MacCleery, Senior Policy Analyst for the Forest Service, the overall objectives of Thomas' document, including restoring and protecting ecosystems, "remain essentially unchanged today" (personal communication, 2008). This assertion was formalized by Forest Service direction in FSM 2000, Chapter 2020 Ecological Restoration and Resilience (September, 2008), which establishes as policy that: "All resource management programs have a responsibility for ecological restoration…" and that "strategic plans for meeting ecological restoration goals and objectives are to be developed."

Ecosystem management direction has been incorporated into handbook direction as well. The *Silvicultural Practices Handbook* (FSH 2409.17) includes direction to "integrate ecosystem concepts into silvicultural prescriptions" and to incorporate landscape analysis into planning and silvicultural prescription development. The *Renewable Resources Handbook* (FSH 2409.19) directs that ecological approaches be incorporated into all projects. The Healthy Forest Restoration Act also mandates ecosystem management: the required fire regime condition class (FRCC) analysis integrates ecological process (fire regime/history) and stand structure and composition into its determination of a landscape's departure from the reference condition.

The Okanogan-Wenatchee National Forest Dry Site Strategy, implemented in 1999 (and revised in 2000 to include the Okanogan National Forest), focused on the threat to forest sustainability caused by uncharacteristic wildfire (the fire regime outside the natural range of variability). The document largely described the situation that set the stage for establishing dry, dense forests within the low severity fire regime as the highest priority for treatment. Broad objectives for fuel and tree density reduction and shifting species composition were included along with tactical approaches selected from traditional forest management practices. The intent of these objectives and options could be inferred from the strategy's narrative but there were no specific implementation protocols or guidelines.

Key ideas from the dry site strategy closely mirrored those of the earlier *Forest Service Ethics and Course to the Future*:

> … manage for, and maintain, healthy forests… provide goods, services, and values that people desire without jeopardizing the capacity of any ecosystem to maintain its structure, composition, and processes through time…management approach will be adaptive and experimental… learn from mistakes and repeat successes (USFS 2000).

Collectively, there is ample management direction and impetus to implement an adaptive ecosystem management approach to forest restoration. This update of the dry forest restoration strategy represents a significant step in adapting the strategy based on what we have learned.

Setting the Stage for the Next Steps - Key Concepts

The purpose of this section is to describe some key concepts that are important for understanding the scientific foundation of this forest restoration strategy (definitions of these concepts are found in the *Glossary*). These concepts provide a baseline of information so that those implementing and adapting the strategy will have a common reference point from which to start.

In addition, this section introduces an approach to the classification of forested vegetation types that is a key part of the strategy, and forms the basis for comparison with both the historical and future reference conditions. The future range of variation is also a new concept and provides insights into how climate change may influence future vegetation conditions.

Ecosystem Management

In the context of the Okanogan-Wenatchee Forest Restoration Strategy, ecosystem management is the overarching principle guiding the restoration strategies implemented by all projects. Manipulation or management of an ecosystem, such as a watershed, does not, by itself constitute ecosystem management because essential components are lacking.

Christensen et al. (1996) suggest that ecosystem management include the following:

1) Long-term ecological sustainability as fundamental value (guided by historical variability and tempered by potential climate change)

2) Clear, operational goals

3) Sound ecological models and understanding

4) Understanding of complexity and interconnectedness

5) Recognition of the dynamic character of ecosystems

6) Attention to context and scale

7) Acknowledgment of humans as ecosystem components

8) Commitment to adaptability and accountability

Forest Restoration

Restoration is the activity used to implement ecosystem management. Restoration aims to enhance the resilience and sustainability of forests through treatments that incrementally return the ecosystem to a state that is within a historical range of conditions (Landres et al. 1999) tempered by potential climate change (Millar and Woolfenden 1999). It is the process of assisting the recovery of resilience and adaptive capacity of ecosystems that have been degraded, damaged, or destroyed (FSM 2020.5). In terms of forest restoration, active techniques are largely tree cutting and prescribed fire, but also include other active treatments focused on roads, weeds, livestock, and streams.

Knowledge of the range of natural variability of forest stands and landscapes can help clarify the types, extent, and causes of ecosystem changes and can help identify restoration objectives (Hessburg et al. 1994, 1999, Landres et al. 1999). However, it is important to consider how climate will potentially change in the future and its potential influences on disturbance regimes. Climate change can affect forests by altering the frequency, intensity, duration, and timing of fire, and can result in drought, introduction of exotic species, and cause insect and disease outbreaks (Dale et al. 2001). Climate change can also affect species composition and structure, hydrologic cycles, genetic complexity, nutrient cycling regimes, mycorrhizal relationships, a host of food webs, and biodiversity (Malcolm et al. 2006, Lucash et al. 2005, GAO 2007, Bassman 2000, Lensing and Wise 2006, Fenn 2006, Whitlock et al. 2003, Gucinski 2006, Kulakowski and Veblen 2006, Franklin et al. 1989, Gray et al. 2006, Warwell et al. 2007, Lenoir et al. 2008). Knowledge of changes in forest conditions and their ecological functions can be combined with climate change predictions to modify restoration activities in ways that will produce and sustain a dynamic and resilient forest mosaic.

Restoration should not be construed as a fixed set of procedures for land management (Moore et al. 1999), but rather it should be based upon a broad scientific framework that includes “ecological fidelity” (structural/compositional replication, functional success, and durability) and mutually beneficial human-wildland interactions (Higgs 1997). In other words, restoration consists not only of restoring ecosystems, but also of developing human uses of wildlands that are in harmony with the disturbance regime of these ecosystems (Society for Ecological Restoration 1993, Moore et al. 1999). Timber management, fuels reduction, habitat improvement, and other single resource management activities in and of themselves do not constitute restoration, but when used as tools to accomplish restoration objectives they can meet management goals for restoration and support sustainable human uses.

It is important to remember that restoration takes time and that objectives might not be met after the initial treatment entry. Forested ecosystems that are resilient to disturbances often include large, fire tolerant trees, which take time to develop. Restoration activities should be planned to set forests on successional trajectories that lead to desired conditions.

Aquatic Disturbance

Resilient and functioning aquatic habitats are maintained through time through natural disturbance processes. Scientists studying disturbance events have characterized them into three categories: *pulse*, *press*, and *ramp*, depending on the duration, intensity, and spatial pattern of impacts, (Lake 2000, Reeves et al. 1995). This discussion will focus on pulse

and press events because these are most relevant to the OWNF aquatic environment. Pulse events are intense and short term, and press events reach a constant level that is maintained over time. A pulse event example would be a flood that occurs over a short period. If the watershed where this event occurs is in a natural condition, the disturbance can be absorbed and, in fact, will help maintain the aquatic function through time. A press disturbance could be a change of land use that, over time, interrupts and maintains altered ecological processes. Extensive road networks are a classic example of a press disturbance. An extensive road network can interrupt and alter flow regimes, alter wood delivery, and contribute excessive amounts of fine sediment to the stream network. This is considered a press effect because it maintains degraded aquatic conditions over time. Human land use patterns have created anthropogenic press disturbances affecting both the terrestrial and aquatic environments in the western United States, especially in lower elevation dry forests (Rieman et al. 2000).

Historical Range of Variability

The purpose of describing the historical variability is to define the bounds of system behavior that remain relatively consistent over time (Morgan et al. 1994). Historical variability is a key component of forest restoration.

Spatial and temporal scales relevant to ecosystem patterns and processes are important to identify and critical to the concept of historical variability (Morgan et al. 1994). Descriptions of historical variability should be site specific, most appropriately at a subwatershed or watershed level (20,000 to 100,000 acres) and at temporal scales of centuries. Ecosystems are structured hierarchically, therefore; historical variability should be characterized at multiple spatial scales appropriate to the patterns and processes being described.

Future Range of Variability

The future range of variability is a concept described by Gartner et al. (2008) and is intended to provide insights into how systems may adjust to changing climate. By comparing current vegetation patterns to both historical and future reference conditions, managers will gain valuable insights into how systems have changed and how they are likely to change over time. Understanding these changes is the key to determining management strategies that provide for more sustainable and resilient forests.

Ecological Subregions

Ecological subregions (ESR) are areas of similar climate, geology, topography, and aquatics and, by extension, disturbance history. As part of the Interior Columbia Basin Ecosystem Management Project (ICBEMP), Hessburg et al. (1999) determined reference variation for ecological subregions (ESRs) of the Okanogan-Wenatchee National Forest *(see fig. XX* : *Map of Ecological Subregions of the Oka-Wen*).

Spatial and Temporal Scales

Issues of scale are important to consider within the context of ecosystem management. Most analyses are done at the scale of a watershed (landscape) to determine where restoration projects should be completed, but management treatments are at the smaller

stand scale. Projects and their stand sub-units are the building blocks to affect changes to the landscape. Treatments will need to be implemented over time because it is likely that no single treatment will restore a landscape, and restored areas will require maintenance.

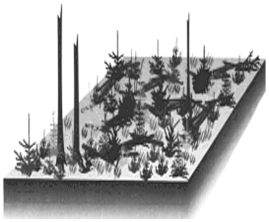
Classification of Forest Vegetation

A host of vegetation classification schemes has been developed. However, the vegetation classification used for the interior Columbia basin ecosystem management project (Hessburg et al. 1999) is the most relevant for our use, is the one for which the historic range of variability and future range of variability estimates are based, and is the most readily available. This classification scheme, developed to facilitate understanding and implementation of ecosystem management, was used for the Interior Columbia Basin Ecosystem Project, is part of the interim direction (Eastside Screens) for east side forests of Oregon and Washington (USFS 1998), and has been the basis of much subsequent research and analysis (Hessburg et al. 1999, 2000). It uses combinations of composition, potential vegetation, and forest structure to classify and evaluate landscapes.

Forest cover types are determined from overstory and understory species composition and crown cover. They are classified according to Society of American Foresters (SAF) forest cover type definitions (as applied by Hessburg et al. 1999a). When overstory crown cover exceeds 25 percent, they are defined by the overstory species. They are defined by the understory species when its crown cover exceeds that of the overstory and the latter is less than 20 percent. In order to be included in a mixed cover type, a species must comprise at least 20 percent of tree density. Rangeland cover types are summarized into woodland, shrubland, or herbland.

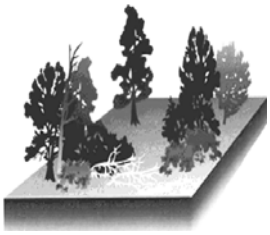
The vegetation that would develop on similar environments in the absence of disturbance is defined as the potential vegetation type (PVT). Forest PVT is classified at the series level (Lillybridge et al. 1995) and is determined from overstory and understory species composition and elevation, slope, and aspect. Potential vegetation type allows evaluation of both cover type and structure class in the context of site.

Stratifying a landscape into these process-based structure classes allows subsequent analysis of landscape pattern and ecological processes, i.e. disturbance and succession. The seven structural/process classes used by Hessburg et al. 2000 are also used in this strategy *(figure 1, table 1).*



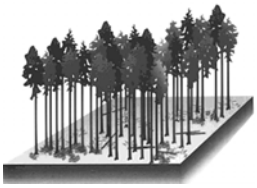
A. Stand Initiation (SI): Growing space is reoccupied following a stand replacing disturbance.

E. Young Forest Multi-Strata (YFMS): Two or more cohorts are present through establishment after periodic disturbances. Large and/or old early seral trees are often at reduced density from fire or logging.

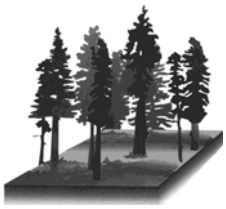


B. Open Stem Exclusion (SEOC): Below-ground competition limits establishment of new individuals.

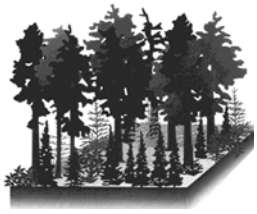
F. Old Forest Multi-Strata (OFMS): Two or more cohorts and strata are present including large, old trees.



C. Closed Stem Exclusion (SECC): New individuals are excluded through light or below-ground competition.



G. Old Forest Single-Strata (OFSS): Single-stratum stands of large, old trees. Relatively few young trees are present in the understory.



D. Understory Reinitiation (UR): Initiation of a new cohort as the older cohort occupies less than full growing space.

Figure 1. Schematic representation and definitions of ICBMP structure classes (from O'Hara et al. 1996, Hessburg et al. 2000)

Table 1--Description of forest structural classes to be used in the landscape assessment for forest restoration projects and structural classes that correspond to the habitat associations for dry and mesic forest and for some focal wildlife species (based on Gaines et al. in prep)

Structural class	Description	Key functions for focal wildlife species
Stand initiation	Single canopy stratum (may be broken or continuous); one cohort[1] seedlings or saplings; grasses, forbs, shrubs may be present with early seral trees.	**Goshawk** – foraging habitat
Stem exclusion open canopy	One broken canopy stratum; one cohort; trees excluding new stems through competition; poles, small or medium trees; understory shrubs, grasses, forbs may be present.	**White-headed woodpecker** -habitat may be provided depending on cover of large trees and cover of understory.
Stem exclusion closed canopy	Continuous closed canopy; one or more canopy strata; one cohort; lower strata, if present, are same age as upper strata; poles, small or medium trees; understory shrubs, grasses, forbs may be present.	**Northern spotted owl** - dispersal habitat
Understory reinitiation	Broken overstory canopy; ≥2 canopy strata; two cohorts; overstory is poles, small, or medium trees; understory is seedlings, saplings, or poles.	**Northern spotted owl** – high-quality habitat depending on the canopy closure and size of overstory trees. **Northern goshawk** – source habitat depending on the canopy closure and size of overstory trees.
Young-forest multistory	Broken overstory canopy; >2 canopy strata; >2 cohorts; large trees are absent in the overstory; stands are characterized by diverse horizontal and vertical distributions of trees and tree sizes; seedlings, saplings, poles, and medium trees are present.	**Northern spotted owl** – high -quality habitat depending on the canopy closure and size of overstory trees. **Northern goshawk** – high -quality habitat depending on the canopy closure and size of overstory trees. **White-headed woodpecker** -habitat may be provided depending on cover of large trees and cover of understory.
Old-forest multistory	Broken overstory canopy; >2 canopy strata; >2 cohorts; large trees dominant in the overstory; stands characterized by diverse horizontal and vertical distributions of trees and tree sizes; all tree sizes may be present.	**Northern spotted owl** – high -quality habitat **Northern goshawk** – source habitat
Old-forest single story	Broken or continuous canopy of large, old trees; one stratum, may be single but usually multicohort; large trees dominate the overstory; understory absent or seedlings or saplings; grasses, forbs, or shrubs may be present in the understory.	**White-headed woodpecker** – source habitat

1/Trees within a cohort share a common disturbance history; they are those initiated or released after a disturbance (natural or artificial). Tree ages within a cohort may span several decades.

Biological Legacies

Biological legacies are known to play important roles in ecosystems, especially those recovering from disturbance (Franklin et al 2007). Biological legacies are the components of a stand or landscape that remain after disturbance, and are critical elements of post-disturbance ecosystem pattern and process. Structural legacies typically: 1) persist as legacies even through the most intense stand replacement disturbances; 2) play critical roles as habitat and modifiers of the physical environment; and 3) are difficult or impossible to re-create in managed stands, requiring the need to carry them over from the pre-disturbance stand (NCSSF 2005, Franklin et al. 2007). Biological legacies may include large, live trees, snags, downed logs, and tree diseases (Franklin et al. 2007).

A Review of New Science and Information

This section is intended to provide an overview of science findings relevant to the development of the forest restoration strategy and is integrated into Part II. The following topic areas are covered below: climate change, landscape ecology, aquatic ecology, fire ecology, forest ecology, wildlife ecology. This section is concluded with an integrated summary of key findings addressed in the remainder of the strategy.

Climate Change

Climate projections for eastern Washington suggest that winter snow packs may decline and the duration and severity of the summer dry period may increase (Bachelet et al. 2001, Mote et al. 2003, McKenzie et al. 2004). East-side forests are particularly dependent on winter snowpack and climate change is expected to have significant direct and indirect effects on forest health in eastern Washington (Mote et al. 2003, Keeton et al. 2007). These effects include:

- Changes in the physiology and ecology of organisms, including trees and forest pests, due to increased temperatures and summer moisture deficits. Elevational and latitudinal shifts in the distribution of species and forest communities.
- In some cases, increased moisture stress will increase tree species vulnerability to insects and diseases, especially on the driest sites in densely forested stands.
- Alteration of insect and pathogen dynamics due to changes in the physiology and reproductive capacity of organisms.
- Increase in the severity and frequency of summer droughts may lengthen fire seasons and result in large and more severe wildfires. A statistical relationship between climatic warming, lengthened snow-free seasons, and the frequency and size of wildfires has already been established for some parts of western North America (Westerling et al. 2006).

Climate change is likely to increase the challenges for sustainable forest management in eastern Washington, including issues associated with wildfire and forest insects and pathogens (Franklin et al. 2008). Fortunately, logical management responses to climate change – such as reducing stand densities and fuels, treating landscapes, and restoring drought-tolerant and fire resistant species and tree size classes – are consistent with management responses to other important issues, including forest health, wildfires, old and large tree structures, and protection of wildlife habitat (Franklin et al. 2008).

Climate change is also expected to increasingly alter hydrologic regime of streams and rivers on the Okanogan-Wenatchee National Forest based on studies that have considered the effects of climate change for the Columbia River basin. A review of scientific information completed by the Independent Scientific Advisory Board (ISAB 2007) identified numerous consequences. Bisson (2008) summarized expected changes from the ISAB report as follows:

- Warmer temperatures will result in more precipitation falling more often as rain rather than snow.
- Snowpack will diminish and streamflow timing will be altered.
- The magnitude will likely increase, with a shift in the timing of peak flow occurrence earlier in the water year.
- Water temperatures will continue to rise.

In addition to an increase in large flood events, wildfires, and forest pathogen and insect outbreaks are expected to increase. These disturbances may reconnect floodplains and increase large wood accumulations, which in combination increase stream channel complexity (Bisson 2008). Depending on landscape position, stream habitat and dependant species such as trout and salmon may also experience negative consequences resulting from climate change. A higher frequency of severe floods will scour streambeds and reduce spawning success for fall spawning fish (Bisson 2008). Smaller snowpacks and earlier spring runoff will affect migration patterns for salmon that could further affect their survival in the ocean (Mote et al. 2003, Pearcy 1997). Summer base flows are expected to be lower and last longer, which would shrink available habitat, forcing fish into smaller and less diverse habitat (Battin et al. 2007, Bisson 2008).Summer temperatures in some streams locations that currently support salmon and trout could rise to a point where they become lethal (Crozier et al. 2008). Higher stream temperatures will likely favor non-salmonid species that are better adapted to warm water, including potential predators and competitors (Reeves et al. 1987, Sanderson et al. 2009).

Landscape Ecology

Our understanding of the landscape ecology of eastern Washington has significantly advanced in recent years. Timber harvest, fire suppression, road construction, and domestic livestock grazing have transformed forest spatial patterns and landscape ecology (Hessburg et al. 1999, Hessburg and Agee 2003). These changes have consequences for very different disturbance regimes, and different availability and distribution of wildlife habitats (Hessburg et al. 1999). Further comparison of current and historic landscape pattern revealed shifts from early to late seral conifer species were evident in many forests. Patch sizes of forest cover types are now smaller, and current land cover is more fragmented (Hessburg et al. 2000, Hessburg et al. 2005). While land cover is more fragmented, forest structure classes were more variable. For example, the landscape area in old multistory, old single story, and stand initiation forest structures has declined with a corresponding increase in area and connectivity of dense, multilayered, intermediate forest structures (Hessburg et al. 2000, Hessburg et al. 2005). Patches with medium (16 to 24 inch dbh) and large (greater than 25 inch dbh) trees, regardless of their structural affiliation are currently less abundant on the landscape. Forests are now dominated by shade-tolerant conifers, with elevated fuel loads, severe fire behavior, and increased incidence of certain defoliators,

dwarf mistletoe, bark beetles, and root diseases (Hessburg et al. 2000, Hessburg et al. 2005).

Agee (2003) developed estimates of the historical range of variability for the east Cascade forested landscapes using historical fire return intervals and the manner in which fire acted as both cyclic and stochastic processes. Early successional forest stages were more common in high elevation forests than low elevation forests. The historical proportion of old growth (including old forest single story) and late successional forest varied from 38 to 63 percent of the entire forested landscape.

Spies et al. (2006) summarized the state of knowledge of old-growth forests in dry provinces of eastern Oregon and Washington, and northern California. They found that historically, old-growth forests ranged from open, patchy stands, maintained by frequent low-severity fire, to a mosaic of dense and open stands maintained by mixed-severity fires. Old growth structure and composition were spatially heterogeneous, varied strongly with topography and elevation, and were shaped by a complex disturbance regime of fire, insects, and disease. With fire exclusion and cutting of large pine and Douglas-firs, old growth diversity across the landscape has declined and dense understories have developed across large areas. Fire exclusion has increased the area of dense, multi-layered forest favored by the northern spotted owl but increased the probability of high-severity fire. Landscape-level strategies are needed to address these issues.

A study conducted by Everett et al. (2008) provides insights into how forested landscapes have changed in the absence of fire but without timber harvest. They reconstructed 26 forest stands on the Okanogan portion of the OWNF that had little or no evidence of past timber harvest. They found that from 1860 to 1940, average stand age increased by 26 percent and number of age cohorts per stand increased by 18 percent. Stands in stand initiation structural classes declined from 27 to 4 percent, and stands in older forest structural classes increased from 23 to 49 percent. Everett et al. (2008) cautioned that estimating the historical range of variability based on 1940 photo records might provide a false metric of structural complexity for dry fir-pine forests in eastern Washington. As a result of the scientific uncertainty about the conclusions of Hessburg et al. 1999, a monitoring item has been identified in the adaptive management section of the strategy. At this time, Hessburg et al. (1999) (and subsequent publications) and Gärtner et al. (2008) present the only peer reviewed works referenced to the future and historical range of variability at landscape and stand scales for use in this restoration strategy.

Aquatic Ecology

Aquatic communities in the western United States have evolved in response to a variety of disturbance regimes including glaciation, volcanism, and fire. Natural disturbances organize and maintain aquatic systems in western landscapes (Reeves et al. 1995) and shape species resilience and persistence (Yount and Niemi 1990). Furthermore, disturbances have a dominant role structuring aquatic communities (Yount and Niemi 1990).

Forest restoration treatments will require a transportation network for access to and removal of trees and forest products; however, roads can have negative impacts on aquatic systems. Road networks affect aquatic environment by blocking fish passage, simplifying stream function, altering sediment delivery mechanisms, and increasing fine sediment

yields, and providing travel routes for grazing animals to the streams (Jones, Trombulak and Frissell 2000, Roath and Krueger 1982, Young et al.1967, Williams1954). Relating to soil disturbance on hill slopes, Rieman and Clayton (1997) wrote, “Road construction causes the most severe disturbance to soils on slopes, far overshadowing fire and logging as a cause of accelerated erosion”. Numerous studies have been completed identifying adverse affects of roads on the aquatic environment (Quigley and Arbelbide 1997, Gresswell 1999, Gucinski et al. 2001). Generally, as the density of roads in a watershed increases, aquatic habitat quality decreases. In a scientific literature review considering the effects of roads, Trombulak and Frissell (2000) stated, “Our review underscores the importance to conservation of avoiding construction of new roads in roadless or sparsely roaded areas and of removal or restoration of existing problematic roads to benefit both terrestrial and aquatic biota.”

Today, roads are recognized as one of the premiere issues affecting the aquatic environment (Gresswell 1999, Trombulak and Frissell 2000, Gucinski et al. 2001, Grace and Clinton 2007). Road management is currently complex for many reasons; one being that many historical roads still in use today were built in locations that would not be currently acceptable (Swift and Burns 1999, Grace and Clinton 2007). Roads built decades ago are often located in valley bottoms next to streams and are difficult to relocate (Swift and Burns 1999). The last iteration of the Okanogan-Wenatchee Dry Forest Strategy (USFS 2000) identified roads as one of the factors impairing watershed function.

Today’s recreation use (duration and intensity) on many forest roads currently surpasses the original road design capability and has resulted in dramatic increases in sediment delivery to the stream network (Grace and Clinton 2007). A lack of sufficient maintenance, as well as increased maintenance above original design needs, increases sediment delivery to water bodies (Grace and Clinton 2007, Luce et al. 2001). Environmental solutions to road issues often call for reconstruction, relocation, or restoration (Swift and Burns 1999, Gresswell 1999, Trombulak and Frissell 2000, Grace and Clinton 2007).

Existing roads are often considered essential for effective fire suppression and fuel reduction management. Brown et al. (2004) calls roads “paradoxical” in relation to fire and fuel management. They state that although roads have negative interactions with some ecological processes and may increase human ignitions, “they decrease response time to wildfire, act as holding lines, and make prescribed fire easier to apply.” They recognized building new roads to implement thinning and prescribed fire might not be appropriate in roadless areas. Further, their findings along with others (Lee et al. 1997, Rieman et al. 2000) recognize that active management to improve forest sustainability will likely improve aquatic function. As related to fuels reduction, Brown et al. (2004) recommend focusing thinning in areas with existing road systems and using minimal impact harvest techniques.

Grace and Clinton (2007) suggest the most acceptable approach to minimizing the harmful effect of the road system on the aquatic environment is to first focus on critical roads and relocate and/or reconstruct them. Landscape planning discussed later in this document will help identify critical transportation needs associated with forest health restoration. Luce et al. (2001) propose a hierarchical set of questions to identify road treatments that are the most ecologically effective and have the least fiscal and social cost: (1) where are the

highest priorities ecologically; (2) within those, where are the most damaging roads; and (3) within those, which ones can we effectively decommission or mitigate?

Rieman et al. (2000) suggest that restoration of low elevation mixed fire severity ponderosa pine forests have short and long-term effects on aquatic ecosystems. In the short term, efforts to restore forests along riparian corridors could increase sediment loads and increase the risk of landslides and debris flows from steep facing drainages (Rieman et al. 2000). Current habitat has been degraded in many of these forest types, and treatments (such as road obliteration and relocation, culvert replacement, and thinning to restore old forest structure) could create more suitable habitat in the long term. Land managers will need to consider a variety of spatial and temporal scales, improve **s**cientific understanding, and emphasize experimental design to understand the effects of treatments (Rieman et al. 2000, Luce and Rieman 2005).

The relative continuity of fire behavior between riparian areas and adjacent uplands is influenced by a variety of factors, contributing to high spatial variation in fire effects to riparian areas. Fire typically occurs less frequently in riparian areas (Russell and McBride 2001; Everett et al. 2003). Riparian areas can act as a buffer against fire and therefore as a refuge for fire-sensitive species, yet under severe fire weather conditions and high fuel accumulation, they may become corridors for fire movement (Pettit and Naiman 2007). Fire effects occurring upstream will likely influence downstream conditions (Wipfli et al. 2007), as well as future fire behavior (Pettit and Naiman, 2007). In the eastern Cascade Range, ecological conditions vary dramatically from the Cascade crest east to the arid conditions adjacent to the Columbia River (Wissmar et al, 1994). Depending on geologic and topographic features, riparian conditions and response to fire also vary (Halofsky and Hibbs, 2008). Biophysical processes within a riparian area, such as climate regime, vegetation composition, and fuel accumulation are often distinct from upland conditions (Dwire and Kaufmann, 2003). This can be especially true for understory conditions (Halosky and Hibbs, 2008). Considering these varied conditions that occur from the stream edge to upslope and from river mouth to mountaintop, riparian response to fire is complex and heterogeneous.

Locally, Everett et al. (2003) studied the continuity of fire disturbance between riparian and adjacent sideslope Douglas-fir forests in the eastern Cascades with some samples on the Entiat and Methow Ranger Districts. Their study findings suggest that 100 years B.P. there were more large trees on sideslopes than in the riparian areas. They found fewer traceable fire disturbance events in riparian forests, which may indicate a reduced disturbance frequency, a more severe disturbance regime, or both. They also suggest the last several decades of vegetation management and fire suppression have caused stand cohorts in the riparian zone and upslope areas to become similar. Everett et al. (2003) cautioned, “Our attempts to protect old trees in the riparian zone buffers at the expense of adjacent sideslopes may be misdirected if old trees have been more historically numerous on the adjacent sideslopes”.

Landform features including broad valley bottoms and headwalls appear to act as fire refugia (Camp et al. 1996, Everett et al. 2003). Halofsky and Hibbs (2008) suggested a general rule from their study: the wider the stream, the lower the fire severity. Both of these studies correlated fire severity to vegetation type to varying degrees. Their studies

combined with local knowledge can help identify portions of riparian reserve/riparian habitat conservation area (RHCA) to minimize or avoid reintroduction of fire.

Shared fire events investigated by Everett et al. (2003) indicated significant continuity often occurred between riparian forests and adjacent sideslopes in steep, narrow valleys, troughs and ravines. Because these upslopes and riparian forests have qualitatively similar fire effects, treatments guided by these findings are likely to restore ecological function of fire regimes at the landscape level (Finney et al. 2007). As treatments are designed for riparian reserves that have departed from their expected range of conditions, their position in the landscape relative to elevation, location within the stream network, and climate regime should be carefully considered to ensure the riparian function is understood (Pettit and Naiman 2007). Due to the uncertainty of the predictability of effects of restoration treatments on riparian habitats, this item has been identified in the monitoring and adaptive section (Part III).

Fire Ecology

This section includes an overview of recently published science relative to fire ecology topics such as fire history and effects of thinning and burning on fire behavior and fuels.

Within the study areas on the Naches and Entiat Ranger Districts, Everett et al. (2000) report mean fire free intervals of 6.6 to 7 years during the pre-settlement period (1700/1750-1860) and lengthened intervals of 38 to 43 years during the fire suppression period (1910-1996). They found a clear shift to a less frequent, but greater severity fire regime, associated with longer recovery intervals (Everett et al. 2000).

Wright and Agee (2004) report mean fire free intervals of 7 to 43 years (1562 to 1995) in dry and mesic forests of the Teanaway drainage, Cle Elum Ranger District. Sampling within dry forests suggested that historical fires were of low intensity, leaving overstory structure intact. The composition and structure of the historical forest was characterized by a preponderance of very large (>100 centimeters in diameter) ponderosa pines. Mesic forests exhibited a wider range of fire severities, with moderate and occasional high-severity fires or crown fires. Fire frequency and size declined dramatically about 1900, coincident with timber harvesting and fire suppression (Wright and Agee 2004).

The effects of thinning and burning on fire behavior and fuels have been well studied in the past decade, although much remains to be learned. When evaluating fuel treatments from across the west, the reduction in fire behavior parameters and fuel loading is maximized by the combination of mechanical thinning plus burning (Schwilk et al. 2009). Thinning alone by traditional commercial harvest methods leads to increases in small diameter (<1 inch diameter) surface fuels immediately after treatments (Agee and Lolley 2006), but these fuels will decrease to pre-treatment levels within 5 years (Youngblood et al. 2008). Amounts of larger fuels (>1 inch diameter) can significantly increase and may not decrease for a long period without the use of prescribed burning. Pre-commercial thinning using mastication equipment can increase total fuel loading and fuel bed depths by as much as 2 inches, but the magnitude varies by fuel size class (Harrod et al. 2008a). Regardless of thinning method, thinning followed by burning will significantly decrease surface fuel loading (Stephens and Moghaddas 2005a, Agee and Lolley 2006, Youngblood et al. 2008, Harrod et al. 2008a).

Canopy closure, canopy bulk density, canopy base height, and surface fuel loading influence torching and crowning fire behavior. Thinning generally reduces canopy closure, canopy bulk density, and increases canopy base height (Stephens and Moghaddas 2005a, Agee and Lolley 2006, Harrod et al. 2007a, Harrod et al. 2007b, Harrod et al. 2008a, Harrod et al. 2009). Burning alone is less effective at altering these characteristics in mature stands (Stephens and Moghaddas 2005a, Agee and Lolley 2006, Harrod et al. 2007b, Harrod et al. 2009, Schwilk et al. 2009), but can reduce surface fuel loading (Youngblood et al. 2008), thereby decreasing surface fire behavior and the potential for fire to move into the canopy. However, burning alone can be effective in young coniferous forests for thinning stands from below, reducing surface fuels, and raising canopy base height (Peterson et al. 2007). Overall, it appears that crown fire severity in wildfires can be mitigated to some degree by some type of fuel treatment (prescribed fire only, thinning only, or combination) as compared to stands with no treatment (Pollet and Omi 2002, Finney et al. 2005).

Forest Ecology

This section includes an overview of recently published science relevant to forest ecology topics such as stand development, effects of thinning and burning treatments on overstory and understory plant species, role, and recruitment of snags and old trees, and the spatial patterning of trees within forest patches.

Everett et al. (2007) reconstructed stands on the Okanogan portion of the OWNF that showed little or no evidence of timber harvest. Historically, frequent fires maintained low tree abundance in these stands, but fire cycles lengthened in the 1860s as euro-settlement progressed. Average stand density had already increased by 194 percent of the 1860 levels by the start of effective fire suppression in 1915. From the 1930s to 1960s, average stand density peaked at 258 percent of 1860 levels and tree densities began declining to 173 percent of the 1860 levels by 2000. In the absence of fire and without human intervention (such as timber harvest), the sampled stands had increased representation of shade-tolerant species and increased in overall mean stand age (Everett et al. 2007).

Thinning and burning have different effects on overstory. To some degree, the influence of thinning treatments on the overstory is much more predictable as compared to other variables because of greater control of tree removal. Thinning treatments throughout the western United States have the greatest effect on reducing stand density and increasing mean diameter (Schwilk et al. 2009). Most thinning treatments focus mainly on removal of smaller trees, but overall tree density can be reduced up to 60 percent (Stephens and Moghaddas 2005a, Youngblood et al. 2006, Harrod et al. 2007b, Harrod et al. 2009). Prescribed burning has less effect on the overstory characteristics and generally does not reduce tree density or basal area of the dominant overstory, but burning is most effective at reducing seedling and sapling density (Harrod et al. 2007a, Harrod et al. 2007b, Harrod et al. 2008b, Harrod et al. 2009, and Schwilk et al. 2009).

Snag density generally decreases following mechanical thinning and increases following burning, including thinning and burning combinations (Stephens and Moghaddas 2005b, Schwilk et al. 2009, Harrod et al. 2009). Snag reductions following thinning can be significant. For example, about 70 percent of snags were cut during thinning operations in the Mission Creek watershed, near Wenatchee, Washington (Harrod et al. 2007b, Harrod et

al. 2009). Proportions of snags cut decline with increasing snag diameter, from 78 percent in the sapling size class, to 50 percent in the large size classes. Conversely, snag densities increase following burning (0 to 14 percent, depending on size class) or thinning and burning (45 to 100 percent, depending on size class) treatments (Harrod et al. 2007b), but burning increases the chance that existing snags will fall as compared to untreated or thin-only sites (Harrod et al. 2009). Snags that are recruited through prescribed burning are hard snags with little decay and it is important to retain legacy snags in a variety of decay classes (Bull et al. 1997).

Old trees

Old trees are the most critical structural attributes in dry forest ecosystems (Franklin et al. 2008). Old trees have distinctive attributes related to crown structure, bark thickness and color, heartwood content, and decadence (wounds, rots, brooms, etc.) and these characteristics are usually developed between 150 to 250 years (Van Pelt 2008, Franklin et al. 2008). These old trees are often large and lead to large snags and down logs. Large, old ponderosa pine, western larch, and Douglas-fir trees are the most likely to survive wildland fire, particularly if ladder fuels are managed (Pollet and Omi 2002, Harrod et al. 2008b), and play important roles in post-fire recovery processes (Covington et al. 1997, Allen et al. 2002). The old tree component of most dry and mesic forest ecosystems within the OWNF is lacking (Harrod et al. 1999, Hessburg et al. 2000), largely because past selective harvesting focused on the removal of these trees.

Understanding the structural composition of old forests is important to developing prescriptions for restoration treatments. Several studies have investigated the historical density of large, old trees. For example, Covington et al. (1997) reported a density of 37 to111 trees per hectare in the southwestern United States. Harrod et al. (1999) estimated a mean of 50 overstory trees per hectare, with a range of 27 to 61 per hectare, depending on plant association at a study site on the Wenatchee River Ranger District. Youngblood et al. (2004) estimated a mean of 50 overstory trees per hectare, ranging from 15 to 94 trees per hectare at three study sites in eastern Oregon.

Spatial patterns of dry forests

Historically, dry forest stands were clumped at fine scales (<1/2 acre) and clumps were composed of even-aged groups of trees (Harrod et al. 1999). Stands were uneven-aged and composed of these even-aged groups. Average tree diameters were considerably larger than compared to contemporary stands. This clumpiness is consistent with the patterns of stand development described by Cooper (1960) and White (1985), in which seedlings are established in a patchy fashion due to frequent fire within occasional ‘hot spots’ that result from accumulated fuel. This process resulted in up to 30 percent of stands in non-forest openings composed of grass or shrub plant communities *(Fig.2).* Present day stands exhibit less clumping, particularly of large trees, than historically (Harrod et al. 1999). Current day stands tend to be homogenous and high density, lacking important spatial patterns.

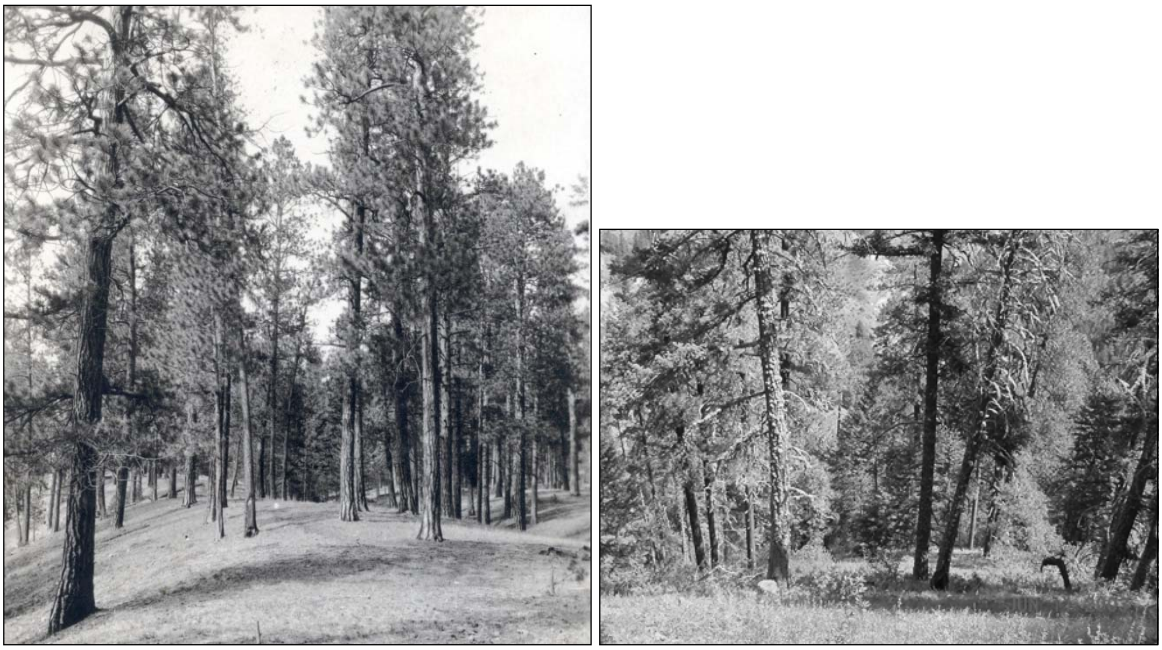


Figure 2. Examples of dominant tree patterns within stands that consist of tree clumps and canopy openings

Spatial patterns influence important ecological processes, such as fire spread and insect outbreaks. Historically, natural openings limited the potential for crown fire and created diversity of habitat for a diverse understory. When trees died in clumps, accumulated fuels created areas for seedling establishment following fire. On average, low-density stands maintained by fire were at or below critical thresholds for serious bark beetle outbreaks; however, beetles were present and largely confined to high-density clumps that were likely above the critical threshold for bark beetles. Disturbance processes, both fire and insects, function differently in clump stands with gaps compared to more evenly spaced stands. Insects cause mortality of high-density clumps allowing fires to burn dead wood and create openings for establishment of new clumps (Agee 1993, Harrod et al. 1999).

Tree clumps can be defined simply as several trees in close enough proximity that their crowns are interlocking (Long 2000). Youngblood et al. (2004) measured stand pattern within three old ponderosa pine stands in Oregon and northern California. For one stand, trees were randomly spaced at all scales. For the other stands, they reported these clumps ranged in diameter from 6-80 feet, with tree spacing random at scales under six feet, and tree distribution was clumpy at scales larger than about six feet. In a study conducted in ponderosa pine forests in northern Arizona, researchers found that in unharvested stands, large trees were aggregated at scales up to 28 meters and that clumps averaged 0.02 to 0.03 hectares in size (Sanchez Meador et al. 2009).

Complex patches are those with more structural and species complexity than the surrounding area. Often, these provide habitat for important wildlife species such as woodrats and/or flying squirrels (Lehmkuhl 2006a, 2006b), which are important prey items for northern spotted owls and raptors. Patch characteristics include large snags, soft down logs, and mistletoe brooms. Additional requirements for flying squirrels are canopy cover over about 55 percent and fruit and seed producers such as Douglas maple, Oregon grape,

serviceberry, rose, snowberry, and huckleberry. Lehmkuhl (2008) suggests that retaining these conditions within riparian buffers could provide adequate habitat for small mammal species associated with riparian areas. On uplands, retaining about 15 percent cover in coarse woody debris within a stand could be expected to provide adequate truffle supplies for these species (Lehmkuhl et al. 2004).

Understory vegetation

Understory vegetation is important for a wide variety of ecosystem functions (Allen et al. 2002) and comprises the vast majority of plant biodiversity (Gildar et al. 2004, Dodson et al. 2008). Understory species provide habitat and forage for many wildlife species, are important for regulating sediment transport and hydrologic regimes (Minshall et al. 1997, Beche et al. 2005, Pettit and Naiman 2007), and are important for nutrient cycling (Franklin et al. 2008). Intact native plant understories may be resistant to invasion by non-native plant species, which can decrease understory diversity (Harrod and Reichard 2001, Harrod 2001 and references therein).

Understory response to restoration treatment (thinning, burning, and thin and burn) is varied, but understory vegetation is largely unchanged, particularly several years after the initial treatment. Most studies have found that understory cover and frequency is maintained or increases 1 to 2 years post-treatment (Collins et al. 2007, Dodson et al. 2008) and these measures, including species richness, will be maintained or increased up to 19 years (Harrod et al. 2007a, Harrod et al. 2008b, Nelson et al. 2008). These findings are consistent with a large body of research completed in other areas in the western U.S. This research suggests thinning and burning treatments in dry coniferous forests have few detrimental effects on native understory vegetation (Abella and Covington 2004, Metlen et al. 2004, Metlen and Fiedler 2006, Moore et al. 2006, Collins et al. 2007, Knapp et al. 2007, Dodson et al. 2007). It is important to consider that pre-treatment condition has a strong effect on understory dynamics (Dodson et al. 2008). Stands that are very dense before treatment have low cover and species richness, and mechanical thinning coupled with drought can reduce the abundance of understory, at least in the short term (Page et al. 2005, Dodson et al. 2008). However, thinning and burning together may maximize benefit of restoration in areas where understory richness is low prior to treatment (Dodson et al. 2008).

There are potential benefits of prescribed fire on increased resistance of native plant communities to non-native invasion or as a method of invasive species control (Harrod and Reichard 2001). Non-native species cover and richness tend to increase after treatment; however, they constitute a minor portion (less than 2 percent cover) of the resulting understory plant community (Collins et al. 2007, Dodson et al. 2008). A long-term study in the eastern Cascade Range found that cover and richness of non-native herbs showed small increases with intensity of disturbance and time (up to 19 years) since treatment (Nelson et al. 2008). Thinning and burning may promote low levels of invasion by non-native species, but their abundance would appear limited and relatively stable over time.

Wildlife ecology

Much has been learned about the ecology of wildlife species and communities within the dry forests of eastern Washington during the decade since the strategy was first developed.

In particular, significant investments have been made to better understand the effects of forest restoration treatments on wildlife. A brief summary of what we have learned follows.

Small mammals

Lehmkuhl et al. (2008) studied the similarities and differences between small mammal communities in dry forest riparian habitats compared with dry forest upland habitats on the Cle Elum and Wenatchee River Ranger Districts. They found that small mammal communities contained several species that were highly associated with riparian forests. Some of these species were generally thought to be associated with moister forests found closer to the crest of the Cascade Range. Species richness and abundance were generally higher within 20 to 35 meters of the stream, indicating that current riparian reserve buffer widths would provide adequate habitat to conserve small mammal riparian associated species (Lehmkuhl et al. 2008).

Lehmkuhl (2009) studied small mammal communities as part of the fire and fire surrogate study conducted on the Wenatchee River Ranger District. The deer mouse *(Peromyscus maniculatus)*, yellow-pine chipmunk *(Neotamias amoenus)*, and Trowbridge's shrew *(Sorex trowbridgii)* were the dominant species. Half of the study units were relatively mesic habitats and supported a richer assemblage of small mammals that included all of the captured species compared to the relatively species-poor dry units. Management practices that reduce overstory density and allow greater wind penetration and drying, reduce large down wood, and shift understory dominance to grass likely will shift mammal species assemblages to favor species associated with the dry end of the moisture gradient (Lehmkuhl 2009).

Lehmkuhl et al. (2006a) studied the demography of the northern flying squirrel in dry forests on the Cle Elum Ranger District. Their results suggest that thinning and prescribed burning in ponderosa pine and dry mixed conifer forests to restore stable fire regimes and forest structure might reduce flying squirrel densities at stand levels by reducing forest canopy, woody debris, and the diversity and biomass of understory plants, truffles, and lichens. A similar result was found for dusky-footed wood rats (Lehmkuhl et al. 2006b). Lehmkuhl et al proposed that patchy harvesting and retention of large trees, woody debris, and mistletoe brooms might ameliorate the impacts to these species. Negative stand-level impacts would be traded for increased resistance and resilience of dry forest landscapes to now-common, large-scale stand replacement fires (Lehmkuhl et al. 2006a).

Munzing and Gaines (2008) monitored American marten abundance within dry and moist late-successional forest habitats on the Cle Elum and Wenatchee River Ranger Districts. They did not detect any marten in two years of sampling within late-successional dry forests. Their results corroborate those of Bull et al. (2005) indicating that conservation efforts for American marten should be focused in mesic and wet forest, not dry forest, habitats, thus reducing concerns about the effects of forest restoration treatments on American marten.

Northern spotted owl

Research and monitoring efforts have been underway to better understand the demography of the northern spotted owl (Lint 2005, Anthony et al. 2006), and trends in the availability of spotted owl habitat (Davis and Lint 2005). A study was recently completed on the Wenatchee River Ranger District on the ecology of barred owls and implications for the recovery of the northern spotted owl (Singleton et al. 2010). The ability to model the tradeoffs between reducing fire risk and protecting spotted owl habitat has advanced considerably (Ager et al. 2007, Lehmkuhl et al. 2007a, and Kennedy et al. 2008). This body of research has identified the following management implications:

- The spotted owl population is declining at a rapid rate in the Wenatchee and Cle Elum study areas.
- Wildland fire was an important factor in the loss of spotted owl habitat in the east-Cascades province.
- Barred owls have successfully invaded and now occupy moist forest types at greater densities than in dry forests. Some habitat partitioning may be occurring between barred and spotted owls based on slope position and forest type, suggesting that dry forest habitats may be important for recovery of the spotted owl.
- Models can be successfully used to inform managers on the tradeoffs between protection of dry forest, spotted owl habitat and treating habitat to alter landscape fire behavior and restore forest structure. In addition, these models can be used to identify strategic locations on forest landscapes where treatments would be particularly effective at reducing landscape fire flow.

HOT BOX 2

The Final Northern Spotted Owl Recovery Plan and Forest Restoration

The final recovery plan for the northern spotted owl (USFWS 2008) outlines a habitat management strategy for the fire-prone forests of eastern Washington, eastern Oregon, and the California Cascade Range and Klamath provinces. The strategy for east-side forests in the final plan represents a substantial shift from the reserve strategy described in the draft recovery plan and in the Northwest Forest Plan. The impetus for this change in strategy comes in large part from the findings of an independent scientific review (Sustainable Ecosystems Institute Review Panel, [SEI Review Panel]) of the draft recovery plan (Courtney et al. 2008) in which the SEI Review Panel reached the following conclusion regarding the recovery of spotted owls on the east-side of Oregon and Washington:

- The threat from wildfire was underestimated in the draft recovery plan for the dry forest provinces, and was inadequately addressed. This threat is likely to increase given both current forest conditions and future climate change.
- In some circumstances, owls may remain in, or rapidly re-colonize habitats that have experienced a low intensity fire. Hence, it is incorrect to assume that all fires result

HOT BOX 2

The Final Northern Spotted Owl Recovery Plan and Forest Restoration

in habitat loss. In other circumstances, owls or their habitats are lost as a consequence of intense or catastrophic fires. It is important to recognize such variation of fire effects when developing a conservation strategy.

- In east-side habitats of the Washington and Oregon Cascade Range, the only viable conservation strategy will be to actively manage fire-prone forests and landscapes to sustain spotted owl habitat. However, this needs to be closely monitored through an adaptive management process.
- A simple reserve network is unsustainable in east-side, fire-prone habitats. Conservation strategies must be designed and implemented at the landscape level to be viable.
- Based on these findings and the recommendations made by the scientific review panel (Courtney et al. 2008), the final spotted owl recovery plan includes a habitat management strategy as described below. In particular, recovery actions 6 and 7 are relevant to this strategy.
- Recovery Action 6: Identify and maintain approximately 30-35 percent of the total dry-mesic forest habitat-capable area as high -quality spotted owl habitat patches. Identify and maintain approximately 50-75 percent of the total moist forests habitat-capable area as high-quality spotted owl habitat patches.
- Recovery Action 7: Manage lands in the province outside of high -quality habitat to restore ecological processes and functions, and to reduce the potential for significant losses by uncharacteristic fires, insects, and diseases. This recovery action includes three elements:
    - Active management of dry forests. This includes the strategic management of at least 20-25 percent of the dry forest area to reduce the risk of habitat loss due to high severity fire, diseases, and insects and to increase the resiliency and sustainability of spotted owl habitat.
    - Development and retention of large trees and snags, an important element of spotted owl habitat that takes the longest to develop once removed. Restoration of large-fire tolerant tree species to their former role in dry-forest landscapes would provide the habitat “anchors” for spotted owls and other species. This includes the retention of large trees and snags following wildfire.
    - Long-term management of dry forests to reduce the potential for future high severity fires and hasten the recovery of structurally diverse forests.
- On the fire-dominated east side of the Cascade Range in Washington, Oregon, and California, the habitat management strategy described in the final recovery plan is intended to maintain spotted owl habitat within an environment of frequent natural disturbances. No habitat reserves are identified in these provinces, given the assumption that the disturbance regimes preclude long-term persistence of any static

HOT BOX 2

The Final Northern Spotted Owl Recovery Plan and Forest Restoration

habitat management areas. Rather, a landscape approach is described that promotes spotted owl recovery within the broader goal of ecological sustainability.

- "High-quality habitat" and "habitat-capable" would be defined by local conditions and a provincial-level interdisciplinary team. It would include the following elements: multi-layer conifer forest with large trees, high amounts of canopy cover, broken top live trees and large snags, and large-diameter down wood.
- Habitat patch sizes are not defined here because identification of patches of high-quality spotted owl habitat will be informed by local conditions as will the appropriate patch size.
- The pattern and distribution of high-quality habitat should be informed by local interdisciplinary teams and based on a number of ecological criteria including: existing spotted owl locations, desired patch sizes, topography, barred owl locations, prey base, risk of loss from fires, future fire behavior, insects, and diseases.
- The size and spacing of these habitat patches should be determined by interdisciplinary teams of appropriate experts.
- Habitat percentages for dry and moist forests should be measured for each sub-basin (example: Methow and Naches Ranger Districts) to assure habitat is well distributed.

Other bird species

A substantial amount of effort has been made to better understand the effects of forest restoration treatments on forest birds in three studies. The Pendleton Ecosystem Restoration study (Gaines et al. 2007) and the Fire and Fire Surrogate study (Lyons et al. 2008, Gaines et al. 2009, Gaines et al. 2010) both occurred on the Wenatchee River Ranger District, and the Birds and Burn study (Saab et al. 2007) occurred on the Methow Ranger District. Based on this body of research we offer the following implications for managers to consider:

- Thinning from below followed by prescribed fire can be used as an effective tool to restore habitat for many avian focal species, including neotropical and migratory species (Gaines et al. 2007, Lyons et al. 2008, Gaines et al. 2010);
- Spring burning (without mechanical treatment) may not have the desirable effects on restoration of habitat structure (reducing canopy closure, removing small trees, creating canopy gaps, creating large snags) for avian species if conducted when conditions are too cool and moist (Gaines et al. 2010);
- Large trees (and snags) in dry forests provide important habitat for foraging (Lyons et al. 2008) and nesting (Gaines et al. 2010), and are a key component in maintaining or restoring the viability of focal avian species;

- The effects of spring burning on ground nesting species needs more focused research with greater sample sizes to better understand the relationship between the timing and intensity of prescribed burns and the effects on avian nesting and survival (Gaines et al. 2010).

Saab et al. (2007) studied the effects of prescribed burning on avian communities across a network of study sites across the western U.S., including a site on the Methow Valley Ranger District. They found that overall, a greater percentage of migrant and resident birds responded with higher abundance and density to prescribed burns during the year of the treatment than in the year after (Russell et al. 2009). Fewer species responded one year after treatments, indicating that the influence of prescribed burning is short-term. Responses were variable for migratory birds, whereas residents generally had positive or neutral responses. They found that prescribed burns not only reduced snag numbers but also recruited snags of all sizes, including large size classes. The retention of large-diameter trees and snags allows for population persistence of cavity-nesting birds (Saab et al. 2007).

Snags provide habitat for a variety of cavity-nesting birds. Snags also become down logs that provide nutrient cycling, soil stabilization, water storage, and habitat for prey species (Bull et al. 1997). Forests within the historically low fire severity regime (e.g., ponderosa pine) would have had more stable snag recruitment over time (Harrod et al. 1998). Therefore, the standards for snag densities, conditions, and arrangement should be supportable under the disturbance regimes of the area (Everett et al. 1999) and will require consideration of wildlife habitat needs. The arrangement of leave snags in patches or clumps was found to be more important to cavity nesters than dispersed or isolated snags (Saab and Dudley 1998, Haggard and Gaines 2001). Large-diameter ponderosa pine (> 19 inches.), Douglas-fir, and western larch were important snags to retain because they meet the requirements of multiple species of cavity excavators (Haggard and Gaines 2001, Lyons et al. 2008) and have the longest residence times (Everett et al. 1999). In addition, the most suitable snags for cavity excavation were found to be large diameter snags that incurred defects, especially broken tops, prior to fire (Lehmkuhl et al. 2003).

Avian species associated with stream-side riparian forests and adjacent uplands within dry forests were studied on the Cle Elum and Wenatchee River Ranger Districts (Lehmkuhl et al. 2007a). They found that riparian forests had the greatest number of strong characteristic, or indicator species compared to dry and mesic upland forests. Their results indicate that current standards and guidelines for riparian buffer zones would allow for avian refuge and wildlife corridor functions along streams.

Snails

Gaines et al. (2005) developed a predictive model of habitat attributes for the Chelan Mountain snail species complex that is endemic to the Chelan and Entiat Ranger Districts. Their results suggest that thinning to restore forest structure would not negatively influence the species as long as canopy closure would be more than ten percent. The effects of spring and fall burning on the Chelan Mountain snail have also been monitored. Preliminary analyses showed that both burning regimes retained the presence of live snails on all treated plots. Some plots showed a reduction in the population density of snails

immediately post-treatment but these numbers generally recovered within a year of the burn (Gaines et al. in prep).

Roads and wildlife

As with aquatic species, terrestrial wildlife species can also be influenced by human activities associated with roads. Recent literature reviews conducted by Gaines et al. (2003), Wisdom et al. (2000), and Singleton and Lehmkuhl (1998) provide a solid scientific foundation for a discussion of the interactions of roads and wildlife. Much of the research on the effects of roads on wildlife has been on wide-ranging carnivores and ungulates; lesser-known species could benefit from additional research, especially those less mobile species where roads may inhibit movements or fragment habitats. The most commonly reported interactions included displacement and avoidance where animals were reported as altering their use of habitats in response to roads or road networks (Gaines et al. 2003). Disturbance at a specific site was also commonly reported and included disruption of animal nesting, breeding or wintering areas. Collisions between animals and vehicles are also common on higher speed roads and affect a diversity of wildlife species, from large mammals to amphibians. Finally, edge effects associated with roads or road networks constructed within habitats, especially late-successional forests, were also identified in this study. The response of wildlife to roads and human activities that occur along roads are often species-specific and can vary depending on animal behavior (nesting, dispersal, foraging, etc.), road type, and traffic patterns.

Summary of New Science Findings

This section summarizes key science findings that are relevant to the sections presented in Part II and carried forward into the strategy.

Science findings relative to the landscape evaluation

- Comparison of current and historic landscape pattern revealed shifts from early to late seral conifer species, patch sizes of all forest cover types are now smaller, and current land cover is more fragmented.
- Across forest landscapes, the area in old multistory, old single story, and stand initiation forest structures has declined with a corresponding increase in area and connectivity of dense, multilayered, intermediate forest structures.
- Dry forest landscapes are now dominated by shade-tolerant conifers, with elevated fuel loads, severe fire behavior, and increased incidence of certain defoliators, dwarf mistletoe, bark beetles, and root diseases.
- The old tree component of most dry and mesic forest ecosystems within the OWNF is lacking, largely because past selective harvesting focused on the removal of these trees.
- In high severity fires, riparian overstories within dry forest landscapes have a high degree of continuity with adjacent overstories on sideslopes, indicating that treatments that disrupt continuity between riparian and uplands may be appropriate so long as ecological processes are considered and treatments are fitted to site conditions.

- Dry and mesic forests provide important habitat for the northern spotted owl and may provide areas of lesser competition from barred owls. Restoration treatments are needed to reduce the risk of landscape fire flow and should be placed in strategic locations. Fire modeling has advanced considerably providing important tools for managers to use to identify the location of strategic restoration treatments.

Science findings relative to the road network evaluation

- Road and forest treatments spread uniformly across large spatial scales press the aquatic condition outside of the range of expected conditions, which in turn reduces the ability of aquatic species to persist over time.
- Roads or road networks affect wildlife habitats and can result in road-related mortality, fragment habitats cause wildlife to be displaced from or avoid areas adjacent to roads.
- Roads affect aquatic environments by blocking fish passage, simplifying stream function, altering sediment delivery, and increasing fine sediment yields.
- Generally, as the density of roads increases within a watershed, the quality of aquatic and terrestrial habitats decreases.

Science findings relative to project level

- Old and/or large trees are ecologically important to dry and mesic forest ecosystems. There is a lack of old trees on the Okanogan-Wenatchee National Forest. Large trees are most resilient to fire disturbances and provide important habitat functions when live and dead.
- Present day stands exhibit less clumping, particularly of large trees, than historically. Current day stands tend to be homogenous and high density, lacking important spatial patterns.
- Thinning and burning treatments in combination are most effective at decreasing stand susceptibility to uncharacteristic wildfire.
- Mechanical thinning reduces snag numbers, but burning can increase the number of snags, including large snags.
- Thinning and burning treatments in dry coniferous forests have few detrimental effects on native understory vegetation.
- Non-native plant species may increase after treatment (thinning and burning), but the magnitude is minor even many years post-treatment.
- Thinning to reduce tree density and favor early seral tree species can reduce the landscape's vulnerability to uncharacteristic insect and disease effects.
- Riparian understory response to fire is often less severe than corresponding understory response to fire upslope.
- In addition to traditional aquatic contributions, riparian areas provide habitat for a unique community of small mammals and birds compared to adjacent upslope

forests. Aquatic and terrestrial biota dependent on riparian areas warrants attention when considering dry forest treatments in the riparian habitat. In some instances, protection may be the most appropriate consideration, while in many situations some type of treatment is warranted to restore ecological processes.

- Spatial variability such as clumps, gaps, and complex patches within treated stands provide important structural diversity for birds and mammals such as the northern flying squirrel and wood rats. Complex patches should also retain large pieces of down wood and tree diseases such as mistletoe to provide important habitat components.
- Several focal bird species, including the white-headed woodpecker and western bluebird, responded favorably to thinning and burning restoration treatments. Restoration treatments should retain the largest trees and provided spatial variability in tree distribution.

PART II: INTEGRATED LANDSCAPE EVALUATION AND PROJECT DEVELOPMENT

Successful restoration of forest ecosystems requires a landscape perspective, which is essential for effective restoration of ecological processes and functions. Forest ecosystems are dynamic and consist of complex interactions between vegetation, wildlife, aquatics, and disturbances, particularly fire. Tools exist to analyze interactions among these key ecosystem components at landscape scales (see process outlined below), but our ability to describe and analyze interactions among individual species and changes to forest communities or disturbance regimes is much more limited. An alternative to developing overly complex restoration models that include all ecosystem components is to alter structure and composition of vegetation and reintroduce processes such as fire (Kenna et al. 1999), while restoring aquatic environments. Restoration plans that change vegetation structure are important to restoring wildlife habitat, physical processes (soil and aquatics), and spatial patterns. The landscape evaluation described below assumes that analyzing and preparing restoration plans that address four key components (vegetation, fire, wildlife habitat, aquatics) will result in restoration for a suite individual species, forest communities, and aquatic systems.

Forest managers face tremendous challenges in determining the strategic placement of treatments that restore landscape fire behavior processes while also being integrated with other important resource values such as reducing risks to human communities and increasing the sustainability of habitat for federally listed species (Collins et al. 2010). Addressing this complexity can be facilitated by the use of spatial tools such as GIS and ArcFuels (Ager et al. 2007, Collins et al. 2010); however, the problem of integrating the datalayers into management alternatives remains. The Ecosystem Management Decision Support (EMDS 3.0.2, Reynolds 2002, Reynolds et al. 2003) provides a useful tool for integrated landscape evaluation and planning (Hessburg et al. 2004, Reynolds and Hessburg 2007). EMDS supports an explicit two-phase, integrated approach to landscape evaluation and planning. The evaluation phase (referred to as the logic part of the model) is designed to get at the question, “What is the state of the system?” and the planning phase (referred to as the decision side of the model) is designed to address, “What are reasonable responses to address the problems revealed from the evaluation phase?” EMDS was chosen as a tool to aid in landscape evaluation for a variety of reasons: 1) synthesis of large amounts of diverse information, such as the comparison of current landscape conditions to the natural and future range of variation (Hessburg et al. 2004, Reynolds and Hessburg 2007, Gartner et al. 2008), 2) analytic steps determined by the landscape evaluation interdisciplinary team are transparent and repeatable, and 3) treatment options (including no action) can be evaluated and discussed in the effects analyses.

Determining what variables (also referred to as ecological indictors) to evaluate in the landscape evaluation is difficult and represents a balance between choosing a few key variables to provide important insights into landscape conditions, but not evaluating so many variables that the process becomes too complicated, inefficient, and impossible to implement. As Reynolds and Hessburg (2005) point out, “Landscape evaluations concerned with the *restoration of ecosystems* might be based on a set of *ecological indicator* measures compared against *reference conditions* for those same indicators.” Using this logic, what are the best indicators for which a set of reference conditions can be

used to compare against? Fortunately, current research has already been conducted on Okanogan-Wenatchee National Forest landscapes, providing insights into what key variables are meaningful at the landscape scale. Reference conditions have been established for both the natural range of variability (Hessburg et al. 1999, Hessburg et al. 2004, Reynolds and Hessburg 2005) and the future range of variability that represent a likely climate change scenario (Gartner et al. 2008). Based on these research results, selected ecological indicators for the landscape evaluation include: 1) landscape pattern and departure, including risk of insects and disease, 2) fire movement potential, and 3) wildlife habitat amount and spatial pattern. A fourth variable, road network evaluation was added because of the connection between road access for recreation and forest management, access needs for restoration treatments, and the significant influences that roads have on the aquatic systems. The Wenatchee Forestry Sciences lab is working with the OWNF in the training and use of EMDS with the Dry Orr landscape evaluation being the first collaborative effort.

This section presents the core components of the forest restoration strategy (*figure 3*). It begins with a process called the landscape evaluation that defines the restoration treatments needed, establishes the context of a restoration project area within the broader landscape, and sets priorities for where restoration should occur. An important outcome of the landscape evaluation will be the identification of potential landscape treatment areas (PLTA). It is anticipated that two to three PLTAs would be identified from each landscape evaluation. Information from the landscape evaluation would be used to develop site-specific purpose and need for the PLTAs and would carry forward into project level planning.

The project development portion of the strategy provides a process for interdisciplinary teams to follow so that restoration projects are designed using the best available science about forest ecosystems. Project level planning considers two spatial scales: project area-wide considerations (the arrangement and interaction of forest stands), and the patch-scale (spatial variability within a forest stand).

The planning and implementation of forest restoration projects should become more effective and efficient by following the process outlined in this section of the strategy. because:

- More than one project NEPA decision would be supported by one landscape evaluation, allowing the information generated in the landscape evaluation to be used repeatedly.
- More site-specific purpose and need statements and proposed actions will result in fewer misidentified proposed treatment areas and missed treatment opportunities, improving layout efficiency of projects. Currently, specialists often redo analyses because site-specific conditions do not match the conditions that were assumed during project planning.
- Better integration across resource disciplines will reduce resource conflicts and provide a high level of ownership in restoration projects.
- Landscape evaluations and field validation will provide better information on which to base decisions about the location, scope, and priority of various potential

projects, so that limited resources for treatments are used where they provide the greatest benefits.

- A focused purpose and need and project design would result in simplified NEPA, by eliminating unresolved conflict, and eliminating the need for alternative development (36 CFR Part 220, Section 220.7 (b) (2) (i).

Figure 3. Schematic of the Forest Restoration Strategy process showing the relationships between landscape departure evaluation, project development and implementation, and monitoring

At this time, there is not a broad-scale evaluation that can be tiered from to select priority watersheds for landscape evaluations. District interdisciplinary teams select watersheds for landscape evaluations based on:

- Focused watershed action plan
- Forest-wide fire modeling
- Priority watersheds for habitat restoration from species sustainability assessment
- District five-year action plan

- Dry and mesic forests considered to have the greatest departure in density and structure
- Consider minimum roads analysis as results become available

Timeline for Completion of Landscape Evaluation and Project Planning

Scheduling the landscape evaluation and project planning phases of the strategy is very important to successful implementation. The following is an example of an ideal scenario:

Fall-Winter of Year 1 – Gather resource information for the subwatershed(s) identified for evaluation. Conduct landscape evaluation to identify and prioritize PLTAs.

Spring-Summer of Year 1 – Interdisciplinary team conducts fieldwork to validate and ground-truth the selected PLTA, develops an integrated purpose and need, and begins to develop a site-specific proposed action.

Fall-Winter-Spring of Year 2 – Interdisciplinary team finalizes a site-specific proposed action and completes necessary NEPA.

Spring-Summer of Year 2 – Complete layout, marking, engineering, monitoring, etc., and other interdisciplinary fieldwork for implementation of the restoration project.

Landscape Evaluation

This section outlines an integrated process for completing a landscape evaluation. There are three objectives for conducting an evaluation at the landscape scale:

1. To provide a context for restoration activities so that project planners can clearly identify and display how their project moves the landscape towards more sustainable and resilient desired conditions.
2. To identify logical project areas and priority areas, using the information generated from the landscape evaluation.
3. To describe desired ecological outcomes and better estimate outputs.

The described landscape evaluation generates information about four core variables that are important indicators of landscape conditions (Reynolds and Hessburg 2005):

- structure and vegetation composition (pattern);
- the flow of fire across the landscape (process) given local weather and existing fuel conditions;
- the movement of water across the landscape (process) and its interaction with the transportation system, and;

- areas where wildlife habitat (function) is likely to be the most sustainable and integrated with restoration treatment areas.

Other variables may be added but must be relevant to the task of identifying priority areas for treatment, are appropriate at the landscape scale, and data are available spatially.

Great care must be taken to not add unnecessary complexity to this already complex process.

The landscape evaluation is an important interdisciplinary process involving a wide range of resource disciplines. Knowledge about disturbance ecology and fire modeling, forest and vegetation ecology, wildlife ecology (in particular, how habitats interact with dominant dry forest disturbances), and aquatics (in particular, how the transportation network interacts with the stream network) is of specific importance to the function of the interdisciplinary team. Other members of the team with knowledge of human uses that occur within the landscape evaluation area will be important. The team should focus on developing outcomes (e.g., ecologically sustainable forests, restoration acres) and not focus on any particular level of target at this time.

Steps to an integrated process for completing a landscape evaluation

The following steps outline the landscape evaluation process, from determining the landscape evaluation area (Step 1), evaluating landscape pattern and departure (Step 2), estimating fire flow and burn probabilities (Step 3), identifying key wildlife habitats and restoration opportunities (Step 4), evaluating road related impacts and restoration opportunities (Step 5), and finally, the development of an integrated landscape prescription (Step 6). Different disciplines will be responsible for completing each of the steps. Steps 1 through 5 would occur concurrently and need to be completed prior to Step 6. These steps are being applied in Dry Orr and will be modified based on what we learned and provide an example for future landscape evaluations.

STEP 1--Determine the extent of the landscape evaluation area

The size of the landscape evaluation has ecological and planning efficiency implications. Two or more sub-watersheds (12th field hydrologic unit code) totaling between 20,000 to 50,000 acres is recommended. This size of evaluation area is based on prior application of EMDS to evaluate landscape departure (Reynolds and Hessburg 2005, Hessburg et al. 2007). It partially coincides with previous watershed assessments, generally provides a range of elevations and forest types, and is useful in evaluating hydrological influences of forest restoration treatments. This size should be large enough to evaluate some cumulative effects, but wide-ranging carnivores may require larger evaluation areas (e.g., Gaines et al. 2003).

STEP 2--Conduct the landscape pattern evaluation

This step is a process that compares landscape pattern between the current and reference landscapes within the landscape evaluation area and identifies restoration needs based on departure from reference conditions (Hessburg et al.1999, Reynolds and Hessburg 2005).

Reference conditions include both historical range of variability developed by Hessburg et al. (1999) and the future range of variability developed by Gärtner et al. (2008).

This section includes four substeps: 2a, determine the current landscape pattern; 2b, determine the reference landscape pattern; 2c, evaluate departure of the landscape; 2d, evaluate insects and disease risk. The results from these analyses are integrated with the fire, wildlife, and road network evaluation in Step 6, using EMDS (Reynolds and Hessburg, 2005).

STEP 2a--Determine the current landscape pattern

Polygons (vegetation patches) are delineated in a geographic information system (GIS) using the most recent aerial photography and a selected set of vegetation patch attributes (details of the patch delineations are described in Hessburg et al. 1999) are recorded for each polygon. Field verification may be necessary to calibrate the photo-interpreter's polygon delineations calls during the initial mapping. Note that an experienced photo-interpreter with good imagery and good knowledge of the landscape can minimize field validation.

A series of automated scripts are used within a GIS to error- check the data and to derive landscape metrics from the characteristics recorded by the photo-interpreter. Another field validation (and associated edits) may be necessary if a preliminary map inspection reveals obvious errors.

The product of this step is a series of maps of vegetation patch types *(Table 2)* for the current landscape *(figure 4)*.

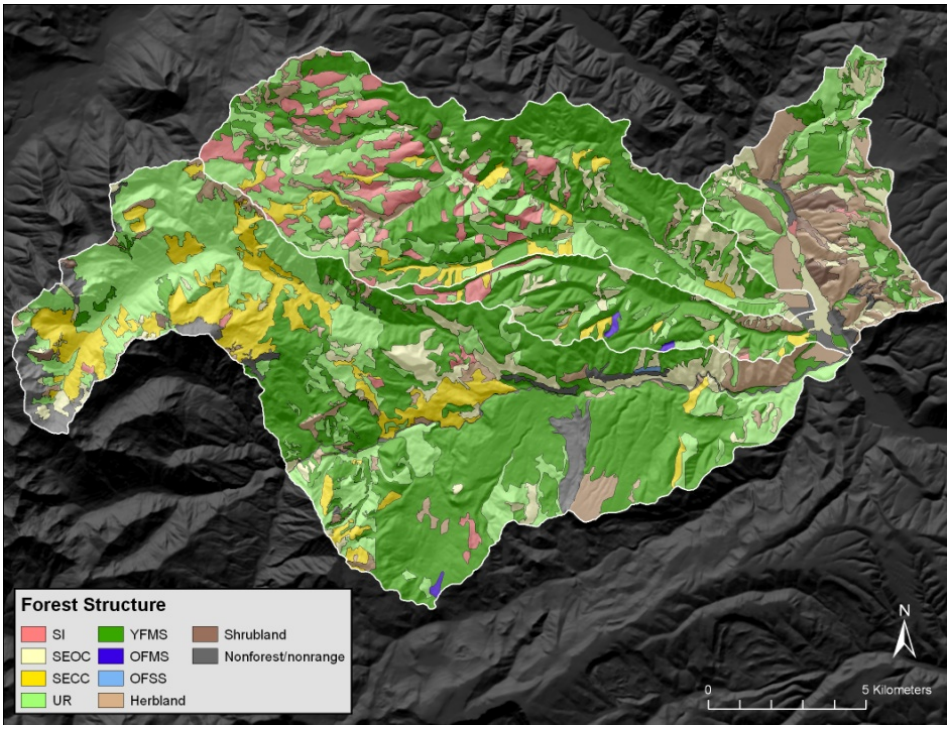


Figure 4. A map of the Dry Orr current landscape pattern. This map, along with various combinations of cover type and potential vegetation, are examples of the products developed from Step 2a.

STEP 2b--Determine the reference landscape patterns

During this step, reference conditions for the landscape evaluation area are selected based on the landscape's ecological subregion (ESR) (Hessburg et al. 1999) and the appropriate climate scenario. The two reference conditions that will be selected at this step are the historic range of variability and the future range of variability. The historical range of variability is derived from landscape reconstructions summarized in Hessburg et al. (1999). These results are summarized in the science overview, landscape ecology section. Reynolds and Hessburg (2005) incorporated the historic range of variability information into EMDS. The future range of variability to address climate change was developed by Gärtner et al. (2008) and incorporated into EMDS for this process.

STEP 2c--Evaluate departure of the landscape

In this step, the departure of the current landscape pattern from the historical and future reference conditions is evaluated using EMDS (Reynolds and Hessburg 2005, Gärtner et al. 2008). Landscape departure will include evaluation of changes to potential vegetation, cover types, and structure classes, and various combinations of these (*figure 5*, *table 2*).

Table 2—Examples of combinations of potential vegetation, cover types, and structure classes evaluated in the landscape departure analysis

Forest cover and potential vegetation group (CTxPVG)
Forest structure class (FRST_SS)
Forest structure and potential vegetation group (SSxPVG)
Forest cover and structure (SSxCT)
Forest cover and structure and potential vegetation group (SSxCTxPVG)

In addition to the analysis described above, at least four landscape metrics will be used in assessing the landscape departure. These four metrics are a subset of those used by Reynolds and Hessburg (2005) and were selected in consultation with Hessburg et al. (pers. comm.) as the most meaningful subset for restoration purposes:

- **Percent Landscape (PL):** Equals the percentage the landscape comprised of the corresponding patch type. This metric allows a comparison of how patch composition has changed over time and is likely to change in the future.
- **Aggregation Index (AI):** Is calculated from an adjacency matrix, which shows the frequency with which different pairs of patch types (including like adjacencies between the same patch type) appear side-by-side on the map. This metric shows how similar patches related to each other (i.e. proximity) in current landscapes compared to future and historical landscapes.
- **Patch Density (PD):** Is a limited (due to smallest defined patch), but fundamental, aspect of landscape pattern that expresses the number of patches on a per unit area basis that facilitates comparisons among landscapes of varying size.
- **Largest Patch Index (LPI):** At the class level, quantifies the percentage of total landscape area comprised by the largest patch. As such, it is a simple measure of

dominance. This metric is important to show how the amount of large patch area has changed over time and is likely to change in the future.

These four metrics are calculated for each of the landscape variables assessed (*e.g. table 2*).

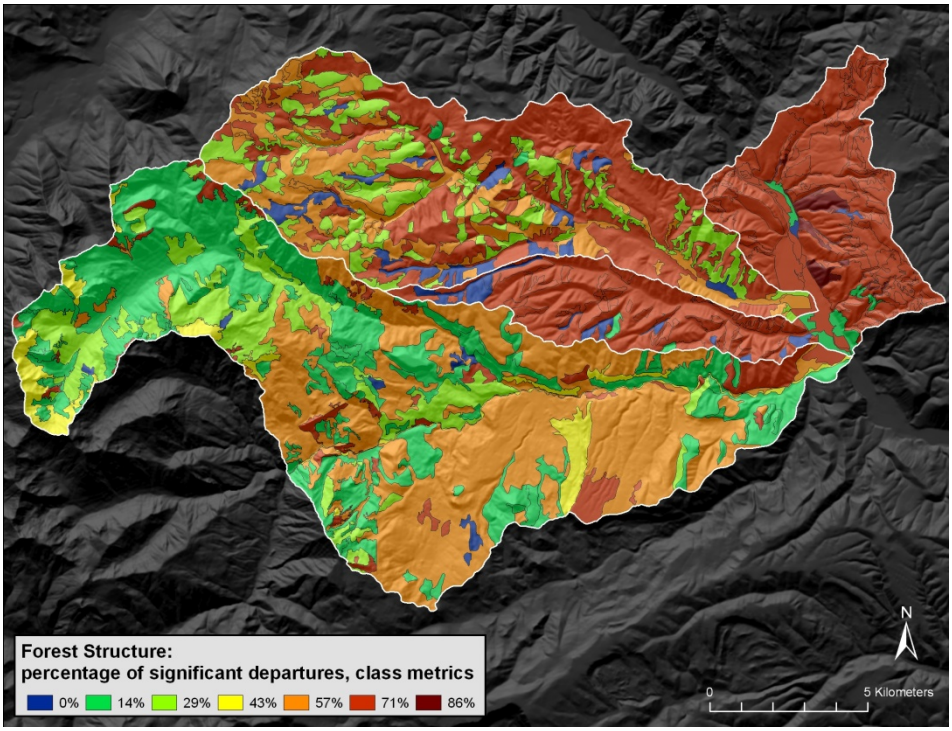


Figure 5. Step 2c - A map of the Dry Orr landscape showing the degree of departure between current and reference conditions for landscape departure analysis

STEP 2d--Evaluate insect and disease risk

In this step, the vulnerability of the landscape, and its component stands, to insects and diseases is evaluated and compared with the reference condition (Hessburg et al. 1999b). Each patch is assigned to a vulnerability class based on vegetation factors for specific insects and diseases. These factors were developed during steps 2a and 2b. Spatial statistics are used to evaluate how vulnerable the landscape is to the propagation of specific insects and diseases. The factors affecting landscape and patch vulnerability to Douglas-fir dwarf mistletoe and spruce budworm are displayed in *table 3*.

Table 3 – Vulnerability factors and rating criteria used in the evaluation of insect and disease risk based on Hessburg et al. 1999b

Vulnerability factor	Rating criteria	
	Western spruce budworm	Douglas-fir dwarf mistletoe
Site quality	Plant association group	Plant association group
Host abundance	Host crown cover	Host crown cover
Canopy structure	Number of canopy layers	Number of canopy layers
Patch (stand) density	Stand total crown cover	
Host age	Estimated age class	Estimated age class
Patch vigor	Degree of overstory differentiation	
Host patch connectivity	Proportion of area within a specified radius occupied by host	Proportion of area within a specified radius occupied by host

The products of this step include:

- Maps of patch vulnerability to Douglas-fir dwarf mistletoe and spruce budworm for the reference and current landscapes.
- A table of spatial statistics describing the current landscape's degree of departure in total area of vulnerability classes and their connectivity.

HOT BOX 3

Consider Role of Each Stand on the Landscape

Approaches to forest management within the context of forest restoration will need to be viewed differently than in the past. There are now more diverse objectives for the landscape and its component stands including barriers to the spread of fire, resilience to characteristic wildfire, habitat for northern spotted owl, habitat for white headed woodpeckers, hydrologic function, and structural conditions that meet a landscape-level pattern or successional objective. To accomplish this, evaluate the landscape and be explicit about the intended role for each stand or, more likely, group of stands. Here are some simplified examples:

- **Role—Old forest single story (OFSS) in the pine cover type as white-headed woodpecker habitat**. Create this structural class by removing understory trees, commercially or otherwise, along with periodic underburning to maintain those conditions. Traditionally, stands were underplanted in anticipation of an overstory removal, but this would compromise the area's ability to function as OFSS.
- **Role—Stem exclusion closed canopy (SECC) in the Douglas-fir cover type as a barrier to fire spread.** SECC can be maintained by thinning the stand from below. However, if the stand has widespread dwarf mistletoe infection,

HOT BOX 3

Consider Role of Each Stand on the Landscape

thinning would cause increased broom mass and ladder fuels, thus fire hazard, so these stands should not be thinned. Commercial thinning would be used in stands with enough deep-crowned trees to balance objectives for crown bulk density, understory shading and wind reduction, and desired growth rates.

- **Role—Stand initiation or understory reinitiation ponderosa pine cover type within the Douglas-fir series**. Development of this type might be done by regeneration favoring ponderosa pine. Traditionally, these sites were planted at high density as fast as possible in order to maximize timber volume production. Now, depending on seed source, wait for natural regeneration and, if planting is necessary, plant at a low and variable density so the stand initiation (SI) function isn't compromised. Over time, SECC or young forest multistory (YFMS), or stem exclusion open canopy SEOC conditions would develop and the stand could be burned or thinned accordingly.

STEP 3—Fire movement potential

In this step, landscape level fire modeling is done at the HUC 8th Code (subbasin) scale, which encompasses approximately 700 square miles. The forest wide fuels layers (re-sampled to 90m pixels), 90th percentile fuel moistures, and representative weather conditions (to condition fuels) are used within the FlamMap fire modeling software. Custom wind grids, derived for the three or four most likely prevailing wind directions, are also used as input to the model. The landscape is repeatedly ignited with 1000 random fires at a time and allowed to burn for six hours, until the majority of the landscape has been exposed to fire (~50,000 ignitions).

Each run creates multiple map outputs that are kept for each subbasin including; fireline intensity, crown fire activity, rate of spread, flame length, and node influence (the number of pixels that burned downwind of that pixel). The node influence changes as a result of ignition locations, so node influence for each individual run is composited to represent the sum of all 50,000 ignitions. This composite node influence is then combined with fireline intensity to create an index that shows the relative importance of each pixel (*figure 6*). This index is subsequently filtered to find clusters of pixels that create more meaningful areas to consider dangerous (since a two-acre area is not useful at the landscape scale).

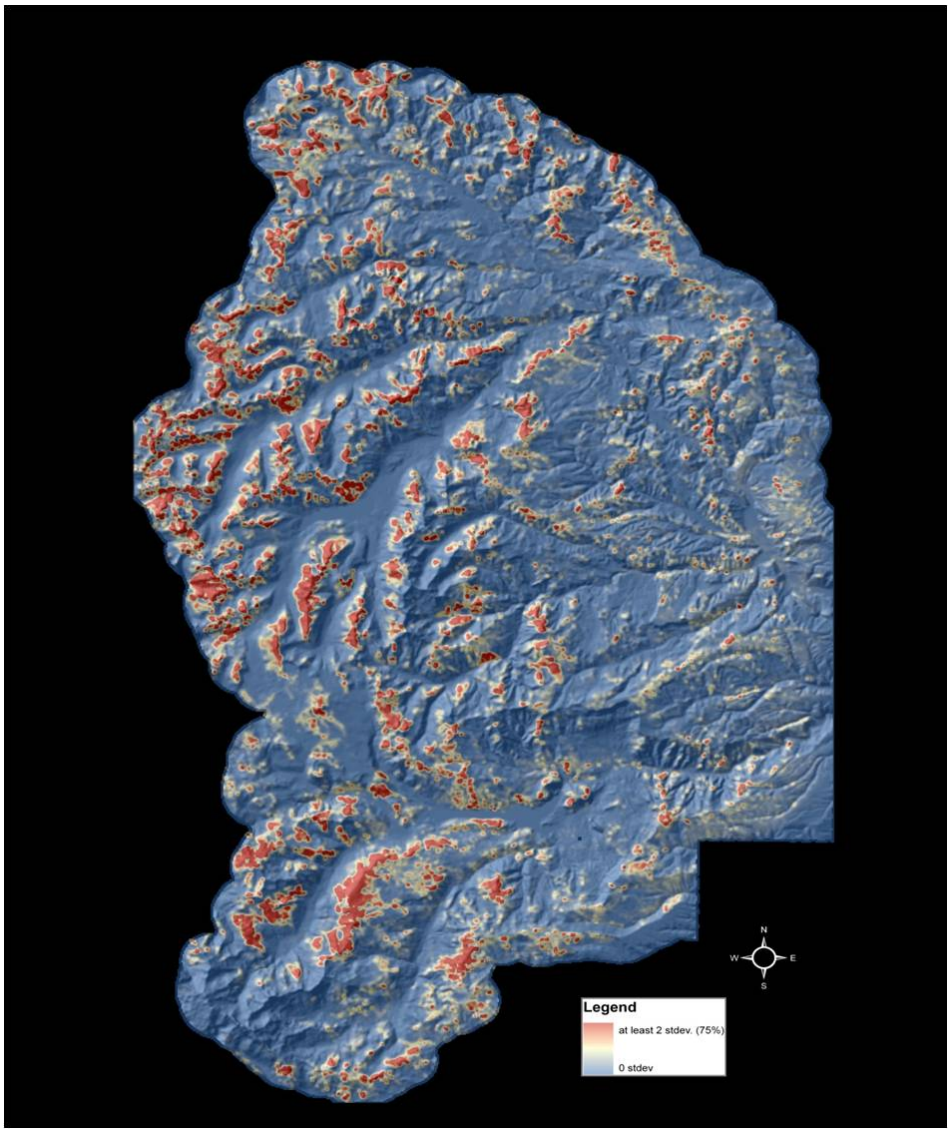


Figure 6. A map showing probability of fire movement produced from Step 3

STEP 4--Habitats for Focal Wildlife Species

The objectives of this step are to: 1) determine the location and amount of habitat for focal wildlife species currently present within the landscape evaluation area, 2) Compare the current amount and configuration of habitats for focal wildlife species to historical and future reference conditions, and 3) identify habitat restoration opportunities and priorities that can be integrated with other resource priorities and carried forward into project level planning. The information about wildlife habitats generated from this step would be incorporated into EMDS for integration in Step 6.

Focal wildlife species were selected because they are either federally listed or identified as a Region 6 focal species (USFS 2006, Gaines et al. in prep). The focal species are closely associated with forested habitats and their populations are influenced by changes to forest structure. Habitat generalists and wide-ranging carnivores were not selected as they are

generally evaluated at broad-spatial scales. These include species such as the grizzly bear (*Ursus arctos*), wolverine (*Gulo gulo*), Canada lynx (*Lynx canadensis*), and gray wolf (*Canis lupus*).

Focal Wildlife Species and Habitats

Focal species used to evaluate wildlife habitats include the northern spotted owl (*Strix occidentalis caurina*), northern goshawk (*Accipiter gentilis*), white-headed woodpecker (*Picoides albolarvatus*), American marten (*Martes americana*), pileated woodpecker (*Dryocopus pileatus*), Lewis's woodpecker (*Melanerpes lewis*), and black-backed woodpecker (*Picoides arcticus*). The habitat definitions that are used in the landscape evaluation for these species are described in *table 4*.

The northern spotted owl is a federally protected threatened species that is associated with late successional forests and would only be addressed in landscape evaluations that occur within the Northwest Forest Plan area. The final spotted owl recovery plan (USFWS 2008) identified an "east-side strategy" that integrates disturbance ecology and high-quality spotted owl habitat within the broader context of ecosystem restoration. The northern spotted owl recovery plan east-side strategy can be implemented through this restoration strategy by identifying sustainable levels of habitat in the landscape evaluation. As a starting point, the recovery plan suggests that 30-35 percent of the habitat-capable dry and mesic forests, and 50-70 percent of the habitat-capable moist forests would be high-quality spotted owl habitat at any point in time (USFWS 2008). The definition of high-quality habitat for the northern spotted owl is based on resource selection modeling described in Gaines et al. (2009). The landscape evaluation would be used to validate these numbers or justify changes to them. In addition, the recovery plan identifies the need to retain or restore large trees and snags as an important component of spotted owl habitat (USFWS 2008). This is one of the reasons that the strategy specifically addresses large trees (see Part II, Project Level).

The northern goshawk is an R6 focal species (USFS 2006) and was a species highlighted in the east-side screens. Like the northern spotted owl, the goshawk is associated with late-successional forests (see Gaines et al. in prep for a summary of habitat relations). The northern goshawk would only be assessed in landscape evaluations that occur outside of the Northwest Forest Plan area.

The white-headed woodpecker, American marten, pileated woodpecker, Lewis's woodpecker, and black-backed woodpecker are all Region 6 focal species (USFS 2006) and are being evaluated in forest plan revisions. These species are associated with a wide variety of cover types and structural classes. Gaines et al. (in prep) presents an extensive literature review that summarizes the habitat relations of these species. This information was used to develop the habitat definitions presented in *table 4*.

Table 4—A description of habitats for focal wildlife species used in the landscape evaluation

Focal species/habitat	Potential vegetation type/cover type/structure class[1]
Northern spotted owl	LSOG[2], OFMS
Northern goshawk	ABAM – OFMS or YFMS w/o logging[3] PIPO, PSME, or TSHE/THPL – OFMS or OFSS or YFMS w/o logging LAOC - OFSS or YFMS w/o logging PICO or ABGR - YFMS w/o logging
White-headed woodpecker	PIPO – OFSS or SEOC (size OS = 5, US = 4) or (OS=4, Layers=1) and CC<40%
American marten	ABGR or PIAL/LALY – YFMS w/o logging ABAM or ABLA2/PIEN - OFMS or YFMS w/o logging LAOC – OFSS or YFMS w/o logging PSME,TSHE/THPL or TSME – OFMS or OFSS or YFMS w/o logging
Pileated woodpecker	ABAM or ABLA2/PIEN – OFMS PSME or TSHE/THPL – OFMS or OFSS LAOC - OFSS
Lewis's woodpecker	PIPO – OFMS PSME – OFSS <10 years post high severity fire
Black-backed woodpecker	ABLA2/PIEN – OFMS PIPO or PSME – OFMS or OFSS LAOC – OFSS PICO – YFMS <10 years post high severity fire w/o post-fire harvest

1/The cover types and structure classes are described in Part I.
2/LSOG = late-successional/old growth
3/For definition of logging see Hessburg et al. 1999

The products from this step include:

- A map showing the location and amount of habitat for each of the focal species *(figure 7).*
- A map of the historical and future references conditions for habitat for each of the focal species.
- Tabular data showing the degree of departure in habitat amounts and configuration between current and reference conditions. The metrics that will be used to evaluate habitat configuration include the following:
- Percent Landscape (PL): Equals the percentage the landscape comprised of the corresponding habitat patch type.
- Aggregation Index (AI): Is calculated from an adjacency matrix, which shows the frequency with which different pairs of habitat patch types (including like adjacencies between the same habitat patch type) appear side-by-side on the map.
- Patch Density (PD): Is a limited (due to smallest defined patch), but fundamental, aspect of landscape pattern that expresses the number of habitat patches on a per unit area basis that facilitates comparisons among landscapes of varying size.

- Largest Patch Index (LPI): At the class level, quantifies the percentage of total landscape area comprised by the largest habitat patch. As such, it is a simple measure of dominance.

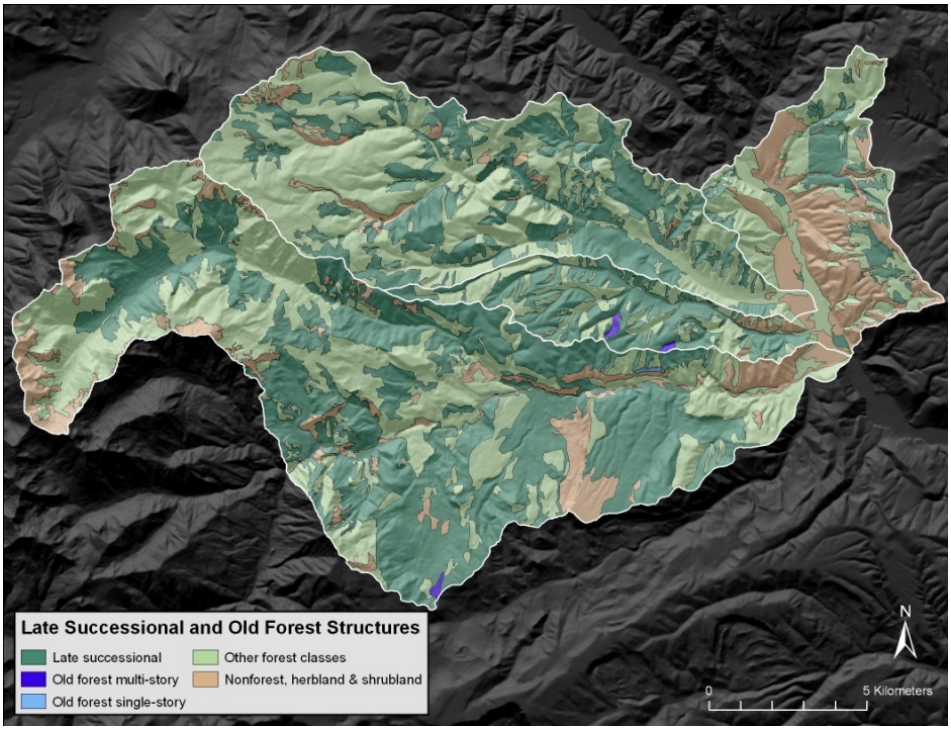


Figure 7. A map of the Dry Orr landscape showing the location of some focal wildlife species habitats. Late successional forest is habitat for focal species such as the northern spotted owl and northern goshawk and old forest single story is habitat for ponderosa pine focal species such as white-headed woodpecker. This map is a result of Step 4

STEP 5--Road Network Evaluation

The purpose of the road network evaluation is to evaluate the impact of roads on the aquatic network. Extensive road networks like the system on the OWNF create a press disturbance that alters the aquatic environment. This evaluation step addresses important aquatic interactions with the road network including: 1) hydrologic connectivity, 2) fish distribution, 3) slope/soil stability, 4) stream channel confinement by the road network, and 5) road condition survey data.

The objectives of this step are: 1) determine what areas within the landscape evaluation area are the highest ecological priority for fish habitats, 2) within the areas that are high priority, identify the most damaging roads, and 3) of the most damaging roads determine how best to mitigate the impacts (surfacing, relocation, decommissioning, etc.).

These are the steps to complete road network evaluation:

Hydrologic connectivity

- Identify flow routes connecting to the road system by intersecting ten-meter digital elevation model with road segments (output is a relative ranking).

- Review sub-elements of road condition survey that interrupt stream connectivity.

Fish distribution

- Update existing fish distribution layer for listed and sensitive species (this updated layer will be connected to the potential treatment polygons) and used in EMDS (when distribution is highly disrupted on the landscape fish distribution should have added emphasis in EMDS).

Slope/soil stability

- This data source is currently under development. Currently, slope/soil stability is modeled by combining the soil layer, SERGO, with the digital elevation model, and assigning slope breaks appropriate for the landscape being analyzed. At this time, default slope breaks are 0 to 35 percent, 35 to 60 percent, and greater than 60 percent.

Stream channel confinement by the road network

- Use the stream channel confinement layer developed for forest planning that identifies stream channels with less than three percent gradient within 30 meters of roads.

Road condition survey data

- Develop an Excel spreadsheet by road segment that summarizes the eight major categories (see Okanogan-Wenatchee N.F. road condition survey protocol) of road condition that are collected during road condition surveys. Link the spreadsheet to the road layer. The output from this step can be used to ensure that those segments most affecting the aquatic environment are appropriately considered in the EMDS model.
- Complete a minimum roads needs assessment to inform project planning (FSH 7709.55, FSM 7712). Outputs from this assessment will be considered by the IDT and line officer when selecting PLTAs.

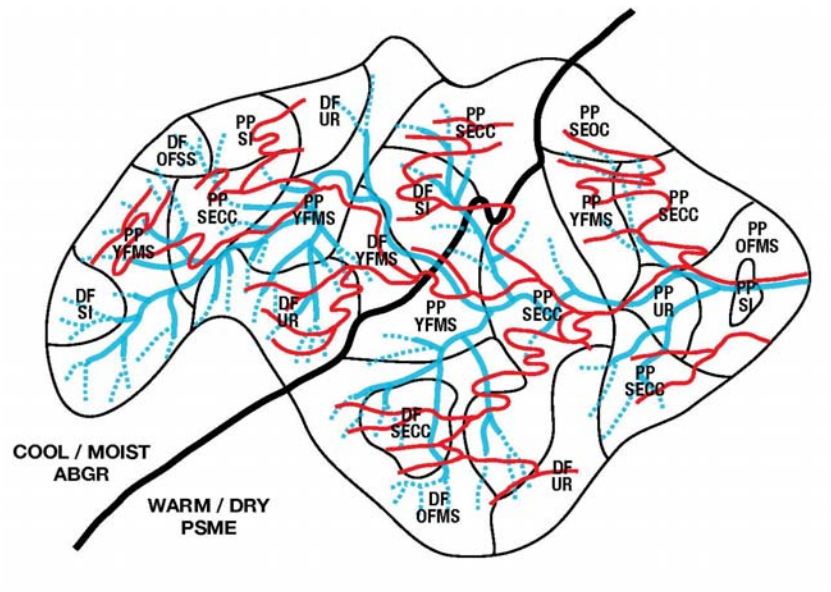


Figure 8. Conceptual map showing existing road network overlain on stream and patch maps. Roads are shown in solid red; perennial streams are shown in solid blue; intermittent

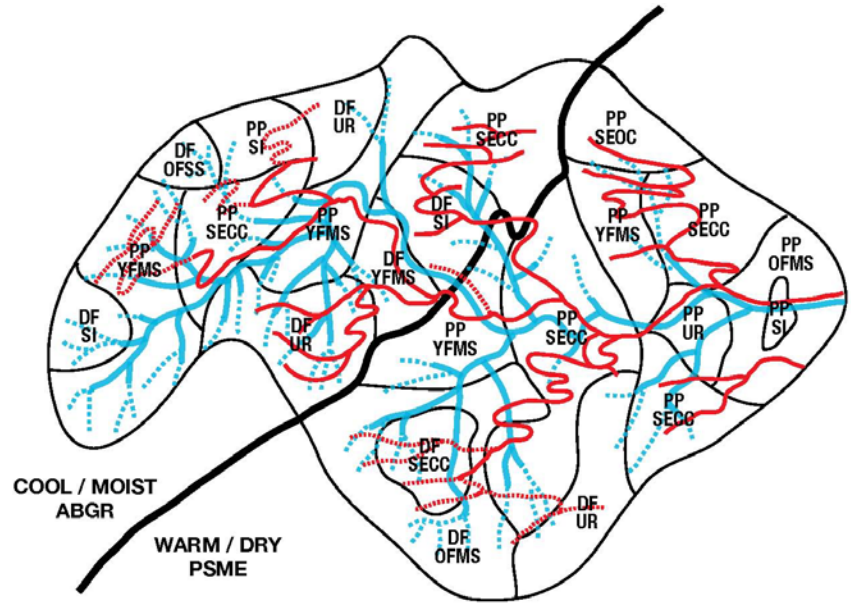


Figure 9. Conceptual map showing priority roads for restoration. Roads are shown in solid red; roads for restoration are shown in dotted red; perennial streams are shown in solid blue; intermittent streams are shown in dotted blue

Step 6: Integration of landscape evaluation results

This step integrates the results from the vegetation pattern analysis (Step 2), the fire movement modeling (Step 3), wildlife habitats (Step 4), and the road network evaluation (Step 5) using EMDS. Then, within EMDS, other management direction is considered and the PLTAs are prioritized according to management or operational considerations. The product is a PLTA that will carry forward to project level planning.

At this step, collaborate with groups or agencies that possess natural resource information that could aid in the landscape evaluation. Emphasize the validation of the information used in the landscape evaluation and the identification of other information sources that would be useful in defining where treatments should occur.

Please note: *The process outlined in the forest restoration strategy does not replace all the requirements for project level planning. By following the strategy, project level planning is now supported by a solid scientific and analytical foundation.*

Step 6a: Develop an integrated landscape prescription

Steps 2, 3, 4 and 5 provide information that can be used to develop prescriptions for the landscape. The information generated from the landscape pattern evaluation, fire and habitat modeling should allow the interdisciplinary team to quantify the amount and location of treatments that accomplish multiple objectives such as strategically altering fire behavior across the landscape, enhancing the sustainability of wildlife habitat, restoring landscape pattern, and reducing risk to communities. In addition, the road network needed to access the treatment areas should be defined along with roads that have been identified as high risk and could cause substantial resource damage.

Integration of all of these resources is extremely complicated and will be aided by the application of EMDS (Reynolds and Hessburg 2005). Using EMDS, the interdisciplinary team (IDT) will be able to evaluate a variety of landscape treatment options and assess how the options affect key resources (e.g. fish habitat, insect and disease risk, landscape departure, etc.). Management direction for land allocations and other resource considerations are included as decision criteria in EMDS (Appendix A). Line officers and IDT members will work together to select and weight decision criteria. Some examples of the kinds of questions that IDT will evaluate in the development of the landscape prescription include:

- What are the critical areas and thresholds (amount of area that needs to be treated) for restoration treatments based on modeled fire behavior in order to reduce fire risk to human developments, communities, and habitats?
- What treatments best restore landscape pattern while meeting other resource objectives?
- What combination of treatments provide habitat and restore patch sizes for wildlife focal species associated with old forest single story?
- What are sustainable levels of high-quality spotted owl habitat or late-successional habitat and how can the sustainability of these habitats be enhanced through strategic placement of restoration treatments?
- Where are the priority roads for restoration opportunities that reduce the negative effects of roads aquatic and wildlife habitats?

The final product of this step would be a PLTA and landscape treatment options that are carried forward into project level planning *(figure 10)*. The final product of Step 6 would be a map that displays multiple, prioritized NEPA analysis areas, each with a specific landscape prescription that would be used to define the purpose and need of each area. These NEPA analysis areas would generally be less than 5,000 acres in size. This process confers huge efficiency and credibility advantages to the NEPA process. It is efficient because attention is focused on smaller, more manageable areas where treatment goals are already identified (by the landscape prescription) so the amount of front-end field time for the interdisciplinary team is reduced. The credibility corollary is that proposed actions can actually be specific as to site and treatment, thus meeting a key NEPA mandate.

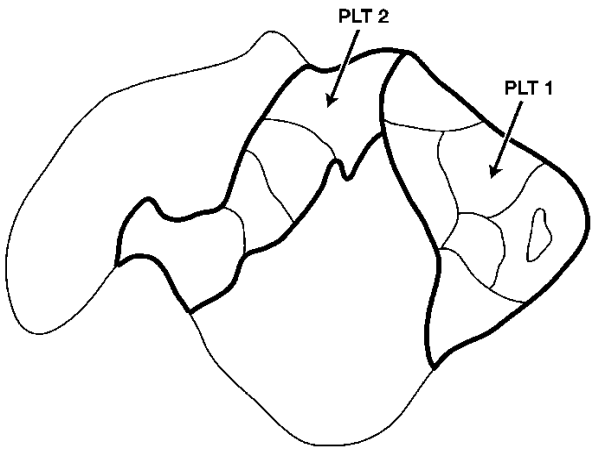


Figure 10. Potential landscape treatment areas identified from the landscape evaluation (depicted by thick-lined polygons).

HOTBOX 4
Climate Change and the Forest Restoration Strategy

Climate change has been referred to as "one of the most urgent tasks facing the Forest Service" and that "as a science-organization, we need to be aware of this information and to consider it any time we make a decision regarding resource information, technical assistance, business operations, or any other aspect of our mission" (Kimbell 2008). As a result of the importance of addressing climate change, the Okanogan-Wenatchee National Forest was involved in a Climate Change Case-Study during the fall of 2008 (Gaines et al. in prep). The results of the Case-Study highlighted management adaptations that scientists and managers identified as important to address current and predicted impacts of changing climate. Several of these suggested adaptations were brought forward and addressed in the Forest Restoration Strategy. This hotbox highlights the relevant management adaptations and displays how they are addressed in the strategy. The management adaptations are presented under headings that correspond to the sections of Part II of the strategy in which they are addressed.

HOTBOX 4
Climate Change and the Forest Restoration Strategy

Management Adaptations Relevant to the Landscape Evaluation

- Use landscape level planning to identify restoration treatment areas, the most effective locations to reduce fire flow, restore patch sizes, and sustain wildlife habitats (Finney 2004, Ager et al. 2007, Franklin et al. 2008).
- Use landscape level planning to evaluate the interaction between hydrologic regimes and infrastructure such as roads. Identify significant problem areas; areas where access is needed for treatments, recreation, etc.; and prioritize road restoration opportunities.
- Landscape planning should occur across ownerships in order to evaluate patterns, processes, and functions (Hessburg et al. 2005, Franklin et al. 2008).
- Use the range of variation (historic and future) to determine where treatments are needed, and to restore landscape pattern, functions, and processes (Hessburg et al. 2005, Gärtner et al. 2008).
- Match treatment unit sizes with desired patch sizes determined from landscape level planning (Hessburg et al. 2005).

Management Adaptations Relevant to the Road Network Evaluation

- Reduce the impacts of roads on water quality, quantity, and flow regimes (Binder et al. 2009).
- Decouple roads or remove roads to keep water on the landscape (Binder et al. 2009).
- Relocate roads and other structures that are at risk from increased peak flows (Woodsmith 2008).

Management Adaptations Relevant to the Project Development

- Use the range of variation (historic and future) to provide guide stand-level restoration of species composition, structure, and spatial pattern (Harrod et al. 1999, Franklin et al. 2008).
- Use thinning (mechanical and through prescribed fire) to reduce biomass, provide more vigorous growing conditions and reduce vulnerability to uncharacteristic wildfire and epidemic insect outbreaks (Hessburg et al. 2005, Franklin et al. 2008).
- Retain the most fire tolerant tree species and size classes commensurate with the forest type (Harrod et al. 1999, Franklin et al. 2008).
- Retain and restore old and large tree structure because they are the most difficult to replace and most resilient to disturbances (Harrod et al. 1999, Hessburg et al. 2005, Franklin et al. 2008).

Project (proposed action) Development and Assessment

In this section, a process is outlined for developing a site-specific proposed action for an individual proposed landscape treatment area that would contribute to implementing the landscape prescription and moving the landscape towards restoration. Recall that the landscape evaluation guided selection of the project/NEPA analysis area and suggested a landscape role for stands and groups of stands. Field reconnaissance is essential in order to

validate assumptions about ecological and operational feasibility and to develop a site-specific proposed action.

STEP 1--Conduct field reconnaissance and refine the landscape prescription into the purpose and need

The goal of this step is to gather information necessary to develop an integrated site-specific purpose and need.

Conduct interdisciplinary team visits to the PLTA. Confirm that the ecological and operational assumptions underlying the landscape prescription were reasonable and that the landscape prescription can be reasonably implemented.

For example, the interdisciplinary team could address the following questions: (1) do the landscape pattern evaluation results seem appropriate (e.g., insects, diseases, tree density), (2) does the fire movement map make sense, (3) are the wildlife habitats identified accurately, and (4) are the at-risk road segments mapped correctly?

Revise the landscape prescription into a purpose and need. This purpose and need would address specific management objectives including restoration. It might read like the following:

> **Example Purpose and Need:** The purpose and need of this project is to maintain and restore forest structure and species composition, commensurate with disturbance regimes, so that human communities are at less risk of fire, habitats are more resilient and sustainable, and forest resources are sustainable. A second purpose and need is to create an affordable road network that provides access for restoration treatments and recreation while reducing negative impacts to aquatic and terrestrial species.

STEP 2--Develop a site-specific proposed action

The proposed action is based on the landscape prescription developed for the PLTA. The proposed action should include quantified amounts of treatment by different treatment types that move the landscape pattern towards the restoration objectives. Once quantified, the silvicultural prescription is developed for each treatment unit or group of units, and included in the proposed action. Four key ecological features should be included in prescription development: snags, spatial patterning, old and large trees, and density of young and understory trees.

Snags

DecAID (Mellen et al. 2006) was used to update snag management recommendations for dry and mesic forests. Estimates (histograms) of the range of variation of snag densities and distributions were developed using two sources of information: Harrod et al. (1998) and inventory data for unharvested plots (including plots with no measurable snags) available in DecAID. For the analysis, a single distribution histogram was developed by

calculating weighted averages by structural stages. These estimates were used to develop desired reference conditions for snag density and distribution by size classes *(table 5).*

Table 5--Desired snag distribution reference conditions for dry and mesic forests by small and large size classes

Snag Size Class	Percent of dry forest landscape in snag density classes (number/acre)				
	0-4	**4-12**	**12-20**	**20-28**	**>28**
>10 in. dbh	82.2	13.7	2.1	1.4	0.4
	0-2	**2-6**	**6-10**	**10-14**	**>14**
>20 in. dbh	89.0	9.6	0.6	0.0	0.0
Snag Size Class	**Snags/acre by tolerance level (TL)[1]**				
	30% TL		**50% TL**		**80% TL**
10-20 in. dbh	3.4		5.0		6.8
>20 in. dbh	1.4		1.8		2.1
Snag Size Class	**Percent of mesic forest Landscape in Snag Density Classes (number/acre)**				
	0-6	**6-18**	**18-30**	**30-42**	**>42**
>10 in. dbh	70.0	18.0	4.7	4.1	2.8
	0-2	**2-6**	**6-10**	**10-14**	**>14**
>20 in. dbh	77.9	12.0	6.0	2.6	1.6
Snag Size Class	**Snags/Acre by Tolerance Level (TL)[1]**				
	30% TL		**50% TL**		**80% TL**
10-20 in. dbh	3.8		8.3		39.2
>20 in. dbh	1.2		4.6		10.7

1/ See Mellen et al. (2006) for a discussion of tolerance levels

Spatial Patterning

Pattern is a product of ecological interactions among site, vegetation, climate, disturbance, and chance (see summary of spatial patterning on pg 26 and 27). Consequently, managing for spatial pattern is complicated. There is no average condition that applies and there are few operationally simple metrics for describing these patterns. The best approach is to apply your knowledge of silvics and ecology and, with local stand reconstruction and published information, develop characterizations of pattern for your site (Appendix D provides examples of silvicultural prescriptions to achieve a desired spatial pattern).

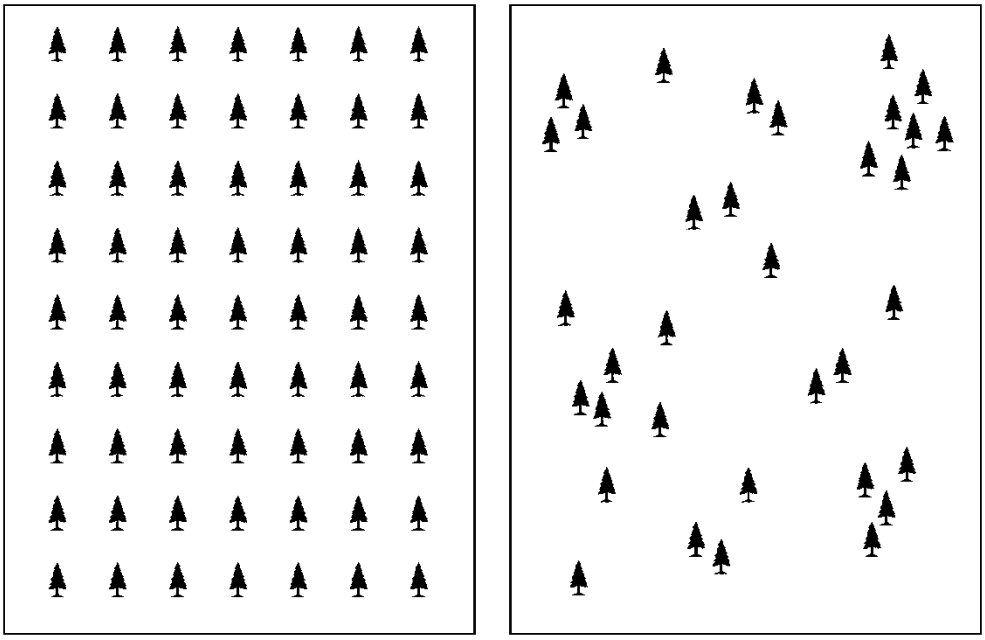
Consider these three components of horizontal pattern (*figure 11*):

1. **Clumpiness:**
   - Clump is defined as two or more trees in close enough proximity that their crowns are interlocking.
   - Clump sizes should range from about 0.01 acres to 0.5 acres (Harrod et al. 1999)
2. **Canopy gaps:** These range in size depending on fire regime *(table 6)* and occur on up to a third of the stand.

Table 6--Gap sizes by fire regime

Fire Regime	Gap description	Author
Low Severity	Median 0.6 ac Range 0.05-0.9 ac	Agee (1998) (summarizing several authors)
Mixed Severity	Mean 14 ac Median 1.5 ac Range 1.2-227 ac	Agee (1998) (summarizing several authors)

3. **Complex patches:** Complex patches are those with more structural and species complexity than the surrounding area. Patch characteristics include large snags, soft down logs, and mistletoe brooms. Utilize microsites, topography, and existing conditions to select locations to leave complex patches (for more in-depth description of complex patches see page 27). In some stands, complex patches are not present and time will be required for them to develop.



A **B**

Figure 11. Examples of stands without (A) and with (B) the desired spatial characteristics of clumps, gaps, and complex patches

Old and large trees

One of the primary objectives of the forest restoration strategy is to restore large and old tree structure (*Hot Box 5*), and consequently the various functions they provide. The guiding principle is that old trees will be retained and will be supplemented by enough of the largest, younger trees to achieve old, large tree restoration objectives *(table 7).* There is strong scientific rationale for retaining old trees, even those in close proximity to each other (*Appendix C*).

Density objectives for large trees would be based on the structure classes used during the landscape evaluation, which informed the landscape prescription and the purpose and need. Specific old and large tree objectives would vary by site condition and be explicitly described in the desired condition for the stand. Deviations from the large tree objectives in *table 7* should be based on site-specific stand reconstruction information.

Table 7--Desired conditions for large, old trees for different combinations of plant association groups and structure classes. Density objectives for large and old trees are based on stand reconstructions (Harrod et al. 1999, Youngblood et al. 2004, unpublished data on file at Okanogan-Wenatchee NF), quantitative definitions of structure classes (Hessburg et al 1999a.), and the relationship between overstory density and the establishment and growth of early seral trees (Becker and Corse 1997). A range of large and old tree densities are provided so that site-specific conditions and objectives can be used to explicitly describe their desired density for stands within the project area. Site and stand conditions, along with site-specific stand reconstructions, would be used to determine which end of the range of densities would be appropriate for a stand

Structure class	Warm/dry Plant Association Groups		Mesic Plant Association Groups	
	Minimum trees/ac over 20 in DBH	Maximum trees/ac over 20 in DBH	Minimum trees/ac over 20 in DBH	Maximum trees/ac over 20 in DBH
Stand Initiation	0	16	0	16
Stem exclusion open canopy and closed canopy	17	34	17	66
Understory reinitiation, Young forest multi-story	11	25	11	25
	Minimum trees/ac over 25 in DBH			
Old Forest multi-story and single story	18			

Density of young and understory trees

Young and understory tree density should be managed in a manner that will create or maintain the spatial pattern described above and be consistent with site and disturbance processes. Some general guidelines for each structural stage are presented below.

- **Stand initiation:** Rely on natural regeneration or planting at a lower density.
- **Stem exclusion closed canopy:** Depending on stand conditions and age use large, overstory tree restoration methods, or relative density and/or crown bulk density approaches.

- **Stem exclusion open canopy:** Depending on stand conditions and age use large, overstory tree restoration methods, or relative density and/or crown bulk density approaches.
- **Understory reinitiation:** Understory density would be limited to that growing space not allocated to the desired overstory trees.
- **Young forest multistory:** Understory density would be limited to that growing space not allocated to the desired overstory trees.
- **Old forest single story:** These stands would likely not be planted.
- **Old forest multistory:** Tree density would be as described for spotted owls or goshawks.

HOTBOX 5
Defining Old and/or Large Trees

Defining "Old" Trees in Dry Forest Ecosystems

There are four species of trees within dry forest ecosystems on the eastside that are important in terms of the development of old tree structures: ponderosa pine, western larch, Douglas-fir, and grand fir. We recommend using the guide to the identification of old trees developed by Van Pelt (2008) to define old trees for the Okanogan-Wenatchee Forest Restoration Strategy. This guide provides a rating system that relies on tree characteristics to determine the general age of the tree. The following ratings should be used to define and identify old trees:

Ponderosa pine……..Score of ≥6

Western larch……Score of ≥7

Douglas-fir……Score of ≥7

Grand fir……No Score (see below)

Defining "Large" Trees in Dry Forest Ecosystems

Several efforts have been made to define large trees for purposes of classification (Lehmkuhl et al. 1994, Hessburg et al. 1999) and to describe historical stand conditions (Harrod et al. 1999, Youngblood et al. 2004). For example, in the east-side forest health assessment, Lehmkuhl defined large trees as 20-24 inches dbh and Hessburg et al. (1999) used trees >25 inches dbh to describe large tree forest types. Harrod et al. (1999) compared the current and historic density of large trees and used trees >20 inches as a definition of large. Youngblood et al. (2004) measured overstory trees within dry forest stands that had limited human disturbances and found that the frequency of large live ponderosa pine trees generally peaked between 16-20 inches dbh.

The potential for a site to grow large trees varies. Generally, these conditions are such that large trees vary from 20-25 inches dbh. Thus we recommend the following distinction in describing large trees:

Large…….20-25 inches dbh

Very large….>25 inches dbh

Step 3: Development of a Road Prescription

- The purpose of this step is to identify restoration treatments for high-risk roads and include, where appropriate, in the proposed action. The information that identifies high-risk roads comes from the road network evaluation. The following are products that will be derived as a result of this step.
- An accurate description of all existing road prisms in the project area using accepted engineering terminology.
- An interdisciplinary, site-specific plan for treating highest risk road segments within the project area, for example, relocating a road out of a valley onto the most stable and practical upslope location. It is expected that treatments of this type will have careful deliberation and are only expected to occur in discrete locations in the project area. It is expected that funding for these types of projects will not be derived from the treatment.
- A map of existing road segments that require reconstruction and storm proofing to decouple them from the aquatic environment. Examples include outsloping, rocking, additional drainage culvert placement, and increasing the size of perennial and intermittent crossing structures. Again, costs for these activities will not necessarily be derived from the treatment.
- A map identifying priority roads for closure and, in some instances, obliteration, even when these roads are not needed to access vegetation treatments in the near future. Roads identified for closure or obliteration must have a clear link to improving the aquatic environment.

PART III: ADAPTIVE ECOSYSTEM MANAGEMENT

Adaptive management is a system of management practices based on clearly identified outcomes and monitoring to determine if management actions are meeting desired outcomes and if not, to facilitate management changes that will best ensure that outcomes are met or reevaluated. Adaptive management stems from the recognition that knowledge about natural resource systems is often uncertain (36 CFR 219.16; FSM 1905).

Adaptive management is a process that deals with complex natural resource management issues that have a high degree of uncertainty. Management proposals are treated as hypotheses for testing. Adaptive management has been used or identified within the Forest Service as an important process for managing natural resources at several levels. For example, at the national level the adaptive planning process is described in the Land Management Planning Handbook (FSH 1909.12 Chapter 20) and is a critical component of the *Forest Service Strategic Framework for Responding to Climate Change* (USFS 2008). At the regional level, the adaptive management process for the Northwest Forest Plan is described in the Record of Decision on pages E12-15. At the forest level, the *Wenatchee National Forest Late Successional Reserve Assessment* includes a chapter (Chapter IX) on monitoring and adaptive management and states: “There is a direct relationship between monitoring and the ability to carry out adaptive management. Information gained by monitoring should help to validate the appropriateness of management actions and provided insights into course corrections should they be needed”. And finally, in the *Okanogan-Wenatchee National Forest Dry Forest Strategy* (pages 22-24), the management intent includes the following statement: “management approach will be adaptive and experimental; they will learn from mistakes and repeat successes”. More recently, the Final Northern Spotted Owl Recovery Plan identifies the need to take an adaptive management approach in the implementation of the strategy for fire-prone provinces. Finally, the forest service manual (FSM 2000, Chapter 2020 Ecological Restoration and Resilience) states that “adaptive management, monitoring, and evaluation are essential to ecological restoration.”

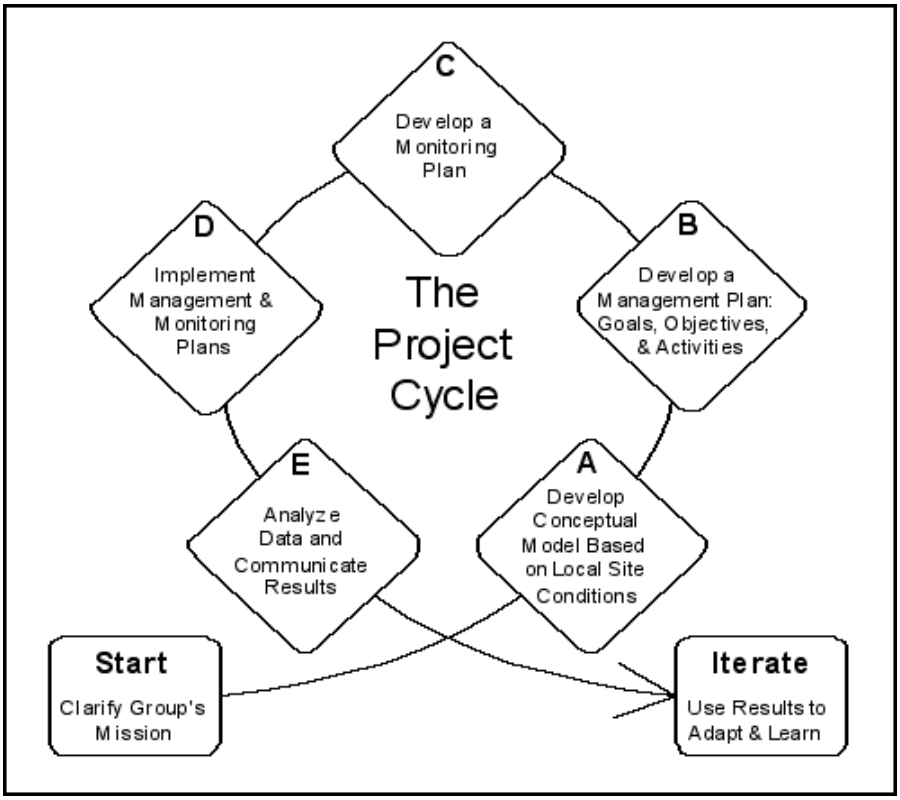


Figure 12. Adaptive ecosystem management project cycle

Clearly, there is ample direction for using an adaptive approach to ecosystem restoration, yet real and perceived barriers to implementing such an approach remain. Following are suggestions for the Okanogan-Wenatchee National Forest:

1) Develop a set of operational goals and principles that begin to institutionalize adaptive management on the Forest.

2) Complete integrated project implementation monitoring.

3) Adjust the area ecology program to provide a baseline of funding for key personnel to conduct effectiveness and validation monitoring, including developing collaborative partnerships and funding sources.

4) Devote one Forest leadership meeting per year to learning about the results of implementation, effectiveness, and validation monitoring, and making decisions that adapt restoration project planning and implementation as needed.

Operational Goals and Principles

The OWNF has developed operation goals and principles to guide the implementation of adaptive ecosystem management. Specific steps including priority monitoring items are identified later in this section.

Goals

- Create a culture that implements an adaptive approach to ecosystem management focused on ecosystem restoration.
- Be effective, efficient, and strategic in planning and implementing quality restoration projects. Project teams are performance based, held accountable by the Forest Leadership Team (FLT), and funded work is completed. Projects teams are supported by the FLT and their staff. Actions and decisions are gauged on how they help project planners and implementers meet ecosystem management goals and objectives.
- Develop and implement restoration projects that are consistent with the best science. This requires that personnel stay current with available science and collaborate often with research personnel.
- Ensure collaboration among resource experts on teams, with partners, and the public while striving to balance the social, economic, and ecological issues to sustain and manage natural resources.

Principles for the Practice of Adaptive Management

These principles describe the characteristics of individuals, projects, and organizations that contribute to effective adaptive management. They are based upon the document *Adaptive Management: A Tool for Conservation Practitioners* (Salafsky et al. 2005).

Principle 1: Do adaptive management at the District level

One of the most important principles is that the people who design and implement the project must also be involved in performing effective adaptive management.

- Involve regular project staff members in the adaptive management and monitoring plan.
- Help people learn about adaptive management.

Principle 2: Promote institutional curiosity and innovation

Effective adaptive management fundamentally requires a sense of wonder about how things work, and a willingness to try new things to see whether they are more effective.

- Survive in a changing world through innovation.
- Promote curiosity and innovation by starting with top managers.

Principle 3: Value failures

Effective adaptive management requires that we value failure instead of fearing it. A willingness to fail is thus an indicator that we are pushing ourselves to get better.

- Learn from our mistakes.

- Create a fail-safe environment.

Principle 4: Expect surprise and capitalize on crisis

Effective adaptive management requires that a project or organization both expect the unexpected and be prepared to act quickly during periods of turmoil. Often it is the strange and surprising results that will lead to new insights and understanding, but only if we are willing to look for them.

- Use surprises to point to flaws in understanding.
- Use crises as opportunities for action.

Principle 5: Encourage personal growth

Effective adaptive management requires individuals who have a commitment to personal growth and learning.

- Encourage employees to be committed to continual learning.
- Invest in helping staff develop skills and experiences.
- Recognize and reward staff that try new things.

Principle 6: Create learning organizations and partnerships

Effective adaptive management requires projects and organizations to capture the learning that individuals develop so that it can be used in the future. Since many projects are implemented through partnerships, it is also important to ensure that knowledge, skills, and information resources are shared.

- Promote organizational learning by working directly with outside partners on the majority of projects. Include these partners in as much of the ID team process as possible.
- Build teams of project partners.
- Ask outside organizations to participate in monitoring of restoration projects.

Principle 7: Contribute to global learning

Effective adaptive management requires learning at personal, organizational, and global levels. Practitioners around the world are struggling with similar problems and challenges. The key is for each project team to make the lessons it has learned available to other Forest employees.

- Encourage use of good science.
- Promote and market work in forest restoration.

Principle 8: Practice the art of adaptive management

Adaptive management is more than just science; it is also an art. Above all, constantly practice adaptive management.

- Treat adaptive management as a craft.
- Pay attention to intuition.
- Practice, practice, practice.

Important Steps to Making Adaptive Ecosystem Management Happen on the Okanogan-Wenatchee National Forest

STEP 1: Conduct Integrated Implementation Monitoring

- Adapt the existing Forest fuels review process into an integrated review process for forest restoration projects.
- Identify key items to monitor at these reviews (*Hot Box 6*) and provide these to the project interdisciplinary team ahead of time.
- Begin with two projects per year. Document results and report to all levels of the Forest with specific improvements (if needed) identified.
- Present a formal presentation to the Forest Leadership Team annually, and make decisions on needed adjustments.
- Present frequent formal results to Provincial Advisory Committee.

HOT BOX 6
Implementation and Monitoring Questions for Forest Restoration Projects

- Was a landscape evaluation completed and was it used to determine the location of the project area and to identify restoration needs?
- Was fire flow considered in the landscape analysis and used to inform treatment locations?
- Did landscape road network evaluation identify opportunities to reduce the effects of the existing road system on the environment? If so, were any opportunities integrated into project implementation?
- Was the project integrated and agreement reached by the interdisciplinary team on types and locations of treatments through on-the-ground field verification?
- Did project treatments move stands towards the desired landscape prescriptions?
- Did the project restore the hydrological function and enhance habitat effectiveness for wildlife?
- Were large and/or old trees and snags protected, or will they be restored?
- Was the desired within -stand spatial variability achieved?
- What worked and what needs to be adapted for next time?

STEP 2: Effectiveness and Validation Monitoring

This level of monitoring is more intense and can be more expensive. It will require partnerships to implement and needs a base level of funding in order to provide resources to work with partners and develop funding proposals.

- Use the area ecology program as a source of funds and a program that can provide expertise on monitoring study design and implementation. For this to happen, the area ecology team will need to coordinate with the Okanogan-Wenatchee Forest

Supervisor, Colville Forest Supervisor, key forest staff, and Regional Office staff to re-orient the program, develop a charter, and identify key personnel and responsibilities.

- Some of the responsibilities of the personnel involved in the area ecology program would include developing and maintaining partnerships with universities, other resource agencies, NGOs, and Forest Service research labs. These partnerships will be vital to obtaining the needed funding and quality of monitoring. In addition, some important resource information needed for the landscape and project level assessments would be developed and kept up-to-date by this group.
- Maintain annual meetings between Forest personnel and the Wenatchee Forestry Sciences Lab. These meetings provide opportunities to hear what is happening with the latest monitoring and research, and to identify future needs and collaboration.
- The results of any effectiveness or validation monitoring should be presented to the annual Forest leadership team's adaptive management meeting along with implementation monitoring results.
- Present a formal presentation to the Forest Leadership Team annually, and make decisions on needed adjustments.
- Present frequent formal results to Provincial Advisory Committee.

HOT BOX 7
Effectiveness and validation monitoring questions relative to forest restoration

- Determine the effectiveness of strategically placed restoration treatments to reduce severe fire and sustain other resource values.
- Monitor the effectiveness of the east-side spotted owl habitat strategy to provide for northern spotted owl recovery objectives.
- Determine the effectiveness of restoration treatments to provide source habitats for focal wildlife species such as the white-headed woodpecker.
- Monitor the effects of prescribed fire treatments on the mortality of large and old trees.
- Monitor the effects of restoration treatments on retention and recruitment of snags and downed wood.
- Monitor the effects of restoration treatments within riparian reserves/RHCAs.

STEP 3: Annual Forest Leadership Meeting to Adapt Forest Restoration Project Planning and Implementation

- Conduct one FLT meeting per year with the express purpose of reviewing results of the implementation, effectiveness, and validation monitoring.
- Decisions should be made on how to adapt forest restoration planning and implementation based on outcomes of the monitoring.

- At this meeting the FLT should clearly identify the parties accountable for making the decisions happen on the ground.

LITERATURE CITATIONS

Abella, S.R.; Covington, W.W. 2004. Monitoring an Arizona ponderosa pine restoration: sampling efficiency and multivariate analysis of understory vegetation. Restoration Ecology 12: 359–367.

Agee, J.K. 1988. Successional dynamics in forest riparian zones. In Raedeke, K. (ed.), Streamside Management: Riparian, wildlife, and forestry interactions. Institute of Forest Resources, Contribution 59, University of Washington, Seattle, WA, pp 31-44.

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Washington, DC: Island Press. 493 p.

Agee, J.K. 2003. Historical range of variability in eastern Cascades forest, Washington, USA. Landscape Ecology. 18(8): 725-740.

Agee, J.K.; Lehmkuhl, J.L. 2009. Dry forests of northeastern Cascades fire and fire surrogate site, Mission Creek, Okanogan-Wenatchee National Forest USDA Forest Service, Research Paper PNW-RP-577, Portland, Oregon.

Agee, J.K.; Lolley, M.R. 2006. Thinning and prescribed fire effects on fuels and potential fire behavior in an eastern Cascades forest, Washington, USA. Fire Ecology. 2(2): 142-158.

Ager, A.A.; Finney, M.A.; Kerns, B.K.; Maffei, H. 2007. Modeling wildfire risk to northern spotted owl (*Strix occidentalis caurina*) habitat in central Oregon, USA. Forest Ecology and Management 246: 45-56.

Allen, C.D.; Savage, M.; Falk, D.A.; Suckling, K.F.; Swetnam, T.W.; Schulke, T.; Stacey, P.B.; Morgan, P.; Hoffman, M.; Klingel, J.T. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective. Ecological Applications 12: 1418–1433.

Anthony, R.G.; Forsman, E.D.; Franklin, A.B. [et al.]. 2006. Status and trends in demography of northern spotted owls, 1985-2003. Wildlife Monograph No. 163.

Bachelet, D.; Neilson, R.P.; Lenihan, J.M.; Drapek, R.J. 2001. Climate change effects on vegetation distribution and carbon budget in the United States. Ecosystems 4: 164-185.

Bassman, J. H. 2000. Process affecting carbon balance in relation to global climate change. Prepared for Natural Resource Institute, May 2000, Washington State University, Pullman, WA.

Battin, J.; Wiley, M.W.; Ruckelshaus, M.H.; Palmer, R.N.; Korb, E.; Bartz, K.K; Imaki, H. 2007. Projected impacts of climate change on salmon habitat restoration. Proceedings of the National Academy of Science. 10.1073/pnas.0701685104.

Beche, L.A.; Stephen, S.L.; Resh, V.H. 2005. Effects of prescribed fire on a Sierra Nevada (California, USA) stream and its riparian zone. Forest Ecology and Management. 218(1-3): 37-59.

Becker, Rolan R.; Corse, Thomas S. 1997. The Flathead Indian Reservation: resetting the clock with uneven-aged management. Journal of Forestry, Vol. 95, No. 11, (Nov. 1997), pgs. 29-32

Benda, L.; Miller, D.; Bigelow, P.; Andrus, K. 2003. Effects of post-wildfire erosion on channel environments, Boise River, Idaho. Forest Ecology and Management, 178(1-2):105–119.

Benda, L.E.; Sias, J.C. 2003. A quantitative framework for evaluating the mass balance of in-stream organic debris. Forest Ecology and Management, 172(1):1-16.

Bisson, P. 2008. Salmon and trout in the Pacific Northwest and climate change. (June 16, 2008). U.S. Department of Agriculture, Forest Service, Climate Change Resource Center. http://www.fs.fed.us/ccrc/topics/salmon-trout.shtml

Bisson, P.A.; Rieman, B.E.; Luce, C.; Hessburg, P.F.; Lee, D.C.; Kershner, J.L.; Reeves, G.H.; Gresswell, R.E. 2003. Fire and aquatic ecosystems of the western USA: current knowledge and key questions. Forest Ecology and Management, 178(1-2):213-229.

Boisvenue, C.; Running, S.W. 2006. Impacts of climate change on natural forest productivity: evidence since the middle of the 20th century. Global Change Biology. Vol. 12, No. 5 (May 2006): p. 862-882.

Bridgham, S.D.; Megonigal, J.P.; Keller, J.K.; Bliss, N.B.; Trettin, C. 2006. The carbon balance of North American wetlands. Wetlands, Vol. 26, No. 4 (Dec. 2006), pgs. 889-916.

Brown, R.T.; Agee, J.K.; Flanklin, J.F. 2004. Forest restoration and fire: principles in the context of place. Conservation Biology. 18(4): 903-912.

Bull, E.L.; Parks, C.G.; Torgerson, T.R. 1997. Trees and logs important to wildlife in the interior Columbia River basin. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. PNW-GTR-391.

Bull, E.L.; Heater, T.W.; Shepherd, J.F. 2005. Habitat selection by American marten in northeastern Oregon. Northwest Science 79: 37-43.

Camp, A.E.; Hessburg, P.F.; Everett, R.L. 1996. Dynamically incorporating late-successional forest in sustainable landscapes. In: Hardy, C., Arno, S. (Eds.), The Use of Fire in Forest Restoration, INT_GTR-341. USDA, Forest Service, Intermountain Research Station, Ogden, UT, pp. 20-24.

Camp, A.E.; Oliver, C.; Hessburg, P.F.; Everett, R.L. 1997. Predicting late-successional fire refugia pre-dating European settlement in the Wenatchee Mountains. Forest Ecology and Management 95; 63-77.

Christensen, N.L.; Bartuska, A.M.; Brown, J.H. [and others]. 1996. The report of the Ecological Society of America committee on the scientific basis for ecosystem management. Ecological Applications. 6(3): 665-691.

Cochran, P.H. 1992. Stocking levels and underlying assumptions for uneven-aged ponderosa pine stands. U.S. Forest Service Research Note PNW. (509): 1-10.

Collins, B.M.; Moghaddas, J.J.; Stephens, S.L. 2007. Initial changes in forest structure and understory plant communities following fuel reduction activities in a Sierra Nevada mixed conifer forest. Forest Ecology and Management 239: 102-111.

Collins, B.M., Stephens, S.L.; Moghaddas, J.J.; Battles, J. 2010. Challenges and approaches in planning fuel treatments across fire-excluded forested landscapes. Journal of Forestry, January/February 24-31.

Cook, J.G.; Quinlin, L.J.; Irwin, L.L.; Bryant, L.D.; Riggs, R.A.; Thomas, J.W. 1996. Nutrition-growth relations of elk calves during late summer and fall. Journal of Wildlife Management. 60: 528-541.

Cook, J.G.; Irwin, L.L.; Bryant, L.D.; Riggs, R.A.; Thomas, J.W. 1998. Relations of forest cover and condition of elk: a test of the thermal cover hypothesis in summer and winter. Wildlife Monograph No. 141.

Cooper, C.F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. Ecological Monographs 30(2): 129-164.

Courtney, S.P.; Carey, A.B.; Cody, M.L.; Engel, K. [et al.]. 2008. Scientific review of the draft northern spotted owl recovery plan and reviewer comments. Sustainable Ecosystems Institute, Portland, Oregon.

Covington, W.W.; Fult, P.Z.; Moore, M.M.; Hart, S.C.; Kolb, T.E.; Mast, J.N.; Wagner, M.R.; Sackett, S.S. 1997. Restoration of ecosystem health in southwestern ponderosa pine forest. Bulletin of the Ecological Society of America. 78(4 SUPPL.): 73

Crist, M.R.; DeLuca, T.H.; Wilmer, B.; Aplet, G.H. 2009. Restoration of low- elevation dry forests of the Northern Rocky Mountains: a holistic approach. Washington, D.C.: The Wilderness Society.

Crozier, L.; Zabel, R.W.; Hamlet, A.F. 2008. Predicting differential effects of climate change at the population level with life-cycle models of spring Chinook salmon. Global Change Biology 14: 236-249.

Curtis, R.O. 1970. Stand density measures: an interpretation. Forest Science. Vol. 16, No. 4. 12 p.

Dale, V.H.; Joyce, L.A.; McNulty, S. [et al.]. 2001. Climate change and forest disturbances. Bioscience. 51(9): 723-734.

Davis, R.; Lint, J. 2005. Chapter 3: Habitat status and trend. Northwest Forest Plan-the first 10 years (1994-2003): Status and trends of northern spotted owl populations and habitat. J. Lint, tech. coor. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. PNW-GTR-648.

Dodson, E.K.; Metlen, K.L.; Fiedler, C.E. 2007. Common and uncommon understory species differentially respond to restoration treatments in ponderosa pine/Douglas-fir forests, Montana. Restoration Ecology 15: 692–704.

Dodson, E.K.; Peterson, D.W.; Harrod, R.J. 2008. Understory vegetation response to thinning and burning restoration treatments in dry conifer forests of the eastern Cascades, USA. Forest Ecology and Management 255:3130-3140.

Dolph, L.K; Mori, R.S.; Oliver, W.W. 1995. Long-term response of old-growth stands to varying levels of partial cutting in the eastside pine type. Western Journal of Applied Forestry. 10(3): 101-108.

Dunham, J.B.; Young, M.K.; Gresswell, R.E.; Rieman, B.E. 2003. Effects of fire on fish populations: landscape perspectives on persistence of native fishes and non-native fish invasions. Forest Ecology and Management 178(1-2):183-196.

Dwire, K.A.; Kauffman, J.B. 2003. Fire and riparian ecosystems in landscapes of the western USA. Forest Ecology and Management 178: 61-74.

Everett, R.; Baumgarther, D.; Ohlson, P.; Schellhaas, R. 2008. Structural classes and age structure in 1860 and 1940 reconstructed fir-pine stands of eastern Washington. Western North American Naturalist. 68(3): 278-290.

Everett, R.; Baumgarther, D.; Ohlson, P.; Schellhaas, R.; Harrod, R. 2007. Development of current stand structure in dry fir-pine forest of eastern Washington. Journal of the Torrey Botanical Society.134(3): 199-214.

Everett, R.; Lehmkuhl, J.; Schellhaas, R.; Ohlson, P.; Keenum, D.; Riesterer, H.; Spurbeck, D. 1999. Snag dynamics in a chronosequence of 26 wildfires on the east slope of the Cascade Range in Washington State, USA. International Journal of Wildland Fire 9(4):223-234.

Everett, R.; Schellhaas, R.; Keenum, D.; Spurbeck, D.;Ohlson, P. 2000. Fire history in the ponderosa pine/Douglas fir forest on the east slope of the Washington Cascades. Forest Ecology and Management. 129(1-3): 207-225.

Everett, R.; Schellhaas, R.; Ohlson, P.; Spurbeck, D.; Keenum, D. 2003. Continuity in fire disturbance between riparian and adjacent sideslope Douglas-fir forests. Forest Ecology and Management. 175: 31-47.

Fenn, M.E. 2006. The effects of nitrogen deposition, ambient ozone, and climate change on forests in the Western U.S., pgs. 2-8. IN: Aguirre-Bravo, C.; Pellicane, Patrick J.; Burns, Denver P.; and Draggan, Sidney, Eds. 2006. Monitoring Science and Technology Symposium: Unifying Knowledge for Sustainability in the Western Hemisphere. 2004 September 20-24; Denver, CO. Proceedings RMRS-P-42CD. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Fort Collins, CO: 990 p.

Finney, M.A. 2001. Design of regular landscape fuel treatment patterns for modifying fire growth and behavior. Forest Science 47: 219-228.

Finney, M.A.; McHugh, C.W.; Grenfell, I.C. 2005. Stand and landscape-level effects of prescribed burning on two Arizona wildfires. Canadian Journal of Forest Research 35: 1714-1722.

Finney, M.A.; Seli, R.C.; McHugh, C.W.; Ager, A.A.; Bahro, B.; Agee. J.K. 2007. Simulation of long-term landscape-level fuel treatment effects on large wildfires. International Journal of Wildland Fire, 16, 712–727.

Franklin, J.F.; Perry, D.A.; Schowalter, T.D.; Harmon, M.E.; McKee, A.; Spies, T.A. 1989. Chapter 6: Importance of ecological diversity in maintaining long-term site productivity, pgs. 82 – 97. In: Perry, D.A.; Meurisse, R.; Thomas, B.; Miller, R.; Boyle, J.;

Means, J.; Perry, C.R.; and Powers, R.F., eds. 1989. Maintaining the long-term productivity of Pacific Northwest forest ecosystems. Timber Press, Portland, OR. 256p.

Franklin, J.F.; Swanson, F.J.; Harmon, M.E. [and others]. 1991. Effects of global climatic change on forests in northwestern North America. The Northwest Environmental Journal. 7:233-254.

Franklin, J.F.; Mitchell, R.J.; Palik, B.J. 2007. Natural disturbance and stand development principles for ecological forestry. General Technical Report NRS-19. U.S. Department of Agriculture, Forest Service, Northern Research Station, Newton Square, PA. 44p.

Franklin, J.F.; Hemstrom, M.A.; Van Pelt, R.; Buchanan. J.B. 2008. The case for active management of dry forest types in eastern Washington: Perpetuating and creating old forest structures and functions. Washington State Department of Natural Resources, Olympia, WA.

Fulé, P.Z.; Covington, W.W.; Moore, M.M. 1997. Determining reference conditions for ecosystem management of southwestern ponderosa pine forests. Ecological Applications. 7(3): 895-908.

Gaines, W.L.; Haggard, M.; Begley, J.; Lehmkuhl, J.F.; Lyons, A.L. 2010. Short-term effects of thinning and burning restoration treatments on avian community composition, density and nest survival in the eastern Cascades dry forests, Washington. Forest Science 56(1): 88-99.

Gaines, W.L.; Haggard, M.; Lehmkuhl, J.F.; Lyons, A.L.; Harrod, R.J. 2007. Short-term response of land birds to ponderosa pine restoration. Restoration Ecology 15(4): 670-678.

Gaines, W.L.; Lyons, A.L.; Lehmkuhl, J.F.; Haggard, M.; Begley, J.S.; Farrell, M. 2009. Chapter 8: Avian community composition, nesting ecology, and cavity-nester foraging ecology. Pages 109-142 in Agee, J.K., and J.F. Lehmkuhl (compilers). Dry Forests of the Northeastern Cascades Fire and Fire Surrogate Project Site, Mission Creek, Okanogan-Wenatchee National Forest. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. PNW-RP-577.

Gaines, W.L.; Lyons, A.L.; Sprague, A. 2005. Predicting the occurrence of a rare mollusk in the dry forests of north-central Washington. Northwest Science 79(2&3): 99-105.

Gaines, W.L.; Singleton, P.H.; Ross, R.C. 2003. Assessing the cumulative effects of linear recreation routes on wildlife habitats on the Okanogan and Wenatchee National Forests. U.S. Department of Agriculture, Forest Service, PNW-GTR-586.

GAO. 2007. Climate change: agencies should develop guidance for addressing the effects on federal land and water resources. GAO-07-863, U.S. Government Accountability Office, Washington, D.C. 180p.

Gärtner, S.; Reynolds, K.M.; Hessburg, P.F.; Hummel, S.; Twery, M. 2008. Decision support for evaluating landscape departure and prioritizing forest management activities in a changing environment. Forest Ecology and Management. 256: 1666-1676.

Gildar, C.N.; Fulé, P.Z.; Covington, W.W. 2004. Plant community variability in ponderosa pine forest has implications for reference conditions. Natural Areas Journal 24: 101–111.

Grace, J.M.; Clinton, B.D. 2007. Protecting soil and water in forest road management. Trans. ASABE, 50 (5): 1579-1584.

Graham, R.T.; Jain, T.B.; Sandquist, J. 2007. Free selection: a silvicultural option, pgs. 121-156. In: Powers, Robert F., tech. ed. 2007. Restoring fire-adapted ecosystems: proceedings of the 2005 national silviculture workshop. General Technical Report PSW-GTR-203. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA. 306p.

Gray, S.T.; Betancourt, J.L.; Jackson, S.T.; Eddy, R.G. 2006. Role of multidecadal climate variability in a range extension of pinyon pine. Ecology. Vol. 87, No. 5 (May 2006): p. 1124-1130.

Gresswell, R.E. 1999. Fire and aquatic ecosystems in forested biomes of North America. Transactions of the American Fisheries Society. 128:193-221.

Gucinski, H. 2006. Terrestrial and aquatic natural ecosystems: potential responses to global climate change, pgs. 41-66. In: Joyce, Linda; Haynes, Richard; White, Rachel; Barbour, R. James, tech. coords. 2006. Bringing climate change into natural resource management: proceedings. General Technical Report PNW-GTR-706. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. 150 p.

Gucinski H.; Furniss, M.J.; Ziemer, R.R.; Brookes, M.H., eds. 2001. Forest roads: a synthesis of scientific information. General Technical Report, PNW-GTR-509. Portland OR: Pacific Northwest Research Station, U.S. Department of Agriculture, Forest Service.

Haggard, M.; Gaines, W.L. 2001. Effects of stand-replacement fire and salvage logging on a cavity-nesting community in eastern Cascades, Washington. Northwest Science 75(4):387-396.

Halofsky, J.E.; Hibbs, D.E. 2008. Determinants of riparian fire severity in two Oregon fires, USA. Can. J. For. Res. 38: 1959-1973.

Harrod, R.J. 2001. The effect of invasive and noxious plants on land management in eastern Oregon and Washington. Northwest Science 75(special issue):85-90.

Harrod, R.J.; Fonda, R.W.; McGrath, M.K. 2007a. Role of fire in restoration of a ponderosa pine forest, Washington. In: B.W. Butler and W. Cook (comp.) The fire environment—innovations, management, and policy; conference proceedings. 26-30 March 2007; Destin, FL. Proceedings RMRS-P-46. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. CD-ROM.

Harrod, R.J.; Fonda, R.W.; McGrath, M.K. 2008b. Vegetation response to thinning and burning in a ponderosa pine forest, Washington. Northwest Science. 82(2): 141-150.

Harrod, R.J.; Gaines,W.L.; Hartl,W.E.; Camp, A.E. 1998. Estimating historic snag density in dry forests east of the Cascade Range. PNW-GTR-428. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, Or. 16p.

Harrod, R.J.; Gaines, W.L.; Taylor, R.J.; Everett,R.; Lillybridge, T.; McIver, J.D. 1996. Biodiversity in the Blue Mountains. In: Quigley, T.; Jaindl, R., eds. Search for a Solution - sustaining the land, people and economy of the Blue Mountains. American Forests, Publ. Co. pp. 81-105.

Harrod, R.J.; McRae, B.H.; Hartl, W.E. 1999. Historical stand reconstruction in ponderosa pine forests to guide silvicultural prescriptions. Forest Ecology and Management. 114: 433-446.

Harrod, R.J.; Reichard, S. 2001. Fire and invasive species within the temperate and boreal coniferous forests of western North America. Tall Timbers Research Station Miscellaneous Publication No. 11: 95-101.

Harrod, R.J.; Peterson, D.W.; Ottmar, R. 2008. Effects of mechanically generated slash particle size on prescribed fire behavior and subsequent vegetation effects. Final Report to the Joint fire Science Program, Project Number 03-3-2-06.

Harrod, R.J.; Peterson, D.W.; Povak, N.A.; Dodson, E.K. 2009. Thinning and prescribed fire effects on overstory tree and snag structure in dry coniferous forest of the interior Pacific Northwest. Forest Ecology and Management. 258(5): 712-721.

Harrod, R.J.; Peterson, D.W.; Povak, N.A.; Dodson, E.K. Unpubl. Report. Thinning and prescribed fire effects on overstory tree and snag structure in dry coniferous forests of the interior Pacific Northwest.

Harrod, R.J.; Povak, N.A.; Peterson, D.W. 2007. Comparing the effectiveness of thinning and prescribed fire for modifying structure in dry coniferous forests. In: Butler, B.W.; Cook, W. (comp.) The fire environment—innovations, management, and policy; conference proceedings. 26-30 March 2007; Destin, FL. Proceedings RMRS-P-46. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. CD-ROM.

Hessburg, P.F.; Mitchell, R.G; Filip, G.M. 1994. Historical and current roles of insects and pathogens in eastern Oregon and Washington forested landscapes. . Gen. Tech. Rpt. PNW-GTR-327. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Hessburg, P.F.; Agee, J.K. 2003. An environmental narrative of Inland Northwest United States forest, 1800-2000. Forest Ecology and Management. 178 (1-2): 23-59.

Hessburg, P.F.; Agee, J.K; Franklin, J.F. 2005. Dry forests and wildland fires of the inland Northwest, USA: Contrasting the landscape ecology of the pre-settlement and modern eras. Forest Ecology and Management. 2-11 (1-2, Sp. Iss. SI): 117-139.

Hessburg, P.F.; Reynolds, K.M.; Salter, R.B.; Richmond, M.B. 2004. Using a decision support system to estimate departure of present forest landscape pattern from historical reference condition. Pages 158-175 in Perera, A.H., L.J. Buse, and M.G. Weber. Emulating Natural Forest Landscape Disturbances. Columbia University Press, New York.

Hessburg, P.F.; Smith, B.G.; Kreiter, S.D. [et al.]. 1999. Historical and current forest and range landscapes in the interior Columbia River basin and portions of the Klamath and Great Basins. Part 1: linking vegetation patterns and landscape vulnerability to potential insect and pathogen disturbances. Gen. Tech. Rpt. PNW-GTR-458. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Hessburg, P.H.; Smith, B.G.; Miller, C.A.; Kreiter, S.D.; Salter, R.B. 1999. Modeling change in potential landscape vulnerability to forest insect and pathogen disturbances: Methods for forested subwatersheds sampled in the midscale interior Columbia River

Basin assessment. Gen. Tech. Rep. PNW-GTR-454. Portland, OR.: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 56 p.

Hessburg, P.F.; Smith, B.G.; Salter, R.B. [et al.]. 2000. Recent changes (1930s-1990s) in spatial patterns of interior northwest forests, USA. Forest Ecology and Management. 136: 53-83.

Higgs, E.S. 1997. What is good ecological restoration? Conservation Biology. 11(2): 338-348.

Independent Scientific Advisory Board [ISAB]. 2007. Climate change impacts on Columbia River Basin fish and wildlife. Northwest Power and Conservation Council. ISAB 2007-2. http://www.nwcouncil.org/library/isab/ISAB%202007-2%20Climate%20Change.pdf

Keeton, W.S., P.W. Mote, J.F. Franklin, T. Austin, and G.K. Roger. 2007. Climate variability, climate change, and western wildfire with implications for urban-wildland interface. Advances in Economics and Environmental Resources. 6:225-253.

Kenna, J.G.; Robinson, Jr., G.R.; Pell, B.; Thompson, M.A.; McNeel, J. 1999. Ecosystem restoration: a manager's perspective. Pages 619-676 *In*: Szaro, R.C., N.C. Johnson, W.T. Sexton, A.J. Malk (eds.) Ecological stewardship: a common reference for ecosystem management. Elsevier Science, Oxford, UK.

Kennedy, M.C.; Ford, E.D.; Singleton, P.; Finney, M.; Agee, J.K. 2008. Informed multi-objective decision-making on environmental management using parento optimality. Journal of Applied Ecology. 45: 181-192.

Kliejunas, J. T.; Geils, B.W.; Glaeser, J.M.; Goheen, E.M.; Hennon, P.; Kim, M.; Kope, H.; Stone, J.; Sturrock, R.; Frankel, S.J. 2009. Review of literature on climate change and forest diseases of western North America. Gen.Tech. Rep. PSW-GTR-225. Albany, CA; U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 54 p

Knapp, E.E.; Schwilk, D.W.; Kane, J.M.; Keeley, J.E. 2007. Role of burning season on initial understory response to prescribed fire in a mixed conifer forest. Canadian Journal of Forest Research 37: 11–22.

Kulakowski, D.; Veblen, T.T. 2006. Historical range of variability for forest vegetation of the Grand Mesa National Forest, Colorado. Final Report: U.S. Department of Agriculture, Forest Service Agreement No. 1102-001-99-033 with the University of Colorado, Boulder. 84p.

Lake, P.S. 2000. Disturbance, patchiness, and diversity in streams. J. N. Am. Benthol. Soc., 2000, 19(4):573-592

Landres, P.; Morgan P.; Swanson F. 1999. Overview of the use of natural variability in managing ecological systems. Ecological Applications. 9: 1279-1288.

Latham, P.; Tappeiner, J. 2002. Response of old-growth conifers to reduction in stand density in western Oregon forest. Tree Physiology. 22(2-3): 137-146.

Lehmkuhl, J.F. 2009. Chapter 9: Small mammals. Pages 143-157 in Agee, J.K., and J.F. Lehmkuhl (compilers). Dry Forests of the Northeastern Cascades Fire and Fire Surrogate

Project Site, Mission Creek, Okanogan-Wenatchee National Forest. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. PNW-RP-577.

Lehmkuhl, J.F.; Hessburg, P.F.; Everett, R.L.; Huff, M.H.; Ottmar, R.D. 1994. Historical and current forest landscapes of eastern Oregon and Washington: part l. vegetation pattern and insect and disease hazards. U.S. Forest Service General Technical Report PNW. 0(328): l-lll, 1-888

Lehmkuhl, J.F.; Everett, R.L.; Schellhaas, R. [et al.]. 2003. Cavities in snags along a wildfire chronosequence in eastern Washington. Journal of Wildlife Management 67(1): 219-228.

Lehmkuhl, J.F.; Gould, L.E.; Cazares, E.; Hosford, D.R. 2004. Truffle abundance and mycophagy by northern flying squirrels in eastern Washington forest. Forest Ecology and Management. 200(1-3): 49-65.

Lehmkuhl, J.F.; Kistler, K.D.; Begley, J.S.; Boulanger, J. 2006a. Demography of northern flying squirrels informs ecosystem management of western interior forests. Ecological Applications 16(2): 584-600.

Lehmkuhl, J.F.; Kistler, K.D.; Begley, J.S. 2006b. Bushy-tailed woodrat abundance in dry forests of eastern Washington. Journal of Mammalogy 87(2): 371-379.

Lehmkuhl, J.F.; Burger, E.D.; Drew, E.K.; Lindsey, J.P.; Haggard, M.; Woodruff, K.Z. 2007a. Breeding birds in riparian and upland dry forests of the Cascade Range. Journal of Wildlife Management 71(8): 2632-2643.

Lehmkuhl, J.F.; Kennedy, M.; Ford, E.D.; Singleton, P.H.; Gaines, W.L.; Lind, R.L. 2007b. Seeing the forest for the fuels: Integrating ecological values and fuel management. Forest Ecology and Management 246: 73-80.

Lehmkuhl, J.F.; Peffer, R.D.; O'Connell, M.A. 2008. Riparian and upland small mammals on the east slope of the Cascade Range, Washington. Northwest Science 82(2): 94-106.

Lensing, J.R.; Wise, D.H. 2006. Predicted climate change alters the indirect effect of predators on an ecosystem process. Proceedings of the National Academy of Sciences of the United States of America. Vol. 103, No. 42 (Oct. 17, 2006): p. 15502-15505.

Lenoir, J.; Gegout, J.C.; Marquet, P.A.; de Raffray, P.; Brisse, H. 2008. A significant upward shift in plant species optimum elevation during the 20th century. Science Vol. 320 No. 5884 (2008), pgs. 1768-1771.

Lichatowich, J. 1999. Salmon without rivers. Washington DC: Island Press.

Lillybridge, T.R.; Kovalchik, B.L.; Williams, C.K.; Smith, B.G. 1995. Field guide for forested plant associations of the Wenatchee National Forest. Gen. Tech. Rep. PNW-GTR-359. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 335 p. In cooperation with: Pacific Northwest Region, Wenatchee National Forest.

Lint, J. 2005. Chapter 2: Population status and trend. Northwest Forest Plan-the first 10 years (1994-2003): Status and trends of northern spotted owl populations and habitat. J. Lint, tech. coor. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. PNW-GTR-648.

Littell, et al. 2009. See climate document

Loewen, M. 2009. Green tree retention and down debris recruitment recommendations, Colville and Okanogan-Wenatchee National Forests. 49 p. Unpublished report. On file with: Okanogan-Wenatchee National Forest, 215 Melody Lane, Wenatchee, WA 98801

Logan, J.A.; Régnière, J.; Powell, J.A. 2003. Assessing the impacts of global warming on forest pest dynamics. Frontiers in Ecological Environment 1(3), (2003) pgs. 130-137.

Long, J.N. 1985. A practical approach to density management. The Forestry Chronicle. February: 23-27

Lucash, M.S.; Farnsworth, B.; Winner, W.E. 2005. Response of sagebrush steppe species to elevated CO_2 and soil temperature. Western North American Naturalist, Vol. 154, No.1 (July 2005), pgs. 80-86.

Luce, A.; Crowe, M. 2001. Invertebrate terrestrial diversity along a gravel road on Barrie Island, Ontario, Canada. Great Lakes Entomologist. 34(1): 55-60.

Luce, C.H.; Rieman, B.E. 2005. Landscape scale effects of fuel management or fire on water resources: the future of cumulative effects analysis*?* Paper presented at the Symposium on Mixed Severity Fire Regimes: Ecology and Management; Spokane, WA; November 15-19, 2004.

Lugo, A.E.; Baron, J.S.; Frost, T.P. [et al.]. 1999. Ecosystem processes and functioning. In: Szaro, R.C.; Johnson, N.C.; Sexton, W.T.; Malk, A.J. (eds.). Ecological stewardship: a common reference for ecosystem management, Vol. II. Elsevier Science, Oxford, UK. Pp. 219-254.

Lyons, A.L.; Gaines, W.L.; Lehmkuhl, J.F.; Harrod, R.J. 2008. Short-term effects of fire and fire surrogate treatments on foraging tree selection by cavity-nesting birds in dry forests of central Washington. Forest Ecology and Management 255: 3203-3211.

Malcolm, J.R.; Liu, C.; Neilson, R.P.; Hansen, L.; and Hannah, L. 2006. Global warming and extinctions of endemic species from biodiversity hotspots. Conservation Biology, Vol. 20, No. 2 (2006), pgs. 538-548.

McDowell, N.; Brooks, J.R.; Fitzgerald, S.A.; Bond, B.J. 2003. Carbon isotope discrimination and growth response of old *Pinus ponderosa* trees to stand density reductions. Plant Cell and Environment. 26(4): 631-644.

McGarigal, K.; Marks, B.J. 1995. FRAGSTATS: Spatial pattern analysis program for quantifying landscape structure. U.S. Forest Service General technical Report PNW. 0(351): I-IV, 1-122.

McKenzie, D.; Gedalof, Z.E.; Peterson, D.L.; Mote, P. 2004. Climatic change, wildfire, and conservation. Conservation Biology 18: 890-902.

Mellen et al. 2006. DecAID (from snag section)

Metlen, K.L.; Fiedler, C.E.; Youngblood, A. 2004. Understory responses to fuel reduction treatments in the Blue Mountains of northeastern Oregon. Northwest Science 78: 175–185

Metlen, K.L.; Fiedler, C.E. 2006. Restoration treatment effects on the understory of ponderosa pine/Douglas-fir forests in western Montana, USA. Forest Ecology and Management 222: 355–369.

Millar, C.; Woolfenden, W.B. 1999. The role of climate change in interpreting historical variability. Ecological Applications. 9(4): 1207-1216.

Minshall, G.W.; Robinson, C.T.; Lawrence, D.E. 1997. Postfire responses of lotic ecosystems in Yellowstone National Park, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences. 54(11): 2509-2525.

Monserud, R.A.; Tchebakova, N.M.; Leemans, R. 1993. Global vegetation change predicted by the modified Budyko model. Climatic Change, 25: pgs. 59-83.

Moore, M.M.; Covington, W.W.; Fulé, P.Z. 1999. Reference conditions and ecological restoration: a southwestern ponderosa pine perspective. Ecological Applications. 9(4): 1266-1277.

Moore, M.M.; Casey, C.A.; Bakker, J.D.; Springer, J.D.; Fule´, P.Z.; Covington, W.W.; Laughlin, D.C. 2006. Herbaceous vegetation responses (1992–2004) to restoration treatments in a ponderosa pine forest. Rangeland Ecology and Management 59: 135–144.

Morgan, P.L.; Aplet, G.H.; Haufler, J.B. [et al.]. 1994. Historical range of variability: a useful tool for evaluating ecosystem change. In: Sampson, R.N.; Adams, D.L., eds. Assessing forest ecosystem health in the inland west. Haworth Press, New York. Pp. 87-111.

Mote, P.W., Parson, E.A.; Hamlet, A.F.; Keeton, W.S.; Lettenmaier, D.; Mantua, N.; Miles, E.L.; Peterson, D.W.; Slaughter, R.; Snover, A.K. 2003. Preparing for climatic change: the water, salmon and forests of the Pacific Northwest. Climatic Change 61: 45-88.

Munzing, D.; Gaines, W.L. 2008. Monitoring American marten on the east-side of the North Cascades of Washington. Northwestern Naturalist 89:67-75.

Naiman, R.J.; Beechie, T.J.; Benda, L.E.; Berg, D.R.; Bisson, P.A.; MacDonald, L.H.; O'Conner, M.D.; Olson, P.L.; Steel, E.A. 1992. Fundamental elements of ecologically healthy watersheds in the Pacific Northwest coastal ecoregion. In: Naiman, R.J., ed. Watershed management: balancing sustainability and environmental change. Springer-Verlag. New York, NY. p. 127-188.

NCSSF. 2005. Science, biodiversity, and sustainable forestry: A findings report of the National Commission on Science for Sustainable Forestry. National Commission on Science for Sustainable Forestry, Washington, DC. 52p.

Nelson, C.R.; Halpern, C.B.; Agee, J.K. 2008. Thinning and burning result in low-level invasion by nonnative plants but neutral effects on natives. Ecological Applications. 18(3): 762-770.

Noss, R.F.; Beier, P.; Covington, W.W.; Grumbine, R.E.; Lindenmayer, D.B.; Prather, J.W.; Schmiegelow, F.; Sisk, T.D.; Vosick, D.J. 2006. Recommendations for integrating restoration ecology and conservation biology in ponderosa pine forests of the Southwestern United States. Restor. Ecol. 14, 4–10.

Oliver, C.D.; Larson, B.C. 1990. Forest Stand Dynamics. New York: McGraw-Hill. 459p.

Ohmann, J.; Gregory, M.; Grossmann, E.; May, H. 2009. GNN accuracy assessment report. Washington Eastern Cascades (modeling Region 207) model type: basal-area by species-size combinations.

O'Hara, K.L.; Latham, P.A.; Hessburg, P.F.; Smith, B.G. 1996. A structural classification for Inland Northwest forest vegetation. Western Journal of Applied Forestry. Vol. 11 No. 3 (1996): 97-102.

O'Laughlin, J.O. 2005. Policies issues relevant to risk assessments, balancing risks, and the National Fire Plan: needs and opportunities. Forest Ecology and Management, 122(1-2):15-27.

O'Neill, R.V.; King, A.W. 1998. Homage to St. Michael; or, why are there so many books on scale? In: Peterson, D.L.; Parker, P.V. (eds.) Ecological scale: theory and applications. Columbia University Press, New York. Pp. 3-16.

Page, H.N.; Bork, E.W.; Newman, R.F. 2005. Understory response to mechanical restoration and drought within montane forests of British Columbia. BC Journal of Ecosystems and Management 6(1): 8-21.

Pearcy, W.G. 1997. Salmon production in changing ocean domains. In: Stouder, D.J.; Bisson, P.A.; Naiman, R.J., eds. Pacific salmon and their ecosystems: status and future options. New York: Chapman and Hall: 331-352.

Peterson, D.W.; Hessburg, P.F.; Salter, B.; James, K.M.; Dahlgreen, M.C.; Barnes, J.A. 2007. Reintroducing fire in regenerated dry forests following stand-replacing wildfire. Gen. Tech. Rep. PSW-GTR-203. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redding CA.

Pettit, M.E.; Naiman, R.J. 2007. Fire in the riparian zone: characteristics and ecological consequences. ecosystems: 10: 673-687.

Pollet, J.; Omi, P.N. 2002. Effect of thinning and prescribed burning on crown fire severity in ponderosa pine forests. International Journal of Wildland Fire 11: 1-10.

Quigley, T.M.; Arbelbide, S.J. tech. eds. 1997. An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great Basins: volume 3. General Technical Report, PNW-GTR-405. Portland, OR: Pacific Northwest Research Station, U.S. Department of Agriculture, Forest Service. p. 1058-1713.

Reeves, G.H.; Everest, F.H.; Hall, J.D. 1987. Interactions between the redside shiner (*Richardsonius balteatus*) and the steelhead trout (*Salmo gairdneri*) in western Oregon: the influence of water temperature. Canadian Journal of Fisheries and Aquatic Sciences. 44: 1602-1613.

Reeves G.H.; Benda, L.E.; Burnett, K.M.; Bisson, P.A.; Sedell, J.R. 1995. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest. American Fisheries Society Symposium, 17:334–349.

Reynolds, K.M. 2002. Prioritizing salmon habitat maintenance and restoration activities. Pages 199-271 in Schmoldt, D.L., J. Kangas, G. Mendoza, and M. Pesonen, eds. The Analytical Hierarchy Process in Natural Resource and Environmental Decision Making. Kluwer Academic Publishers, Boston, MA.

Reynolds, K.M.; Johnson, K.N.; Gordon, S.N. 2003. The science/policy interface in logic-based evaluation of forest ecosystem sustainability. Forest Policy and Economics 5: 433-446.

Reynolds, K.M.; Rodriquez, S.; Bevens, K. 2003. User guide for the Ecosystem Management Decision Support System, Version 3.0. Environmental Systems Research Institute, Redlands, CA. 82pp.

Reynolds, K.M.; Hessburg, P.F. 2005. Decision support for integrated landscape evaluation and restoration planning. Forest Ecology and Management. 207:263-278.

Rieman, B.; Clayton, J. 1997. Wildfire and native fish: issues of forest health and conservation of sensitive species. Fisheries, 22(11):6-15.

Rieman, B. E.; Lee, D.C.; Thurow, R. F.; Hessberg, P.G.; Sedell, J.R. 2000. Toward an integrated classification of ecosystems: defining opportunities for managing fish and forest health. Environmental Management 25: 425–444.

Rieman, B.; Luce, C.H.; Dunham, J.B.; Rosenberger, A.L. 2005. Implications of changing fire regimes for aquatic ecosystems. In: Taylor, L., J. Zelnik, S. Cadwallader, and B. Hughes (comps., eds). Mixed severity fire regimes: ecology and management. Symposium proceedings; Spokane, WA; November 15-19, 2004. Association for Fire Ecology and Washington State University; WSU Extension, Pullman, WA. p. 187-191.

Russell, R. E.; Royle, J.A., Saab, V.A.; Lehmkuhl, J.F., Block, W.M.; Sauer, J.R. 2009. Modeling the effects of environmental disturbance on wildlife communities: avian responses to prescribed fire. Ecological Applications 19: 1253-1263.

Russell, W.H.; McBride, J.R. 2001. The relative importance of fire and watercourse proximity in determining stand composition in mixed conifer riparian forests. Forest Ecology and Management. 150: 259-265.

Saab, V.; Block, W.; Russell, R.; Lehmkuhl, J.: Bate, L.; White, R. 2007. Birds and burns of the interior West: descriptions, habitats, and management in western Forests. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. PNW-GTR-712.

Salafsky et al. 2005. Adaptive Management.

Sanchez Meador, A.J.; Moore, M.M.; Bakker, J.D.; Parysow, P.F. 2009. 108 years of change in spatial pattern following selective harvest of a *Pinus ponderosa* stand in northern Arizona, USA. Journal of Vegetation Science. 20: 1-12.

Sanderson, B.L.; K.A. Barnas; A. Michelle Wargo Rub. 2009. Nonindigenous species of the Pacific Northwest: an overlooked risk to endangered salmon? Bioscience 59 (3), 245-256.

Schwilk, D.W.; Keeley, J.E.; Knapp, E.E. [et al.]. 2009. The national fire and fire surrogate study: effects of fuel reduction methods on forest vegetation structure and fuels. Ecological Applications.

Singleton, P.H.; Lehmkuhl, J.F.; Gaines, W.L.; Graham, S.A. 2010. Barred owl space use and habitat selection in the eastern Cascades, Washington: implications for northern spotted owl conservation. Journal of Wildlife Management 74(2): 285-294.

Society for Ecological Restoration. 1993.

Spies, T.A.; Hemstrom, M.A.; Youngblood, A.; Hummel, S. 2006. Conserving old-growth forest diversity in disturbance-prone landscapes. Conservation Biology. 20(2): 351-362.

Stephens, S.L.; Moghaddas, J.J. 2005a. Experimental fuel treatment impacts on forest structure, potential fire behavior, and predicted tree mortality in a California mixed conifer forest. Forest Ecology and Management 215: 21-36.

Stephens, S.L.; Moghaddas, J.J. 2005b. Fuel treatment effects on snags and coarse woody debris in a Sierra Nevada mixed conifer forest. Forest Ecology and Management 214: 53-64.

Swanson, F.J.; Jones, J.A.; Wallin, D.O. [et al.]. 1994. Natural variability-implications for ecosystem management. Gen. Tech Rpt. PNW-GTR-318. Portland, OR: U.S. Department of Agriculture, Forest Service, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 376 p.

Swift, L.W., Jr.; Burns, R.G. 1999. The three R's of roads: redesign, reconstruction, and restoration. J. Forestry 97(8): 41-44.

Trombulak, S.T; Frissell, C.A. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology, 14(1):18-30.

U.S. Fish and Wildlife Service (USFWS). 2008. Final recovery plan for the northern spotted owl. U.S. Department of Agriculture, Fish and Wildlife Service, Portland, OR.

U.S. Forest Service (USFS). 2006. Terrestrial species assessments: Region 6 forest plan revisions. USDA Forest Service, Pacific Northwest Region, Portland, OR.

U.S. Forest Service (USFS). 2000. Strategy for the management of dry forest vegetation: Okanogan and Wenatchee National Forests. U.S. Department of Agriculture, Forest Service, Okanogan-Wenatchee National Forest, Wenatchee, WA.

USDA and USDI. 2006. Protecting people and natural resources, a cohesive fuels treatment strategy. U.S. Department of Agriculture, Forest Service and USDI (Bureau of Indian Affairs, Bureau of Land Management, National Park Service, Fish and Wildlife Service. February 2006. 60 pp.

Van Pelt, R. 2008. Identifying old trees and forests in eastern Washington. Washington State Department of Natural Resources, Olympia, WA.

Vanno, et al. 2009. See Climate Change document

Warwell, M. V.; Rehfeldt, G. E.; Crookston, N. 2007. Modeling contemporary climate profiles of whitebark pine (*Pinus albicaulis*) and predicting responses to global warming, pgs. 139-142. IN: Goheen, Ellen M.; and Sniezko, Richard A., tech. coords. 2007. Proceedings of the conference whitebark pine: a Pacific Coast perspective. 2006 August

27-31: Ashland, OR. R6-NR-FHP-2007-01. Portland, OR: U. S. Department of Agriculture Forest Service, Pacific Northwest Region, 175p.

Westerling, A.L.; Hidalgo, H.G.; Cayan, D.R.; Swetnam, T.W. 2006. Warming and earlier spring increase western U.S. forest wildfire activity. Science 313:940-943.

White, A.S. 1985. Presettlement regeneration patterns in a Southwestern ponderosa pine stand. Ecology 66(2): 589-594.

White, J.; Harper, J.L. 1970. Correlated changes in plant size and number in plants populations. Journal of Ecology. 58 (2): 467-485.

Whitlock, C.; Shafer, S.L.; Marlon, J. 2003. The role of climate and vegetation change in shaping past and future fire regimes in the northwestern U.S. and the implications for ecosystem management. Forest Ecology and Management 178 (2003) pgs. 5-21.

Wikipedia. Ecosystem management decision support. http://en.wikipedia.org/wiki/Ecosystem_Management_Decision_Support. 5 October 2009.

Wipfli, M.S.; Richardson, J.S.; Naiman, R.J. 2007. Ecological linkages between headwaters and downstream ecosystems: transport of organic matter, invertebrates, and wood down headwater channels. JAWRA 43 (1): 72-85.

Wisdom, M.J.; Holthausen, R.S.; Wales, B.C.; Hargis, C.D.; Saab, V.A.; Lee, D.C.; Hann, W.J.; Rch, T.D.; Rowland, M.M.; Murphy, W.J.; Eames, M.R. 2000. Source habitats for terrestrial vertebrates in focus in the interior Columbia basin: broad scale trends and management implications. U.S. Forest Service General Technical Report PNW. (485): 1-529.

Wissmar, R.C.; Smith, J.E.; McIntosh, B.A.; Li, H.W.; Reeves, G.H.; Sedell, J.R. 1994. Ecological health of river basins in forested regions of eastern Washington and Oregon, PNW-GTR-326. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Wright, C.S.; Agee, J.K. 2004. Fire and vegetation history in the eastern Cascade Mountains, Washington. Ecological Applications. 14(2): 443-459.

Youngblood, A.; Max. T.; Coe, K. 2004. Stand structure in eastside old-growth ponderosa pine forest of Oregon and northern California. Forest Ecology and Management. 199(2-3): 191-217.

Youngblood, A.; Metlen, K.L.; Coe, K. 2006. Changes in stand structure and composition after restoration treatments in low elevation dry forests of northeastern Oregon. Forest Ecology and Management 234: 143-163.

Youngblood, A.; Wright, C.S.; Ottmar, R.D.; McIver, J.D. 2008. Changes in fuelbed characteristics and resulting fire potentials after fuel reduction treatments in dry forests of the Blue Mountains, northeastern Oregon. Forest Ecology and Management 255: 3151-3169.

Yount, J.D.; Niemi, G.J. 1990. Recovery of lotic communities and ecosystems from disturbance a narrative review of case studies. Environmental Management. 14(5): 547-570

APPENDIX A - Considerations for implementing forest restoration within land allocations

1. **Roadless area inventories** – Roadless areas pose limits on the kinds of treatments that can be implemented. By intersecting the fire modeling results with the roadless inventory, the location of strategic treatment areas can be identified and treatment options that do not require road construction can be discussed by the interdisciplinary team to determine their feasibility.

2. **Late-successional reserves, managed late-successional areas, critical habitat units (LSR, MLSA, CHU)** – These areas are likely to change due to the final spotted owl recovery plan through the revision of the Okanogan-Wenatchee National Forest plan. However, this is likely a couple years off. In the interim it is imperative that LSR, MLSA, and CHU be evaluated as part of the landscape within dry forests where treatments are needed to restore forests and reduce the risk of fire flow across the landscape. These restoration treatments should: 1) be supported by the landscape assessment; 2) be implemented in strategic locations where the landscape assessment shows they are necessary to reduce landscape fire risk to old forest habitats; 3) be designed to emphasize old forest associated species such as the white-headed woodpecker, flammulated owl, and pygmy nuthatch where treatments are identified; and 4) consider the sustainability of existing and future habitat for the northern spotted owl and associated late-successional species.

3. **Matrix, General Forest** – Historically, the emphasis for general forest and matrix was on timber production, maximized for the former and programmed for the latter. However, traditionally implemented production forestry is generally inconsistent with fire, endangered species, and restoration objectives. Consequently, these areas are now considered with the rest of the landscape and any treatments that are proposed are guided by restoration principles.

4. **Riparian Reserves/Riparian Habitat Conservation Areas** – Riparian and upslope forests have significant continuity in disturbance events, especially overstory fire severity (Everett et al. 2003) , thus making it important that the management of riparian forests take into consideration the types of disturbance that typically affect these areas (Agee 1988). Treatments within RR/RHCAs are appropriate when they help restore the mosaic of conditions expected to occur in the riparian zone at a watershed scale. Any treatment proposed should maintain understory processes, improve riparian conditions long term, and avoid headwalls entirely.

5. **Deer and Elk Winter Range** – Previously, the retention or creation of winter thermal cover was deemed the most important habitat variable for winter survival of deer and elk. However, studies have shown that thermal cover is not as critical as other factors such as forage quality and quantity, and human disturbance (Cook et al. 1996, 1998).

The forest plan for the Okanogan National Forest identifies explicit standards for the amount of thermal (snow intercept and winter) cover of 30-40 percent on deer winter range. However, the plan states that: where natural forest vegetation is not present to support optimal cover amounts, manage existing vegetation to approach cover objectives on a sustained basis (MA5-6B).

The Wenatchee National Forest Land and Resource Management Plan relies on a Habitat Effectiveness Index that considers road density, thermal cover, and forage (Thomas et al. 1986). By emphasizing the reduction of road density and enhancement of forage, thermal cover can be reduced and still meet forest plan standards for deer and elk winter ranges. In this manner, the potential conflict between restoring forests and not meeting the winter range thermal cover standards can be resolved.

6. **Key Watershed Direction for portions of the Forest contained within the area of the Northwest Forest Plan --** no new road construction in identified roadless areas. Road density outside of roadless areas should be reduced. If funding to do so is not available, there should be no net increase in road miles within key watersheds.

APPENDIX B - Silvicultural Considerations for Restoration Treatments

Why There Should be no Standard Basal Area Objective for Dry Forest Treatments

Over the years, a misunderstanding of basal area has grown into a misapplied basal area objective of about 60 square feet following dry forest treatments. Reasons include the universal misapplication of references such as the average 70 square feet in Harrod et al. (1999) and rules of thumb such as this one: "bark beetle risk is acceptable at about 60 square feet of basal area" (Paul Flanagan personal communication). It is inappropriate to assign a basal area target of about 60 square feet to all dry forests due to the inherent variability among dry forest sites. Basal area is a mensurational tool and only represents competitive processes indirectly as a proxy for leaf area. Consequently, its ecological meaning is less straightforward than that of Stand Density Index (Dave Perry, Oregon State University, pers comm).

As is widely known, basal area's utility for describing tree density is limited without an accompanying diameter description, but there are other important aspects to consider. Consider two young pine stands, one less than 50 years old so the proportion of heartwood is very low, and another over 100 years old so the proportion of heartwood is quite high. Both stands could average 120 square feet of basal area per acre but tree density and diameter would be quite different for each stand: 150, 12 inch diameter trees in the young stand and 24, 30 inch diameter trees in the older stand. Because the proportion of physiologically inert heartwood is so much higher in the old stand, 120 square feet of basal area in the old stand represents considerably less resource use and competition than does the same basal area in the younger stand. As another example, a young stand that has recently been thinned to 60 square feet of basal area with a residual stand diameter of 6 inches will result in a tree density of 306 per acre. This resulting density would not meet our dry forests objectives.

In spite of the preceding discussion, basal area used appropriately, can be a useful tool for describing a stand or marking objectives. Basal area can support understanding of the relative competitive changes from various levels of density reduction for a particular stand when accompanied by a measure of diameter distribution. Most importantly, it can be used to communicate marking objectives, e.g. as a means to quantify gap and clump creation or to translate SDI objectives.

APPENDIX C - Weak Rationale for "Thinning" Old Trees

Given our direction to restore forest ecosystems, there is little, if any, rationale for intra-cohort thinning of old trees. On the other hand, inter-cohort, or understory density reduction, is supported as a means to favor old trees although the response appears to vary among tree species.

Competitive relationships among trees in young, closed, evenly spaced, conifer stands are different than they are within older, more variable ones. In young stands, self-thinning is occurring and competition is the primary cause of mortality that is distributed somewhat evenly across the stand. In old stands, after the period of rapid height growth and crown expansion, mortality is mostly density independent. In young stands, growing space, made available as subordinate trees are killed by dominant trees, is rapidly filled by those survivors and the competitive process continues. In older stands, as the trees approach their maximum size, growth slows and self thinning finally ceases as the stand "falls off the self-thinning curve." Explanations for this include the reduced ability of older trees to capitalize on released growing space (White and Harper 1970) and the canopy architecture of older stands (David Perry, Oregon State University, pers. comm., Zeide 1987). This "falling off" is incorporated in Forest Vegetation Simulator (James Long, Utah State University, pers. comm.).

Density management regimes based on the self-thinning curve have a long history (Curtis 1970, Long 1985) and have been commonly used by silviculturists to prescribe thinnings in young, dense, evenly spaced, even-aged stands. More recently, Cochran (1992) suggested an application of SDI for uneven-aged ponderosa pine stands and, in fact, its qualified extension to uneven-aged, mixed species stands (Pat Cochran, Forest Service, USDA, pers. comm.) However, these concepts and the management thresholds derived from them are based on stand level averages. They do not address resource use at the neighborhood scale. This shortcoming limits their applicability in most of our dry forest mixed species, multi-aged, clumpy stands. It is inappropriate to use them as a justification or guide for intra-cohort thinning of old stands or clumps of old trees in mixed age stands.

This is not to suggest that thinning does not result in increased growth and vigor of old trees. On the contrary, increased growth for old trees following density reduction in old stands has been reported (Latham and Tappeiner 2002, McDowell et al. (2003). These authors suggest, with some ambiguity, that the density reduction was from understory removal. Others (Wallin et al. (2004), and Dolph et al.(1995)) unambiguously report increased growth and vigor for old ponderosa pines following understory density reduction. McDowell et al. (2003) report that the growth effect can last for up to 15 years. Site and individual tree characteristics (Latham and Tappeiner 2002) and tree/stand history (Kaufmann 1995) appear to be important factors.

Increased resistance to insects, as a function of increased vigor, has been considered to accompany this kind of understory thinning. Considering the previous discussion however, applying these results as a rationale for intra-cohort thinning of old stands and clumps seems weakly supported, if at all. In any event, Goheen (personal communication) suggested that the pattern of bark beetle-caused mortality is different in stands subject to the self-thinning process, where large-scale tree mortality can occur, than in older stands where tree mortality would be patchy, excepting the effect of regional drought. This

observation is supported by Edminster and Olsen (in Long (2000) and Youngblood et al. (2004). This kind of mortality among older trees is likely the process, along with fire, by which successional processes were historically maintained in our dry forests (Agee 1993).

APPENDIX D – Prescriptions That Address Old and Large Trees and Spatial Patterning

Example 1: This prescription excerpt implements the results of a site-specific stand-reconstruction to create spatial pattern. It retains all old, very large, and most large trees.

Table 8--Prescription/Marking Guide

Project Wildcat	**Unit 44 version 2**	**Name Dahlgreen**	**Date May 28, 2009**
Locate	series	Dry/mesic dry	Data exam/recon
Acres 48	Aspect S	Slope <35	Elev 32-3600
NWFP Matrix	Wen FP ST 1	Act Code: HTH	

Stand Description (exam 15% error at 68.3 confidence):

spp	**dbh**	**tpa**	**growth**	**aveBA**	**ave space**	**LCR**	**CC**	**MBF**
DF>PP	>25	7	+-20/20	35	80	>40		
DF>>P	21-25	13	+-20/20	40	60	>40		
	16-20.9	13		20	60	>35		
	9-15.9	5		5				
Stand average		40		100	30		SVS 25-30	7-9

Stand Structure after treatment: SEOC becoming OFSS with time: Key Feature large trees, esp. pp

Spacing: Leave an average of 40 trees/ac.

- Leave 5 clumps/ac w/ 2-4 trees and 2 clumps/ac w/>=5 trees. Clumps have trees w/in 20 of another tree. Spacing outside clump should be at least 45 feet on two sides.
- Leave 18 tpa as individuals with average spacing about 50 ft. Vary spacing for tree condition with average spacing about 50 ft and minimum about 30.

Guidelines

- Retain all old trees, established before about 1900. Note, that is younger than Van Pelt (2008) rating greater than 6 for PP and 7 for DF
- Around old PP, remove 100yr age class DF for 1-2 driplines—OK to keep 1-2 large/vigorous DF occasionally-use judgement.
- Thin from below removing mostly trees <21 inch to meet tree density/LCR objectives. Removal of trees >21 isn't expected. Maybe on east end as needed to prevent mistletoe spread to the west. Remove INT DF w/LCR <40 (Can go to <35 for clumping,check growth). Retain occasional understory/INT w/LCR > 40 (+-2/ac)
- Remove 100 yr PP w/LCR <30% or with Van Pelt fig.69 form C or D (check growth)
- In areas of +- pure younger PP leave BA 40-60 and/or open around them for 2-4 driplines.
- On slope > 10-15% leave BA nearer low end. On flatter ground and mesic on west edge stay nearer 100.

- Retain GF as part of complex patch on SW, otherwise they're not an issue either way.
- Retain complex patch at point 41 on SW corner wet area.
- Canopy gaps (fewer than about 5 TPA) between 1/10 to 1/2 ac will be created in patches of INT trees or where DF mistletoe buffers are created.

Example 2: This prescription excerpt is not based on an explicit clump/gap objective. Instead it utilizes stand conditions and objectives to create spatial pattern. It retains all old, very large, and most large trees.

Table 9--Prescription/Marking Guide

Project Gold Spr	**Unit 6**	**Name Dahlgreen**	**Date 1-10**
Locate Naches	Series GF	Dry/mesic	Data recon/CSE
Acres 123	Aspect West	Slope <30	Elev 26-3400
NWFP Mtrx +-90 & MLSA/AWD	Wen FP GF +- 95% & MP1	FWS none	Act Code: HSA

Stand Description (exam 11 % error at 68 % confidence):

spp	**dbh**	**Current TPA**	**Post mech TPA**	**Post-mech BA**		**Current CC**	**Desired CC**	**Acceptable CC**
	>25	<1	<1	4		2	2	2
	16-25	17	13	27		18	14	20-22
	9-16	39	13	15		23	8	
	5-9	3	0	0		1	0	
	<5	n/a	n/a	n/a		n/a	n/a	
stand average/ac (68% confidence interval)		59 (53-65)	27 (24-31)	46 (41-51)		43 (38-48)	24 (21-27)	
Range across unit				0-120				

Stand Structure after treatment: YFMS (assuming SS currently > 10% cover).
Pattern: Gaps created by: a) dripline thinning around old PP ; b) around OS WL; c) releasing PP/WL advance regen; d) removing about 65% of trees from about 45% of the stand (due to mistletoe infection) and about 25% of the trees elsewhere. Clumps provided by uninfected DF. Basal area across unit will range from 0 to 120 ft. Complex patches: moist sinks on SE boundary and where found elsewhere.
Residual density/spacing: See Table.
Guidelines

1. Old trees: retain all Van Pelt rated DF >= 7 and PP >=6 and WL >=7
2. Retain all trees over 25 inches and all between 21 and 25 except rare removal for old PP release, or DF dwarf mistletoe containment.
3. Around Van Pelt >= 6 rated PP, retain only 0-2 younger trees for 1-2 driplines.
4. Thin uninfected DF clumps from below removing only INT and COD trees with poor growth (below about 15/20ths, narrow bark fissures, and/or LCR < 40% for DF and <35% for PP).
5. Release advanced PP/WL regen by removing OS DF to open sky for 90-130 degrees, east to west and neighborhood basal area < 30.
6. For about 1 acre around retained WL, remove DF to about 20% canopy cover.
7. Retain all WL except for mistletoe infected ones < 21 inches.
8. Retain all old and >25 inch dwarf mistletoe infected DF. Retain infected trees between 21-25 inches as groups of 3 or more. Isolate all retained trees. Remove individual

infected DF under 25 inches and all under 21 inches as well as adjacent, apparently uninfected ones..

9. Confine GF to less than about 6 acres on moist areas, usually clumped, preferably as unthinned patches. On dry, upslope areas retain them if > 25 inches.
10. Retain wildlife trees
    - Buffer snags >25 inches as needed.
    - Retain live trees with dead, broken, forked tops or obvious sign of use

GLOSSARY

Term	Definition
Adaptive Management	A system of management practices based on clearly identified outcomes and monitoring to determine if management actions are meeting desired outcomes, and if not, to facilitate management changes that will best ensure that outcomes are met or reevaluated. Adaptive management stems from the recognition that knowledge about natural resource systems is often uncertain (36 CFR 219.16; FSM 1905).
Biological Legacies	"Biological legacies are defined as the organisms, organic matter (including structures), and biologically created patterns that persist from the pre-disturbance ecosystem and influence recovery processes in the post-disturbance ecosystem. Legacies occur in varied forms and densities, depending upon the nature of both the disturbance and the forest ecosystem" (Franklin et al. 2007). Other biological legacies can include fire refugia areas that either escape fire due to landscape position (ex: rocky areas, ridgetops) or are non-burned islands within a mixed fire event (Camp et al. 1997).
Disturbance	
Forest Restoration	Restoration is the activity used to implement ecosystem management. Restoration aims to enhance the resilience and sustainability of forests through treatments that incrementally return the ecosystem to a state that is within a historical range of conditions (Landres et al. 1999) tempered by potential climate change (Millar and Woolfenden 1999). It is the process of assisting the recovery of resilience and adaptive capacity of ecosystems that have been degraded, damaged, or destroyed (FSM 2020.5). In terms of forest restoration, active techniques are largely tree cutting and prescribed fire, but also include other active treatments focused on roads, weeds, livestock, and streams.
Ecosystem Management	Ecosystem management is driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring

Term	Definition
	and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem structure and function (Christensen et al. 1996). It emphasizes management of systems rather than their component parts, while integrating economic and soil values (Harrod et al. 1996). The goal of ecosystem management is to achieve sustainability of ecosystem structure and processes necessary to deliver goods and services rather focusing on "deliverables."
Future Range of Variability	The future range of variability is a concept described by Gartner et al. (2008) and is intended to provide insights into how systems may adjust to changing climate. By comparing current vegetation patterns to both historical and future reference conditions, managers will gain valuable insights into how systems have changed and how they are likely to change over time. Understanding these changes is the key to determining management strategies that provide for more sustainable and resilient forests.
Function	Function in an ecosystem is the role that any given process, species, population, or physical attribute play in the interrelation between various ecosystem components or processes (Lugo et al. 1999). For example, standing snags in forests provide habitat for many wildlife species and when snags fall, they serve as substrate for seedling establishment and wildlife cover. Downed wood creates aquatic habitat complexity (Naiman et al. 1992; Benda and Sias, 2003) which in turn supports listed fish species (Lichatowich 1999, ISAB 2007). Functional roles can be lost or diminished by management practices that do not incorporate ecosystem interrelations.
Historical range of variability	Historical range of variability refers to the fluctuations in ecosystem composition, structure, and process over time, especially prior to the influence of Euro-American settlers (Morgan et al. 1994, Swanson et al. 1994, Fulé et al. 1997, Landres et al. 1999, Agee 2003). Such variations include a diverse array of characteristics such as tree density, population

Term	Definition
	sizes of organisms, water temperature, sediment delivery and so on. It can be applied at multiple spatial scales from the site to biogeographic region, and at multiple temporal scales from decades or centuries for landform erosion to millennia for geologic processes (Swanson et al. 1994, Landres et al. 1999).
Monitoring	The systematic collection and analysis of repeated observations or measurements used to evaluate changes in condition and progress towards meeting a management objective. This could include: *Implementation Monitoring* – helps to evaluate how closely management plan guidelines were followed. *Effectiveness Monitoring* – helps to evaluate whether the management plan achieves the desired conditions. *Validation Monitoring* – helps to evaluate if the underlying assumptions regarding cause and effect relationships are correct. Monitoring is an integral part of adaptive management.
Pattern	Pattern is the spatial distribution of ecological characteristics of forest or other ecosystems. Like process, pattern changes over time and space. Discernable patterns can be described at the level of tree or shrub clumps to large scale patterns of vegetation types in a biophysical zone. Patterns in forest ecosystems arise from broad differences in topography, geomorphic processes, climate regime, and large-scale disturbances (Hessburg et al. 2000).
Process	A process as defined in the dictionary is a sequence of events or states, one following from and dependent on another, which lead to some outcome. Processes that are important to ecosystems are disturbances that include both one-way fluxes and cycles (Lugo et al. 1999). For example, the process of soil erosion, the movement of soil particles from one location to another, represents a flux, while frequent fire in a dry forest stand would be considered a cycle. Many disturbances in ecosystems are merely processes that occur at different temporal and spatial scales.
Resilient	
Spatial and temporal scales	Scale refers to physical dimensions of observed entities (e.g. a watershed) and phenomena (e.g.

Term	Definition
	fire), and to the scale of observations (O'Neill and King 1998). Scale has both spatial and temporal dimensions. Ecosystem processes, structures, and functions occur at different scales and, therefore, ecosystems are hierarchically organized. For example, frequent fire in ponderosa pine historically? created small clumps of even-aged trees that resulted in un-even aged stands with a generally regular, open structure. At the scale of a watershed, the ponderosa pine vegetation zone was highly variable and influenced by precipitation zones, soil types, variation in fire size and higher frequency than any one individual stand. In this example, ponderosa pine pattern varied with space and with time (fire more frequent at larger scales).
Stochastic	
Structure	Structures are the living and non-living physical components and spatial arrangement of an ecosystem. Multi-layered stands are structurally diverse, but so are landscapes with multiple patches of stands of different ages. Ecosystem structures are important because processes are influenced by structure and management is typically focused on the manipulation of structures.
Sub-Basin	An 8th Hydrologic Unit Code (HUC) basin typically covering a few hundred thousand acres to over one million acres. Examples include the Methow, Entiat, and upper Yakima Sub-basins..{These are different interpretations of HUCs than I'm used to. Is this a new system?}
Sub-Watershed	A 12th HUC basin typically covering 10,000 to 40,000 acres. This scale will be used to identify "Key Watersheds" in the Okanogan-Wenatchee Forest Plan Revision. Examples include Cub Creek, Upper Entiat, and North Fork Teanaway.
Sustainable	
Watershed	A 10th HUC basin typically covering 40,000 to over one hundred thousand acres. Key Watershed Identification and Watershed Assessments completed under NWFP typically were accomplished at this scale. Examples include the Chewuch, Mainstem Entiat River, and the Teanaway.

2606