Chapter 6: Maintaining Old-Growth Forests

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Introduction

The Forest Ecosystem Management Assessment Team (FEMAT 1993) was directed to develop alternatives that met this objective, among others:

> Maintenance and/or creation of a connected or interactive old-growth forest ecosystem on the federal land within the region under consideration.

The FEMAT produced several alternatives, one of which, option 9, was selected by the President as the basis of the Northwest Forest Plan (the Plan), described in the Record of Decision (ROD) (USDA and USDI 1994). To a large degree, the success of the Plan depended on the structure, composition, and dynamics of forest vegetation. In this chapter, I describe the general and specific expectations of the Plan, what has happened, and what we have learned from monitoring. Critical Plan assumptions are reviewed in the context of recent science findings and new perspectives, and alternative approaches to meeting the Plan's goals are discussed.

The terminology associated with the concept of old growth is often confusing. Other terms associated with old-growth forests have included mature forest, old forest, older forest, and late-successional. In this chapter, "mature" forests refer to the stage of stand development that occurs just prior to the old-growth stage (figs. 6-1, 6-2), "older" forest encompasses both mature and old-growth stages and is the term used in the status and trends report (Moeur and others 2005) for the general set of different inventory definitions. "Late-successional" has also been used in FEMAT and the ROD for these later two stages of stand development, but its usage in the Plan is somewhat confusing. In this chapter, I will use "older" forest as it was used in the status and trend report. Some authors will use the term "old forests" as a substitute for "old growth" if they consider that term too limited (for example, only forests with massive old trees) or too value laden. I will use "old growth" to refer to the last stage of stand development that is typically associated with stands with large old trees and complex structure (figs. 6-3 through 6-6). I present a more indepth discussion of definitions and the ecological concepts of forest development later in the chapter.

What Was Expected?

The assessment of the state of old-growth forests was based on the assumption and observations (Bolsinger and Waddell 1993) that amounts of old-growth forest had steeply declined during the 20th century, placing associated species at risk and reducing the contribution of old-growth forests to ecosystem functions such as carbon storage and the hydrologic cycle. The obvious correction for this problem was to develop management policies that reduced the rate of loss of existing old-growth forests and at the same time promoted the growth of new areas of older forest. Because the problem is rooted in the loss of old-growth forest, relative to past amounts, the solutions under the Plan were based on returning the federal landscape toward an extent of old-growth forest more in line with what was here before widespread logging on federal lands. The historical extent was assumed to be adequate to sustain the native biological diversity associated with older forest. To do this, the amount of the historical landscape covered by older forest in the past had to be estimated. The answer to this question, however, was not as simple as determining how much older forest occurred at some past point or period in time, such as the early 1800s before Euro-American settlement. Forests are dynamic as a result of disturbance, growth, and succession; consequently, the abundance of older forest varies over time—no single point or short period can realistically be used to characterize this dynamic system. Under the historical natural disturbance regime (type, severity, and frequency of disturbance), the amount of

Expectations for the Old-Growth Network in Fire-Prone Landscapes

The old-growth reserve network was established under the assumption that some areas of old forest would be lost to stand-replacement disturbances including wildfire. Given the forest types, environments, and disturbance history of the Plan area, this assumption is entirely warranted. It is not realistic to assume that fire suppression will stop wildfires—the monitoring results demonstrate this—and it is not desirable to stop all fires in these landscapes given their importance to the functioning of these ecosystems. For example, old growth in ponderosa pine and dry mixed-conifer types is maintained by frequent low-severity wildfire and patchy disturbances from insects and disease (Spies and others 2006). The Plan did not explicitly evaluate how changes in fire regimes resulting from fire exclusion might affect the amount and dynamics of old growth in dry provinces, however, and it did not state expectations for forest dynamics in these areas.

A key part of the monitoring strategy was the development of expected trends in key indicators. For example, the total amount of older forest was expected to increase at a mean annual rate of 1.2 percent (FEMAT 1993 fig. IV-2) despite losses to high-severity wildfire, which were projected at an annual rate of 0.25 percent for the Plan area. The actual rates of net increase (1.9 percent) were higher and the rates of loss (0.18 percent) were lower than expected—deviations that are consistent with old-growth goals of the Plan. The establishment of expected trends was necessary to provide a context for evaluating the significance of the changes that do occur. Given the uncertainties and variability of disturbance regimes and forest development, the expected trends should be viewed largely as educated guesses based on historical dynamics and our general understanding of forest growth and disturbance.

Although the overall rates of loss of older forest to high-severity fire were lower than expected, some of the dry provinces had much higher rates than the average. For example, the Oregon Klamath province had a decadal rate of loss of about 9.5 percent, compared to the regionwide average of 1.8 percent. If we assume that this percentage loss was similar for the province as a whole (not just the older forest part), then the high-severity fire rotation would be about 105 years. Assuming a stochastic pattern of burning and a negative exponential model (Agee 1993), this would create a landscape that on average had about 15 percent of the area in forest with large pines and Douglas-firs over 200 years of age. The Eastern Cascades province in Oregon had a relatively low rate of loss up to 2002, the end of the measurement period. However, if 2003, the year of the B and B Fire, were included, an additional 25,000 acres of older forest would have been burned, and the decadal rate of loss would have increased to 14.6 percent (a high-severity fire rotation of 69 years). If this rate of disturbance were sustained, then the percentage of forest with old trees would be around 5 percent on average. Clearly, these outcomes would not be desirable because the area of dense mixed-conifer old growth, which was subject to mixed-severity fire, and open pine old growth, which was maintained by frequent low-severity fire, would decline.

This simple analysis only tells part of the story because it does not take into account other disturbances from insects and disease and the cascading effects of increased high-severity fire. Losses of old trees to insects and disease would continue to occur and further reduce the amount of older forest and trees in these landscapes (Spies and others 2006). Increased occurrence of high-severity fires could lead to stands and landscapes with a more uniform structure (either shrubby fields or areas of dense regeneration) than could have occurred under the low- to mixed-severity fire regime. This uniformity would create a positive feedback loop that further increases high-severity fire and insect and disease outbreaks. Although some uniform patches of early-successional forest would have occurred and contributed to biological diversity, large areas of such stands would be less desirable for the goals of the Plan, which emphasize retaining structurally complex stands including large live trees. Within ponderosa pine and dry mixed-conifer types, large patches of early-successional forest are thought to have been historically rare, although Hessburg and others (2005) argued that high-severity fire in dry mixed-conifer forests was more common than previously thought.

The FEMAT recognized that the desired outcomes of the Plan had a lower chance of success in the dry provinces; however, the situation may be worse than expected. The assessment of option 9 (the selected option) assumed that the fuel reduction treatments would be sufficient to lower the risk of high-severity fire. The lack of fuel treatments in and around late-successional reserves probably has decreased the likelihood of success of the Plan. Furthermore, recent models of climate change effects project some of the greatest changes to occur in the driest parts of the Plan area.

A reassessment of current and potential future landscape patterns and dynamics at the province level would be beneficial. A reassessment would provide managers and the public with a clearer set of expectations for provinces and large landscapes. Many are confused at present about what to expect from the Plan in dry provinces and how management practices should differ across the diverse environments of the Plan area. It would also provide guidance for actions to reduce risks of loss of older forest to natural disturbances and clarify the tradeoffs associated with different management approaches for these dynamic landscapes.


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Figure 6-1—One-hundred-forty-year-old mature Douglas-fir stand in the western Oregon Cascade Range.


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Figure 6-2—Ninety-year-old mature Douglas-fir stand in the western Washington Cacade Range.


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Figure 6-3—Old-growth Douglas-fir, western hemlock forest in the Western Oregon Cascade Range.


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Figure 6-4—Old-growth Douglas-fir and western hemlock stand illustrating tall, deep canopies in the western Cascade Range of Oregon.

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Figure 6-5—Open old-growth ponderosa pine with a history of surface fires at Pringle Falls Experimental Forest in the eastern Cascades of Oregon.

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Figure 6-6—Dense old-growth ponderosa pine stand without history of recent low-severity fire at Pringle Falls Experimental Forest in the eastern Cascades of Oregon.

particular young and old forest stages can vary from 0 to 100 percent of a small landscape or watershed. At larger spatial scales, the amounts of different seral stages typically have a more restricted range of proportions because most disturbances do not cover entire provinces or regions (Wimberly and others 2000). For example, the amount of old-growth forest in coastal Oregon was estimated to range between about 35 and 75 percent of the province under the historical fire regime (Wimberly and others 2000). This range is termed the historical range of variation (HRV) (Landres and others 1999). This reference to historical disturbance regimes was used in characterizing the potential outcomes of the options considered in FEMAT (1993: IV-49 to IV-51).

The expert panel assessments in FEMAT were based on outcomes for older forest described in terms of historical abundance and diversity, ecological processes, and spatial pattern or connectivity under the historical disturbance regimes of the region. For example, the outcomes for abundance and diversity were described as (1) at least as high as the long-term average amount of late-successional forest, (2) below the long-term average but within the historical range that would be expected under past disturbance regimes, (3) considerably below the low end of the historical range of conditions, and (4) very low in abundance and may be restricted to just a few provinces or elevations within a province (FEMAT 1993: IV-49 to IV-53). The panels characterized the options by the likelihood that the policy option would lead to the outcomes described above. This characterization was done separately for the moist provinces, where fire frequencies were relatively low, and for the dry provinces, where fire frequencies were relatively high. For the moist provinces, the panels estimated a 77 percent likelihood of achieving outcome 2 under option 9; for dry provinces, this likelihood dropped to 63 percent.

The assessments (FEMAT 1993) set the general expectations and context for older forests under the Plan: it will probably lead to an outcome in which the abundance and ecological characteristics of late-successional forest at the scale of the Plan area fall within the range of what might have occurred under the historical disturbance regimes of the past; significant uncertainty exists about outcomes over the lifetime of the Plan; the uncertainty in outcomes is especially high in dry provinces, where decades of fire suppression makes it difficult to achieve outcomes based on disturbance regimes of the past.

What Are the Status and Trends and What Differences Were Found Between Expectations and Observations From Effectiveness Monitoring?

The older forest status and trend report (Moeur and others 2005) provides a wealth of information over the Plan's first 10 years. That report may be the most comprehensive monitoring of old-growth conditions that has ever been written. Despite the richness of the data sets, the monitoring timeframe is only 1/10 of the 100-year timeframe of the Plan, 1/20 of a 200-year return interval between lethal fires typical in some areas, and only 1/100 of the potential maximum age of a Douglas-fir tree (see appendix for scientific names). Consequently, these trends should be viewed with caution because they could be quite different in the next 10-year period.

The specific outcomes and expectations for older forest under the Plan can be divided into three major areas: abundance and diversity; process and functions; and connectivity.

Abundance and diversity—

Most of the findings from the status and trend report (Moeur and others 2005) are related to the abundance and diversity of older forest, where "older forest" is the term used to refer to mature and old-growth stands. The following findings are especially significant:

- The estimate of the amount of older forest depends on which structural definition is used—adding more structural criteria to the definition would reduce the area of forest that meets a definition because not all older forest stands possess all of the structural features associated with the general population of older forests.
- The area of older forest (as defined by medium- and large-diameter trees [>20 inches and 29.5 inches in diameter, respectively] with simple or complex canopies) on federal lands estimated from remote sensing at the Plan's beginning was within 10 percent of the value estimated in the recent monitoring analysis, which was based on improved remote sensing models and inventory plots.
- The Plan assumed that most of the remaining older forest in the Plan area was on federal land. Although some provinces have some significant areas of mature forest (medium- and large-diameter trees) on nonfederal lands, nearly 80 percent of the largest and most structurally complex class occurs on federal land. This assumption is supported by the new inventory information (table 6-1), which confirms estimates of earlier inventories (Haynes 1986, SAF 1984).
- Thirty-four percent of the federal land base was covered by older forest with medium to large trees and simple to complex canopies. Older forest with very large trees and complex canopies covers about 12 percent of the federal land base and is concentrated in forests west of the Cascade divide.
- The reserve system captured the most structurally complex portion of the remaining older forest; for example, the proportion of large multistoried old forest in reserves was nearly twice as high as in matrix lands.

Table 6-1—Area and percentage of older forest on federal and nonfederal[a] land

Province	Federal		Nonfederal		Federal land	
	ML	LMS	ML	LMS	ML	LMS
	– – – – – – – – – – – *Acres* – – – – – – – – – – – –				– – *Percent* – –	
California Cascades	356,778	24,656	320,507	26,035	52.7	48.6
California Coast	167,582	75,017	1,425,813	240,719	10.5	23.8
California Klamath	1,833,569	385,706	321,383	25,400	85.1	93.8
Oregon Coast	522,962	295,504	727,137	268,009	41.8	52.4
Oregon eastern Cascades	222,787	26,654	94,522	5,120	70.2	83.9
Oregon Klamath	719,296	384,597	233,374	86,557	75.5	81.6
Oregon western Cascades	1,909,647	733,603	268,008	60,476	87.7	92.4
Oregon Willamette Valley	4,644	0	194,992	0	2.3	0.0
Washington eastern Cascades	164,336	0	82,097	0	66.7	0.0
Washington Olympic Peninsula	612,770	284,444	140,968	28,485	81.3	90.9
Washington western Cascades	1,353,454	512,275	308,726	72,159	81.4	87.7
Washington Lowlands	108	0	256,755	0	0	0
Plan area	7,867,932	2,722,454	4,374,287	812,958	64.3	77.0

Note: Totals may not add because of rounding.

ML = medium and large conifers; LMS = large multistoried conifers.

[a] The area on nonfederal land was estimated by using a geographic information system with remote sensing vegetation layers of Moeur and others (2005) and a layer of federal and nonfederal forest land in the Plan area.

- Losses to older forest from stand-replacement natural disturbances, such as fire, were actually less than what was expected for the Plan area (0.18 percent annually vs. expected 0.25 percent) (FEMAT 1993) as a whole. However, within several of the dry provinces, rates of loss of older forest to wildfire were much higher than the overall average, and these provinces accounted for most of the losses to high-severity wildfire.
- The average net increase in older forest with a quadradic mean diameter (qmd) of >20 inches (1.9 percent average annual increase in the area of old forest) since the Plan began was higher than the 1.2 percent annual net increase expected in the ROD (the ROD estimate did not include California).[1] Some of this higher rate of increase was because much less old forest was cut in the matrix than the Plan originally called for (Baker and others, in press). This lack of logging, however, accounts for only about half of the higher net rate of increase. If logging of old forest in the matrix had occurred at the expected rate of 800 million board feet per year, I estimate that the net rate of increase of older

[1] The net annual increase of 2.2 percent in stands with a quadratic mean diameter (qmd) of at least 20 inches probably results largely from growth and development of natural stands with qmd greater than 17.7 inches in the 1990s. Natural Douglas-fir stands of this diameter would probably be 80 to 100 years old, assuming site class III (McArdle and others 1961). The immediate effects of thinning on the size distribution of plantations, and thus on qmd, might account for some of this increase, but most plantations on federal land were less than 40 years old in the mid-1990s and would be expected to have qmd of less than 13.8 inches at that time. Thinning from below to remove smaller diameter classes would not change stand structure enough to increase qmd beyond 20 inches, in most cases.

forest would have been reduced by about 19,000 acres/yr or about 0.3 percent per year. (This assumes a volume removal of about 42,000 board feet/acre).

- Rates of loss of older forest differed widely among provinces; annual rates of loss to high-severity fire ranged from 0.05 to 0.95 percent in dry provinces and 0.0 to 0.14 percent in wet provinces (table 6-2).
- Fifty-five percent of the area of older forest types occurred in climatic zones and vegetation types, in which relatively frequent low-severity fire or thinning is needed to maintain desired old-forest structures and to reduce the probability of high-severity fire (table 18 in Moeur and others 2005).

The status and trend results for abundance and diversity should be viewed with several cautions. First, the remote sensing and inventory plot data are not a complete picture of the ecological characteristics of the older forests of the region. Only broad classes of canopy size and canopy patchiness were used in inventories. Information about numbers of large trees, subcanopy trees, and large pieces of dead wood, for example, were not included. A more comprehensive analysis might reveal a different picture.

Second, the area lost to timber harvest logging (16,900 acres) and wildfire (102,500 acres) is probably underestimated because only disturbances larger than 5 acres were analyzed. In contrast, Courtney et al. (2004) in an owl status report estimated that almost 156,000 acres of owl habitat were lost to timber harvesting between 1994 and 2003. The status report estimate is almost certainly too high because it was based on timber harvest plans that were submitted by the USDA Forest Service (FS) and Bureau of Land Management (BLM) during consultation, and the agency does not typically update its database for what was actually implemented (Thraikill 2005). A large number of projects to harvest older forest in the matrix lands were not implemented because of legal challenges and other factors (Baker and others, in press). Furthermore, federal forest managers frequently submit plans that overestimate the area of owl habitat affected by project activities to give themselves flexibility in the implementation stage (Forrester 2005). Although the remote-sensing-based change analysis cannot detect very small patch disturbances, it has relatively high accuracy (88 percent) for small to large stand-replacement disturbances (Cohen and others 2002). Because most timber harvesting plans in older forest in matrix lands would use cutting units larger than 5 acres, the change analysis probably does not underestimate loss by a large factor.

Third, the net changes in older forest come largely from the gradual growth of the diameter of stands into the lower end of the 20-inch diameter class and not much from the development of old-growth forest with very large trees and complex structure. The relative high percentage increase comes in part because of a bulge in the size-class distribution of forests with diameters just below the 20-inch class. After this bulge moves into the >20-inch class, rates of increase in this forest size class will decline. Given the limitations of the change analysis, we do not know the actual net changes in old-growth forest that occur from losses to fire and timber harvest and increases from the development of mature forests into old-growth forest.

Processes and functions—
The effectiveness monitoring program was not designed to provide information about the status and trend in the processes and functions of older forest. Processes refer to ecological dynamics that lead to development and maintenance of old-growth forests. For example, rates of succession, gap formation, low-severity fire, productivity, decomposition, and so on are all important to the development of old-growth forest. Some process trends can be inferred, however. For example, the amount of low-severity fire in old forest in dry provinces is probably not enough to sustain old forests (for example, Ponderosa pine) that depend on fires with frequencies of less than 35 years (Agee 1993). Little data were available to support this hypothesis, but if historical rates had occurred, fires would have been widespread throughout the forests in these provinces. Data from the implementation monitoring report (Baker and others, in press) suggest that the area of forests

Table 6-2—Area and percentage of old forest lost to wildfire, and mean fire frequency in years between 1994 and 2003[a] for the entire Plan area and by province

Province	LM[b]	Forest-capable area[b]	LM	Loss to fire	Period	Annual rate	Decade rate	Frequency
	Percent	*– – – – – – – – – Acres*		*– – – – – – – – –*	*Years*	*– – – Percent*	*– – –*	*Years*
Oregon Klamath	34	2,104,367	715,485	47,600	7	0.95	9.5	105
Washington Eastern Cascades	5	3,347,553	167,380	3,700	6	.37	3.7	271
California Klamath	43	4,221,438	1,815,202	29,900	9	.18	1.8	546
Oregon Western Cascades	44	4,379,051	1,935,208	18,700	7	.14	1.4	724
Oregon Eastern Cascades	15	1,477,506	221,626	800	7	.05	.5	>1000
California Cascades	36	999,795	359,926	500	9	.02	.2	>1000
Washington Western Cascades	38	3,516,105	1,336,120	300	6	0	0	>1000
California Coast	47	357,822	168,176	0	9	0	0	>1000
Washington Olympic Peninsula	43	1,419,276	610,289	0	6	0	0	>1000
Oregon Coast	37	1,396,232	516,606	0	7	0	0	>1000
Oregon Willamette Valley	25	18,521	4,630	0	7	0	0	>1000
Washington Lowlands	5	2,173	108	0	6	0	0	>1000
Plan area			7,850,758	101,500	7.2	.18	1.8	560

Based on (Moeur and others 2005).

[a] Periods differ by province: California 1994-2003; Oregon 1995-2002, Washington 1996-2002.

[b] LM = forests with large and medium-size conifers (>20 inches d.b.h.) as a percentage of forest-capable area.

treated to reduce understory fuels either through prescribed fire or mechanical means was not high. The rates of other processes such as gap formation, regeneration, and nitrogen fixation are not known. The effects of invasion by nonnative species on old-forest development are also unknown.

The functions of old forest are those ecological characteristics that are of value to other organisms or humans. For example, old-growth forest provides ecological legacies (for example, large live and dead trees) used by organisms in open and young forests that develop following stand-replacement disturbances (McIver and Starr 2000). This function is operating largely as it would have under a natural disturbance regime. This observation is based on the assumption that few acres of old forest killed by stand-replacement disturbances (more than 120,000 acres) were salvaged logged, which would have been the standard practice when timber production was a major goal on the federal lands. We know little about other potential functions of older forest such as production of clean water and nitrogen fixation.

Connectivity—

Connectivity in the Plan refers to the degree to which the spatial distribution of older forest provides for movement of plants and animals between old-forest patches. Connectivity can be measured in many different ways and does not necessarily mean that the patches of old forest need to be physically connected to each other. Most organisms can disperse across areas that are not prime habitat, but some are better dispersers than others. The FEMAT defined connectivity in terms of distance between areas of older forest and the portion of older forest in the landscape. The expected outcome for connectivity was that the distances between large blocks of late-successional forest would be less than 12 miles on average (FEMAT 1993: IV-52). The status of connectivity over the entire region depends on the definition of old forest and the process examined. Connectivity for the mature and old types together appears moderate to strong, based on the fact that the average distance between large blocks of this type was 6 miles for most provinces and that the proportion of the landscape in old forest is above 25 percent. When older forest was defined more restrictively, that is, large multistoried, then connectivity was less but still within 12 miles for most provinces, except the California coast.

Are the Plan's Assumptions and Approaches Still Valid?

The Plan was based on many assumptions about natural forest ecosystems, management effects, and forest dynamics. If these assumptions are no longer valid, it could mean that the Plan will not work as intended, that it might be modified to achieve its goals, or even that the goals should be changed. The assumptions could change for several reasons: first, the status and trend of old forest might not be what was expected; second, new scientific findings could emerge from work outside of the effectiveness monitoring program that would change the validity of underlying assumptions; third, new perspectives about forest ecosystems might have emerged from new interpretations of existing scientific information. In reality, our assumptions about ecosystem management plans often change as a result of both new research studies and new interpretations. The status and trend summarized in the previous section do appear to meet Plan expectations. In the following sections, I address new scientific findings and perspectives that might be relevant to the success of the Plan.

Old-Growth Forest Definitions

The Plan used the term "late-successional/old-growth" to describe the older forest conditions that were of concern. This term includes the mature and old-growth stages of stand development, where old growth is defined as a stand containing large live and dead trees, a variety of sizes of trees, and vertical and horizontal heterogeneity (figs. 6-3 through 6-6). The mature stage of development occurs as trees approach their maximum height and crown diameter but lack the heterogeneity of older forests (figs. 6-1 and 6-2). In Douglas-fir forests, the old-growth stage typically occurs at 150 to 250 years after a stand-replacement disturbance and can persist with slow changes for an additional 500 years or more (Franklin and others 2002). The mature stage typically begins around 80 to 120 years of age in Douglas-fir forests. These age ranges and degree of structural development may differ in other forest types in the region. The mature stage of stand development was considered in FEMAT along with old growth because it could develop into old-growth conditions within the lifetime of the Plan, it can be structurally and compositionally similar to old growth, and, in some areas, the most ecologically valuable large patches of uncut forest were in the mature stage of stand development. Many of today's mature forests will become the old-growth of the future and are needed to maintain old growth over time.

Use of the term "late-successional" to describe older forest has caused some confusion. It was really intended to refer to both the mature and old-growth stages of development, but it is frequently used as if it were a stage that is separate from old growth, that is, the mature stage. This usage is confusing because the mature stage of forest development is actually not as successionally advanced as old growth. The status and trend report of Moeur and others (2005) uses the term "older forest" to refer to the mature and old-growth stages. This term is simpler and more descriptive of the conditions of mature and old forests than is the term late-successional.

Another source of confusion stems from the two ways that plant ecologists conceptualize vegetation change over time following stand-replacement disturbance: succession and stand development (Frelich 2002). Succession typically refers to a directional change in species composition over time where one or more species replaces others. Generally the species that come later are more shade tolerant and are often referred to as late-successional species, because they can regenerate in canopy gaps and maintain themselves within closed-canopy forests in the absence of stand-replacement disturbance. Stand development refers to population/structure changes as forests age. Stand development may or may not be accompanied by a change in species composition. For example, fire in ponderosa pine forests may simply regenerate new populations of ponderosa pine but not change species composition. Consequently, it is possible to have old growth (an aging population of trees and associated structures) composed of early-successional species (for example, ponderosa pine, aspen) and old growth that is composed entirely of late-successional species (for example, western hemlock, or grand fir). One could distinguish early-successional old growth from late-successional old growth.

The ecological characterization (with the exception of the terminology) of older forest in the Plan is generally valid, but since then researchers have become aware that the diversity and complexity of natural forests is greater than some of our conceptual models have portrayed. Our general scientific model of older forest and forest dynamics in general has become more refined as a result of studies of old-growth structure in Douglas-fir and other forest types (Youngblood and others 2004), old-growth stand development (Ishii and Ford 2001, Poage and Tappeiner 2002, Tappeiner and others 1997, Winter and others 2002), disturbance history (Weisberg and Swanson 2003), and from new perspectives on forest complexity and stand development (Franklin and others 2002, Spies 2004). Collectively, these studies lead to several important observations about older forests, which are described in the next several paragraphs.

Old growth is part of a multivariate continuum of forest structure and composition, and breaking this continuum up into classes is arbitrary (Spies 2004, Spies and Franklin 1991). This continuum can be divided into classes in various ways, and a larger variety of classes may be needed to capture the diversity of types than has been used previously (Franklin and others 2002).

For Douglas-fir forests, old-growth characteristics typically begin to emerge at 150 to 250 years following stand-replacement disturbances. These characteristics include trees greater than 39.4 inches diameter at breast height (d.b.h.), associated lower and midstory shade-tolerant trees, large dead trees (>49 feet tall and 20 inches d.b.h.), large fallen tree boles on the forest floor, a diversity of heights of foliage, and patchy distribution of canopy gaps and understory vegetation. On high-productivity sites, some of these characteristics can begin to appear as early as 100 years. Where the initial disturbance was patchy, structures characteristic of older forest can emerge much earlier, sometimes as soon as 80 years depending on how much was killed in the initial disturbance. Age can be a rough approximation for old-growth stands in the northern and coastal provinces of the Plan area where disturbances are relatively large and kill most of the trees. Where disturbance regimes are characterized by patchy low- to moderate-severity fires, however, stand age is not a very useful measure of old-growth condition.

Old-growth structure and composition can change over time within a stand. For example, in the dry provinces, old-growth ponderosa pine can succeed to old-growth pine and fir.

Not all old-growth forests share all of the same attributes or have the same expression of structural complexity. For example, fire-prone old-growth ponderosa pine forests have relatively open understories and patches of regeneration, whereas old-growth mixed-conifer forests in the same landscape have dense understories. These structural compositional differences affect stability, resistance, and ecological characteristics. For example, in the absence of fire, open, old-growth ponderosa pine forest can develop into dense mixed-conifer forests that have a lower resistance to high-severity fire than does fire-dependent pine old growth.

Old growth is a complex ecological concept that requires a multiscale perspective ranging from individual live or dead trees, stands or patches, and landscapes, to whole regions. At broad scales, the old growth is clearly part of a mosaic of open, young and mature forest types. A comprehensive strategy, which is currently lacking in the Plan, to conserve any one stage of this mosaic requires considering all stages (Spies 2004). Although the structures associated with these old-growth (for example, large live and dead trees, patchiness) typically develop and appear in old stands, they can also be found in young forests as survivors of disturbance. Thus, the ecological contributions of old growth can occur in stands of all ages.

Given the complexity of forest development and the concept of old growth, definitions used for inventory (Moeur and others 2005) can only be approximations. Inventorying the amount and distribution of old-growth forest by all of the attributes that have been associated with it and using the same inventory tools is impossible. For example, remote sensing can be used to estimate the size of trees in the upper canopy and characterize spatial patterns, but it cannot be used to estimate dead wood and understory patchiness. Inventory plots can be used to characterize the size distribution of live and dead trees, but they cannot be used to measure spatial pattern. Inventory information is a composite of surrogates from remote sensing (for example, size of canopy trees) or nonspatial structural information from inventory plots (dead wood and tree size distributions). For this reason the monitoring plan recommended a two-pronged approach—remote sensing and inventory plots—for assessing the amount and distribution of forest conditions (Hemstrom and others 1998).

The new perspectives on old-growth complexity underscore the need to adjust conservation and management strategies to forest types and environments. For example, old-growth goals and strategies could differ by province, potential vegetation type (plant association groups), and disturbance regime. The Plan recognized this complexity to some degree, but more could be done to incorporate it into practice. For example, specific older forest definitions are lacking for dry old-forest types and for younger forest stages or mixes of younger and older forests. Clarification of the definitions of older forest stages and their significance for the Plan is important for the following reasons:

The Plan is based on conservation of a particular stage or stages of older forest. Without a clear definition or set of definitions, the goals of the Plan become confusing and difficult to communicate.

Because forests are dynamic systems, conservation of a single stage, even a long-lived one, is really impossible without considering other stages and transitions among them. For example, many of today's mature forests will be the old-growth forests of the future, and today's old-growth forest may be the early-successional forest of the future. If the Plan focuses exclusively on one or more older stages, it may not sustain native biological diversity associated with other stages.

Current Amounts of Old Growth Compared to the Historical Conditions

Conservation concerns about biodiversity in this region stem from the observation that amounts of old growth and associated forest structures (large live and dead trees) have declined strongly over the 20^{th} century as a result of logging and wildfire (Bolsinger and Waddell 1993). Fire suppression has also contributed to the loss of some fire-dependent old-growth types. References to past forest conditions can be problematic, however, because forest landscapes are dynamic and the amount of any particular forest compositional or structural type will differ depending on the time and location of the observation. Recognizing these inherent dynamics, ecologists have developed the concept of historical range of variation (HRV), which is the range of variation in forest attributes that might be expected in a landscape over time under a particular disturbance regime (for example, frequency, type, and severity) (Landres and others 1999).

Historical range of variation in forest age or stage classes can be a useful context for understanding the state of present landscapes (Agee 2003, Wimberly 2002). For example, the percentage of old forest (forests >200 years old) in the Oregon Coast Range was estimated to range between about 25 and 75 percent of the forest area (Wimberly and others 2000). For forests more than 80 years old, Wimberly and others (2000) estimated the range to be about 50 to 85 percent. Today, the amount of old-growth forest containing 39.4-inches diameter trees, size diversity, and large amounts of standing and fallen dead wood is estimated to be around 1 percent of that province (Ohmann and others, in press). (The smaller proportion of old growth in Coastal Oregon estimated by Ohmann and others [in press] compared to Moeur and others [2005], probably results from the fact that Ohmann used a more restrictive structural definition.) In the central eastern Cascades of Washington, Agee (2003) estimated that multistoried old-growth forest covered 38 to 63 percent of the landscape. Comparable estimates of current amounts were not made in that study. Moeur and others (2005), however, estimated that the percentage of older forest in the eastern Cascades of Washington—an area that encompasses the Agee (2003) study—was about 12 percent, with older forest defined as medium and large trees whose diameter limits differ by species and site productivity.

The HRV was used in the ecosystem assessment in FEMAT to describe possible Plan outcomes. But the original evaluations of various options showed that reaching that range may not be possible in future landscapes given possible changes in climate and disturbance regimes. The concept of variation in amounts of old and young forest over time does have value in understanding the degree of change that has occurred and in setting general expectations for landscapes, where native biodiversity is a dominant management goal. Even with disturbance regimes and climate change, a range of forest ages and structures will typically be present in landscapes over time if disturbances are spread across all stages, which would usually be the case under natural disturbance regimes including fire, wind, insects, and disease.

The HRV studies have shown that landscapes the size of large national forests (that is, >1,235,527 acres) were unlikely to be completely covered by old forests (Wimberly and others 2000). For example, in the Oregon Coast Range, a mosaic of open, young closed-canopy and older stages is more likely (Nonaka and Spies 2005). Current policies on federal lands in wetter provinces could lead to more old growth than would be expected under the historical wildfire regime.

History of Development of Old-Growth Stands

Several studies in the Pacific Northwest have examined how old-growth stands have developed over time (Poage and Tappeiner 2002, Weisberg 2004, Winter and others 2002). In the moist provinces, these studies confirm the model set forth by Franklin and Hemstrom (1981) of stands with a wide range of ages of the dominant Douglas-firs, implying slow establishment after fire, a history of moderate-severity fire that results in regeneration of Douglas-fir, or both. Studies of stand development history are less common in the dry provinces. Where studies have been done, the range of age variation in the older trees is wide; old trees established almost continuously over several centuries as a result of frequent low-severity fires (Sensenig 2002).

Studies also indicate that many old-growth stands in the moist provinces developed from young stands with low stem densities compared with today's forest plantations (fig. 6-7). The densities of young stands will influence the diameters of the trees when they reach old age (Poage and Tappeiner 2002). Not all stands developed with multiaged old trees; some older forests have relatively uniform-aged canopy trees (Winter and others 2002), although this pathway seems to be less common across the Plan area than the multiaged pathway.

Much has been learned in the last 10 years about the diversity and role of fire in the development of old growth. Increasingly, the variation in disturbance regimes across the Plan area is appreciated (Brown and others 2004, Sensenig 2002, Weisberg and Swanson 2003). Although the role of fire in creating structural complexity in old growth was known for the dry types with frequent fire-return intervals, the role of fire in the west side was less appreciated. Typically, fire on the west side was largely seen as a destroyer of old growth. Recent research (Weisberg 2004) confirms the understanding that fire in mixed-fire-regime landscapes on the west side contributes to a particular spatial pattern and structure of old-growth Douglas-fir and western hemlock forests.

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Figure 6-7—Dense young plantation and old-growth stand in the western Oregon Cascades.

Silviculture to Restore Ecological Diversity and Accelerate Old-Growth Development in Plantations

The effects of thinning on the long-term development of old-growth characteristics in plantations are understood only from modeling studies and just a few years of experimental work. Retrospective studies of old-growth development have also provided insights useful to understanding how silviculture might affect old-growth development (Tappeiner and others 1997).

Results thus far show that thinning plantations is important to restoring structural and compositional diversity on federal lands. Dense young plantations (fig. 6-7) have lower species diversity than more heterogeneous young stands, and they may not develop old-growth characteristics like large trees and complex canopies as rapidly as less dense young stands. Thus, the goals of thinning are really twofold: diversify young stands now and accelerate the developing of old-growth characteristics in the future.

The literature supports the practice of thinning to increase species diversity in stands (Muir and others 2002). Many ecologists believe that thinning for biodiversity goals should seek to promote spatial heterogeneity in stands, rather than the uniform spacing and density of trees produced in thinning for timber production. Spatial variation in stand density creates a diversity of microsites and promotes species diversity. Leaving some areas of stands unthinned is important to provide the shaded microclimates favored by some species. For example, some species of bryophytes have been shown to decline in thinned areas compared with unthinned areas (Thomas and others 2001). The most effective spatial patterns of thinning in young stands to create ecological diversity are not known and probably vary across the Plan area. Caution needs to be exercised in applying the same spatial pattern of thinning in all areas and at all spatial scales, since scientific research on this practice is only in the early stages.

The effects of thinning on development of old-growth characteristics in plantations are only partially understood. Certainly, the growth of trees into larger diameter classes will increase as stand density declines (Tappeiner and others 1997). At some point, however, the effect of thinning on tree diameter growth levels off and, if thinning is too heavy, the density of large trees later in succession may eventually be lower than what is observed in current old-growth stands. In some cases, opening the stand up too much can also create a dense layer of regeneration that could become a relatively homogenous and dominating stratum in the stand. Furthermore, if residual densities are too low, the production of dead trees may be reduced (Garman and others 2003). Thinning should allow for future mortality in the canopy trees. Modeling studies indicate that thinnings in plantations could accelerate development of some old-growth characteristics by as much as 60 to 80 years, depending on the thinning regime and the age of the plantation at initial entry. Multiple thinning entries typically had more effect than a single entry.

Data from implementation monitoring (Baker and others, in press) are not adequate to evaluate the degree to which thinning operations were conducted in plantations in late-successional reserves. The implementation report indicates that a total of 287,414 acres was treated with partial removal, which includes commercial thinning but not precommerial thinning. If we assume that 30 percent of the late-successional reserves (based on the fact that most reserves contain a significant area of plantations) are in plantations suitable for thinning, then 2.2 million acres would potentially be eligible for thinning at the beginning of the Plan. If the treated acres reported by Baker and others (in press) were all thinnings in late-successional reserves, the amount of plantations thinned thus far would be about 13 percent of the total in 9 years, or a mean annual rate of 1.4 percent. At this rate of thinning, 71 years would be needed to thin all of the plantations at least once, and many would become too old for thinning (80 years) under the ROD before they were treated. Better data are clearly needed to evaluate the scope of the problem, but these limited data show that the rate of thinning may not be coming close to meeting the need and intent of the Plan. The implication is that many stands are exposed to blowdown and other disturbances, and could experience delayed structural development, jeopardizing their expected contributions to the biodiversity goals of the Plan. For example, if left untreated, the plantations would probably develop fewer very large trees (for example, >60 inches d.b.h.) in 100 to 200 years than occur in many of today's old-growth stands.

Why Do Some Species Occur More Commonly in Older Forests?

The distinctive plant, animal, and fungal communities of old-growth forests are typically associated with the habitat elements such as large trees, dead and down trees, and microclimates. Species associated with habitat structure include the northern spotted owl and the marbled murrelet. Another reason for the occurrence of species in old growth is simply the passage of time (Halpern and Spies 1995). Unique species may occur in old growth because enough time has elapsed since major disturbance that species with relatively weak dispersal powers can colonize and grow. Old-growth-associated species that disperse in this way include some vascular plants (Halpern and Spies 1995) and some lichens and bryophytes (Muir and others 2002). The implication for the Plan is that the occurrence of some rare species may not be accelerated through manipulations of forest structure. These species may simply require long periods to recolonize forests after stand-replacement disturbance. Such species would potentially be retained through natural and managed disturbances that leave structures (for example, large live and dead trees) and patches of forest (for example, patch retention, riparian zones) that become refugia from which the species could recolonize younger forests. The presence of some old-growth-associated species in predominantly young forest is associated with survival of large old trees (Sillett and Goslin 1999).

The Effect of Natural Disturbances on the Abundance and Spatial Pattern of the Late-Successional Reserve Network

At current rates of disturbance, the regional late-successional reserve network still appears robust, and losses would be replaced by growth of smaller diameter stands into larger diameter classes. In some dry provinces, however, the rates of disturbance have been higher, and the risk of substaintial loss of old forest is high. Although this risk was recognized by FEMAT and the ROD, implementing fuel reduction activities has apparently not been sufficient to reduce risk of stand-replacement disturbances. The risk assessment of FEMAT for these dry provinces is consistent with the fire condition class analysis (Schmidt and others 2002), which rated most of these areas as condition class 3, forests that have been significantly altered by fire exclusion and whose ecosystem components are at high risk of loss to fire. Under changing climate, increased threats to old forests from high-severity disturbances in dry provinces and other disturbances could lead to declines in the abundance of older forests resulting in increased gaps in the reserve network among and within provinces.

Fire-Prone Forests

The Plan distinguished two major fire-regime zones: the low-frequency, high-severity regimes of the northern and west-side provinces and fire-prone forests of the eastern and southern provinces (for example, eastern Cascades, Klamath, and southern Cascades) characterized by historical regimes with high frequency (fires every 10 to 50 years) and low to mixed severity (fig. 6-8). A third type was not included: the moderate- or mixed-severity fire regime (Agee 1993, Brown and others 2004). This type is typically found in the western Cascade provinces where the fire regimes are a complex mixture of stand-replacing and low-severity fires. It is also found in the fire-prone provinces where topography creates a complex mosaic of fire regimes (Agee 2003). The assumption that the approaches to conserving older forest (that is, standards and guidelines) should be different

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Figure 6-8—Patchy pattern of fire mortality resulting from the 2002 Biscuit Fire in southwest Oregon.

for the fire-prone and fire-infrequent regions of the Plan still holds. Although fuel reduction treatments such as cutting out small-diameter understory trees and prescribed fire are less necessary in the mixed-fire-regime areas because these forests were naturally more dense under the historical regime (Brown and others 2004), fire suppression in these types could alter their structure and function in the future (Weisberg 2004). Recent fire-history research supports a strategy in which management activities, such as thinning and prescribed burning, take into account variation within those major zones that result from climate, topography, and vegetation types (Camp and others 1997, Wright and Agee 2004).

The Plan recognized the increased risks to old growth in fire-prone forest types and identified that fuel reduction activities would need to be carried out in late-successional reserves to restore desired old-growth structures and reduce risk of stand-replacement fires in old growth and owl habitat. The assumption that fuel reduction will reduce probability of high-severity fire is still valid (Graham and others 2004), although many of the large fires in the region are limited more by climate than by fuel.

The standards and guidelines clearly allowed for manipulations to reduce risk of loss to stand-replacement fires in the dry provinces. Such manipulations were probably not at a high enough rate to significantly reduce the probability of stand-replacement fire in dense old growth in these provinces and restore the open old-growth types. In 2003, the only year for which data exist, it was estimated that fuel reduction activities were applied on 131,603 acres (Baker and others, in press). These data are very weak, however, in that they do not cover all forests in the Plan area and some of the data come from forests not entirely in the Plan area. A crude estimate of the upper limit of the annual area needed for treatment by mechanical means or prescribed fire can be made by estimating the area of fire-prone forest types (all ages and allocations) in the dry provinces (about 12 million acres), and assuming that 80 percent of these landscapes (9.6 million acres) were characterized by low-severity, high-frequency fires with a return interval of less than 25 years (Agee 1993, Taylor and Skinner 1998). If the low end of this frequency (25 years) was restored through active management on these 9.6 million acres, then 384,000 acres would need to be treated every year. That amount would be at least three times the area treated in 2003. The acres treated might actually have to be much higher initially because some stands might need to be treated mechanically before using prescribed fire. In practice, the area treated would be governed by landscape patterns of topography, accumulated fuel, and other objectives. Consequently, not all acres and allocations potentially eligible for treatment would need to be treated. Nevertheless, the total area treated is still probably much less than is needed. The relatively low rate of fuel treatments may have several causes including lack of funding, legal challenges, and risk aversion on the part of stakeholders, regulators, and managers. For example, the Fish and Wildlife Service concluded in one opinion that thinning around an owl nest would constitute “take” of an endangered species (Irwin and Thomas 2002). Everett and others (2000) estimated that a large proportion of area would need to be burned every year in the eastern Washington Cascades to maintain landscape heterogeneity and reduce hazard from high-severity fire.

The standards and guidelines for these provinces appear to limit thinning in old forests in reserves. For example, although FEMAT and the standards and guidelines in the Plan recognized the need for mechanical treatments and prescribed fire to reduce risk of stand replacement in these forests, they do not clearly state that large areas would need to be treated and that the dual goals of owl habitat and old-growth ecosystem diversity and function cannot be met without a landscape (midscale) strategy. These goals are often in conflict in the fire-prone provinces (Irwin and Thomas 2002) where owl habitat has increased in some forest types (for example, ponderosa pine) as stands have become dense, shade-tolerant tree species (for example, *Abies* spp.) have filled the understories, and fires have been excluded. The standards and guidelines first emphasized treating young stands in the late-successional reserves, but they are more cautious when it comes to treating older forests in reserves. For example, they stated that activities should “be focused on young stands,” but that actions in older stands may be appropriate as long as “they do not prevent the late-successional reserves from playing an effective role in the objectives for which they were established” and “should not generally result in degradation of currently suitable owl habitat.” This language is somewhat ambiguous and conflicting, especially at the stand scale, where simultaneously reducing risk of loss to large pines and Douglas-firs by thinning out mid- and lower-story trees is impossible without reducing the quality of owl habitat.

Landscape-level (midscale) strategies would identify key places for treatments, including repeated treatments. Without this approach, the likelihood of sustaining suitable owl habitat will remain low. It is important also to recognize that these treatments will not prevent losses of owl habitat to wildfire. Consequently, plans assume losses will occur and allow for replacement habitat over the landscape as a whole.

Salvage in Late-Successional Reserves After Stand-Replacement Disturbance

The Plan assumed that some old forests in late-successional reserves would burn in high-severity fire during the lifetime of the Plan and that the area and number of reserves was sufficient to maintain old-growth functions in spite of this loss. The goal of the reserves has clearly emphasized conservation and restoration of late-successional forest including old-growth forest. When those forests are burned by high-severity fire, 100 to 200 years or more may elapse before they return to older forest conditions. The ecological influences of old growth do not end with the death of the tree layer in a high-severity fire, however. Biological legacies of old growth, including dead trees, surviving live trees, and other organisms and organic matter carry over into the young forests and can persist for many decades as the new younger forest develops (Harmon and others 1986). For example, significant amounts of dead wood from the previous stand can be found 100 years later in postfire stands, and trace amounts can be detected in some 200-year-old stands (Spies and others 1988). The amount and duration of this legacy wood varies greatly with species, climate, and disturbance history. The "connected old-growth network" is more than a spatial concept—it is also a temporal one, in which developmental stages are connected to each other through surviving and slow-decaying structural and compositional components of previous stages.

The Plan was somewhat vague, however, when it came to the role and management of these postfire stages in reserves. The standards and guidelines about salvage in late-successional reserves acknowledge that guidelines are intended to prevent "negative effects on late-successional habitat while permitting some commercial wood volume removal." They go on to state that some salvage may actually facilitate habitat recovery (for example, making it easier to regenerate the site) or reduce the risk of future stand-replacing disturbances.

The ROD could be interpreted in at least two ways:

- Salvage is permitted only for ecological goals that maintain or enhance late-successional habitat with commercial wood volume as a byproduct; or
- A removal of "conservative" quantities of salvage material is permitted for commercial objectives.

Several arguments can be made in support of the first interpretation. First, although a high-severity fire would kill an old-growth forest, it does not remove all of the late-successional habitat elements that will be in the young forest for many decades. Thus, removing any large dead trees would diminish amounts of late-successional habitat elements in young forests. Second, these early-successional stages, with many large dead trees, contribute to an important but not often stated goal[2] of the Plan, which is to maintain biological diversity. The stage of natural stand development after stand-replacement disturbance in old forest is particularly rare. It was not common in landscapes under a historical disturbance regime (Nonaka and Spies 2005), but occasionally it was widespread after large fires. This stage has become very rare in an era of fire suppression, salvage logging, and plantation forestry. Third, salvage of dead old-growth trees would not be consistent with the precautionary principle (Kriebel and others 2001) that underlies much of the Plan's design and implementation.

At the time of the Plan, the ecological values of dead wood were known (Harmon and others 1986, Thomas 1979). Although little new research has been conducted on the ecological effects of salvage logging after stand-replacement disturbance since the Plan was adopted, the ecological value of large dead trees in early-successional forests has been reaffirmed in several synthesis papers on the subject (Beschta and others 2004, Lindenmayer and others 2004, McIver and Starr 2000). In addition, no empirical evidence has emerged that salvage logging can improve the desired ecological diversity of young forest or the development of late-successional forests later in succession. Brown and others (2003) found some indication that removing large dead trees could reduce the spread and severity of reburns that often follow high-severity fires. The magnitude of this effect is unknown, and the indirect effects of salvage logging—including soil disturbance and increased fine fuel from slash left on the site—may outweigh any benefits of removing large fuel.

Several arguments can also be made for the second interpretation of the standards and guidelines for salvaging in reserves. First, option 9 in FEMAT allowed salvage for disturbances larger than 24.7 acres. Second, the language in the standards and guidelines implies that, where salvaging is done it should "retain snags that persist until late-successional conditions have developed" (C-14). In fact, very few of the fire-killed trees will persist until the next late-successional forest develops in 100 to 200 years. Most trees will decay and disappear well before the next older forest (Spies and others 1988); however, some small fraction of biomass could persist. Thus, most of the smaller diameter trees would not persist for long periods and would not meet persistence criterion. Third, the allowance of some commercial wood production in this case would meet one of the President's principles, which was to provide for economic

[2] See appendix B-1 in the ROD (USDA and USDI 1994).

and social values after meeting the criteria of the environmental laws. Removing trees for commercial purposes could also be justified in supporting the management infrastructure needed to carry out the broader goals of ecological restoration, which are typically underfunded.

The primary benefit of the large snags is in the first few decades, first as standing dead trees and in subsequent decades as fallen trees. Smaller diameter trees (for example, <20 inches d.b.h.) and species with high decay rates (for example, hemlock and true firs) could be salvaged with much less effect on biological diversity. The particular effects of different rates of salvaging operations on ecological functions in reserves are generally unknown. Consequently, scientifically identifying amount of salvaging that "should not diminish habitat suitability now or in the future" is probably impossible (C-13) for the foreseeable future.

In conclusion, the ROD did leave open the possibility of salvage logging for commercial purposes in the reserves after large stand-replacing disturbances, but it also clearly states the ecological value of dead and live trees in these situations. The ROD did not indicate any specific amounts of salvage logging that would be compatible with the major goals of the Plan. Essentially, no new scientific studies have emerged on either side of the debate that can shed light on the essential question: How much salvaging could be done before habitat suitability is diminished now or in the future? New studies outside of the Pacific Northwest indicate that widespread salvage logging can negatively affect many taxa and ecosystem processes (Lindenmayer and others 2004), but widespread salvaging was not the intent of the salvage guidelines in the ROD. An interpretation of the ROD that no salvage logging for commercial purposes should occur in late-successional reserves would largely be based on the general ecological values associated with dead trees in postfire vegetation, and application of the precautionary principle. An interpretation that allowed limited salvaging in reserves would be based on the judgment that the economic benefits of commercial production would be greater than the negative effects on ecological values associated with reserves.

Reforestation in Late-Successional Reserves Following Wildfire

Natural regeneration typically occurs after fire in most of the forests of the region. Consequently, reforestation activities in late-successional reserves following fire are often not needed. However, the densities of regeneration can vary widely across the region, and in some situations reforestation may be warranted. For example, where seed sources of dominant conifers, such as ponderosa pine and Douglas-fir, have been lost through historical cutting of individual large trees and recent high-severity fire, some planting may be needed. Studies in southwestern Oregon showed that natural conifer regeneration can be difficult to obtain on many sites because of moisture limitations and competition with sprouting shrubs and trees (Minore and Laacke 1992). If timber production is a goal, planting and treatments of competing vegetation are clearly needed to establish conifer plantations. The amount of planting needed to restore structurally diverse forests in dry landscapes is not known, however. Historical studies of old forests have shown that natural regeneration and development of young stands took many decades, and the densities of trees in these young stands were often relatively low. In some dry landscapes, open brush fields probably persisted for long periods as trees slowly invaded. These shrubby areas were important to the general biological diversity of the landscape and can contribute nutrients such as nitrogen by nitrogen-fixing shrubs. If recent fires have had a much higher proportion of high-severity damage than in the past, then it is possible that vegetation development after these fires would be quite different than under natural disturbances, where patches of surviving old trees and seed sources would have been common in postfire landscapes. Under these circumstances, some reforestation could be justified for ecological goals.

The Plan Is Based on the Geographic Distribution of a Single Species

The Plan assumed that a region defined by the range of a single species, the northern spotted owl, could form the basis of a cohesive unit for ecosystem management. The region encompassed a wide range of ecosystem types and disturbance regimes. The Plan attempted to deal with variability in that area through province and watershed analyses, geographic variation in standards and guidelines, and adaptive management areas distributed across the Plan area. In the first decade of implementation, however, the diversity of approaches appears to be much less than was intended. Consequently, the use of a single species to define the boundaries of a complex ecosystem plan is difficult to defend ecologically or administratively.

Treatment of the Matrix for Both Ecological Values and Commodity Production

The ecological value of leaving large live trees as individuals and groups as a way of supporting older forest species in areas managed for timber production has been supported by habitat studies of individual species (Sillett and McCune 1998). In addition, fire history studies show that many old-growth stands may have gone through periods in which the stand was partly or almost completely killed by disturbance. Approximating some of the characteristics of these natural disturbances with green-tree retention harvesting approaches in the matrix is consistent with this information. Despite the technical and scientific basis of commodity production from the matrix, harvest of older forest did not occur. No new scientific evidence has emerged that the standards and guidelines for the matrix, which allowed cutting of old trees, would not meet the ecological and viability goals of the Plan.

The Reserve Strategy of the Plan

The Plan has sometimes been criticized for using a reserve-based approach. At other times, it has been criticized for not placing all of the remaining old growth into "true protection," such as a park or wilderness area. These criticisms imply that "reserve" means one thing—a no-touch-no-management zone and that a reserve approach is either not valid for dynamic forests or is the only way to conserve the old growth. The reality is that conservation biology and the Plan rest on various kinds of reserves and protected areas. Most of the protected areas allow active management for ecological goals, and the matrix allows active management for a blend of commodity and ecological goals. As implemented, however, the differences among the land allocations have been much less than intended.

A reserve is defined as an "area of land especially dedicated to the protection and maintenance of biological diversity, and natural and associated cultural resources, and managed through legal or other effective means" (IUCN 1994). It has also been defined as, "extensive tracts managed primarily to perpetuate natural ecosystems and related processes, including biota" (Lindenmayer and Franklin 2002: 75). According to these authors, reserves are to provide:

- Examples of [natural] ecosystems, landscapes, stands, biota, etc. and contribute to natural evolutionary processes.
- Strongholds for sensitive species (for example, particular habitats or species sensitive to human intrusions).
- Control areas against which to measure effects of human activities.

Reserves are an administrative or legal vehicle to reach an ecological goal rather than the goal itself. In other words, species and ecosystems do not respond to why people's activities vary across a landscape—only that they **do** vary. The ecological goals for reserves are typically so generally defined "for example, natural processes and ecosystems" that specific measures of success do not exist other than the goal of keeping direct human effects out of the area. If "natural"—little or no human presence—is the goal, then all ecological states, species, and ecosystems that develop are equally desirable. Ecological conditions in a reserve may conflict with more specific vegetation or habitat goals for species or landscapes, however. Northern spotted owl habitat in fire-prone landscapes is a good example of this conflict.

The Plan contains many types of reserves or protected areas. All of these reserve strategies are consistent with internationally recognized approaches to conservation (table 6-3). A similar although simpler set of protection classes has been developed by the Gap Analysis Program of the U.S. Geological Survey (http://www.gap.uidaho.edu/).

Note that several of these protected areas allow active management to achieve ecological goals. For example, the late-successional reserves are closest to International Union for Conservation of Nature (IUCN 1994) category IV, which allows active management for habitat and conservation objectives. Note also that the last category of protection, code VI, actually allows for producing wood products. In fact, the entire federal forest landscape has many of the attributes of IUCN-protected category VI because under the Plan, biodiversity goals are paramount, sustainable use of forests is also a goal, and no large commercial plantations are allowed (matrix standards and guidelines with green-tree retention do not create standard commercial plantations).

The notion of reserves implies the existence of a surrounding landscape that is not reserved or is a "matrix" of other uses, typically commodity production. Normally, the matrix is the dominant land area and the reserves are embedded in it. In the Plan, however, the matrix in most provinces is not the majority of the federal landscape. The Plan has created a situation in which the "matrix" in the sense of the dominant landscape is really the reserves, and the commodity production areas are minority land allocations that are embedded in those areas. In another sense, the true matrix for the federal land is the nonfederal land, where commodity production is typically the major goal. The implication of this structure is that, because this reserve network covers very large areas, many of them in fire-prone forest types, losses of old forest will undoubtedly happen regularly within the network. Because the reserve system is so extensive, it was hypothesized that it would be robust to these losses. In most forest regions of the world, reserves are a relatively small part of the forest. Consequently, losses to habitat within these small areas can be devastating; it is less of a problem here, although, in some provinces the sizes of the disturbances can be large. The assumption that the reserve network was sufficient to meet the Plan's goals has never been examined at province or larger scales as part of its adoption. At the landscape level, only the Blue River Landscape Study (Cissel and others 1999) addressed this issue.

The federal matrix was intended to allow stand-replacement logging for commodity production, but the logging has not been done to the degree expected. Consequently, the matrix and the reserves have been treated similarly in terms of regeneration harvesting and the rate of planned, stand-replacement disturbances. Consequently, the production of diverse early-successional forests, which would have been a byproduct of green-tree retention logging practices in the matrix, has not happened. In dry provinces this early-successional habitat has developed from wildfires; in wetter provinces, however, this habitat has probably declined, generally reducing seral-stage diversity on federal lands.

Forests are dynamic but reserve boundaries are not. This reality raises the question of whether a reserve-based strategy is the best approach. The Plan's reserves are not no-touch zones, especially in the fire-prone provinces, and the large size of the reserve network means that it is relatively robust against high-severity disturbances. Still, examining alternatives would be helpful, to see if more effective strategies exist to meet the Plan's ecological goals.

One approach might be to move reserve boundaries after a stand-replacement wildfire. Some adjustments to reserves can be consistent with the Plan (FEMAT 1993: VIII-30; USDA and USDI 1994: E-18) and adaptive management. However, moving late-successional reserve boundaries as a standard response to high-severity fire in late-successional and old-growth forests was not part of the Plan

Table 6-3—Correspondence of Plan land allocations to International Union for Conservation of Nature (IUCN) protected-area categories

	IUCN characteristics			
Plan allocation	**Closest IUCN category**	**Code**	**Goal**	**Human intervention**
Research natural area	Strict nature reserve	Ia	Science	Minimal
Wilderness (29 percent of Plan area)	Wilderness area	Ib	Natural character and absence of human impacts	Minimal
National park including wilderness	National park	II	Ecosystem protection and recreation	Localized impacts, restoration
Administratively withdrawn (7 percent of area)	Natural monument	III	Specific natural feature	Possibly restoration
Late-successional reserves (44 percent of area)	Habitat, species management area	IV	Conservation through management intervention	Restoration, active management for ecological goals only
No counterpart in Plan other than some Native American sites	Protected landscape	V	Desired cultural (historical) landscapes containing human interactions with nature	Traditional or historical (pre-industrial) uses
Entire federal landscape including reserves (~50%) and matrix (~20%)	Managed resource protected area	VI	Sustainable use of natural ecosystems with biodiversity protection paramount	Limited harvesting allowed to provide a sustainable flow of natural products, no large commercial plantations

and may require a reexamination of network and other components (for example, key watersheds, aquatic habitat). The interconnectedness of the Plan's conservation strategies[3] makes it difficult to modify any single part of it without potentially compromising its goals.

Alternatives to the Plan's reserve strategy exist, and their suitability depends on the particular desired balance between ecological and commodity goals, the decision process used to manage the forests, and the natural dynamics of the forest landscapes. The following are several possibilities:

- Structure-based management. This approach would have no fixed reserves and the entire landscape would be managed for both ecological and commodity goals to be achieved through variable timber rotations ranging from standard industrial rotations to rotations of 150 years or more (ODF 2001). Green-tree retention may be practiced with regeneration harvests. This approach was briefly considered during FEMAT, but it was rejected for several reasons: to meet commodity objectives would require the logging of large areas of existing old growth; it was unknown how well sensitive species, processes, and habitats could be maintained entirely through managed systems; risks to viability of late-successional species were considered too large, it would not produce the full diversity of old-growth forest conditions (for example, forests older than 400 years) and functions that currently exist in the region; and the road systems required to maintain active management across the landscape could be detrimental to the other goals.
- Temporary reserves. Under this approach, a reserve would exist until the trees are killed in a stand-replacement disturbance. At this point, the reserve would revert to the matrix allocation or an adaptive management area. Unless new reserves were designated, the approach would be problematic for Plan goals because, over time, the forest would change from reserves to more active management, changing the mix of biodiversity and commodity goals.
- Hybrid of disturbance-based management and reserves. The Blue River Landscape Study is an example of this approach (Cissel and others 1999), which demonstrates how watershed analysis in the Plan could have been used to revise the spatial pattern of allocations and management prescriptions based on knowledge of fire history and landscape dynamics. Reserves are designated, but the boundaries and their landscape distribution are fundamentally different from the Plan's. Riparian reserves are blocked into larger patches, leaving matrix areas larger and more operationally feasible. The matrix is managed on longer rotations (with greater live and dead tree retention) producing less of a gap in midaged stands (80 to 200 years) in the long run than under the Plan in which the matrix would largely be less than 80 years and the reserves would largely be over 200 years old. This plan assumes continued cutting of some older forest but at a lower rate than would happen in the Plan. Although this approach has less area in reserves than does the Plan, it produces less timber than would be expected under the fully implemented Plan because of long rotations and higher retention of live trees.
- Reserve all remaining old growth or mature and old growth. Under this approach all old-growth forests—including those in the matrix—would be reserved from logging. The timber production goals would have to come from younger natural

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[3] Option 9 was an attempt to achieve efficiency through coordination of aquatic and terrestrial strategies and ecosystem and species strategies.

forests and existing plantations. The effects of this alternative would depend on the definition of old forest, the expected rate of timber production, and the kind of activities permitted in the reserves. This approach would have some elements of option 1 from FEMAT, in which most of the remaining old forest was reserved and the largest numbers of species were considered to have sufficient habitat. The long-term effects of this approach are uncertain. If plantations were the main location of regeneration harvest, such an approach might perpetuate undesirable spatial patterns that were set earlier under different forest management objectives. If pattern goals were part of this strategy, some plantations would have to be excluded from the timber production base, which would reduce expected timber outputs. This approach would require a different strategy in the fire-prone provinces where open, fire-dependent old-growth types have largely been replaced by late-successional types with dense understories of shade-tolerant conifers. In many areas, selective logging of large pines and Douglas-firs has removed the large tree components. Thus, reserving the old-growth in these landscapes means locating the large remaining trees and using them as foci for restoration activities that would include thinning, mechanical fuel reduction, and prescribed fire. Timber production in these types would have to come from smaller diameter trees that were removed in the process of protecting old, large trees. Of course, to meet owl habitat objectives, areas of dense late-successional old-growth forest would have to be retained.

- Landscape restoration in fire-prone provinces. The most urgent need for improving the effectiveness of the Plan lies in the fire-prone provinces. The standards and guidelines for reserves and matrix do not adequately address the landscape perspectives that are really needed to conduct ecosystem management in these areas. This approach is not simply a matter of abolishing all land allocations and using a "shifting mosaic" approach to management. The owl's habitat requirements necessitate zoning the landscape both to provide the appropriate amount and spacing of owl habitat and to prioritize fuel treatments based on plant association groups and the landscape ecology of fire. We do not know how close the current pattern of Plan allocations comes to landscape zoning where the goal is to reduce risk to loss of owl habitat from fire and pathogens. It seems likely that a more effective landscape strategy could be developed, especially given the losses of owl habitat that have already occurred in many provinces and the fact that matrix lands currently appear to be managed as though they were late-successional reserves (that is, little cutting of older forest for timber goals). Of course, any landscape plan would be subject to the unpredictable elements of natural disturbances, which can only be treated in a probabilistic sense. High-severity fires would still occur under more effective fuel reduction strategies, but management actions could reduce their effects.

Developing a new strategy for implementing the Plan in the fire-prone provinces is beyond the scope of this document, but whatever strategy is developed could include:

- More explicit guidelines on balancing the area of dense older forests for northern spotted owl habitat and for other species, and the risks of loss of those habitats from the stand-replacement disturbances that are more likely in dense forests. For example, how large should the habitat areas be, and how should they be placed to reduce risk of loss of habitat areas? How should the habitats be placed relative to the potential vegetation (plant association groups) and disturbance regimes?

- A strategy to retain large-diameter trees for ecological and social reasons; for example, what diameters and species should be retained in restoration activities in matrix and late-successional reserves?
- A more explicit approach for restoring open old-growth forest types and landscape patterns and reducing the probability of high-severity fire. This approach would be more explicit and emphatic about the need for active management, including mechanical treatments, prescribed fire, and reestablishing seed sources of desired tree species over large areas and across all allocations. For example, what stand-level prescriptions should be used, and how should they be distributed across landscapes?
- A more explicit plan for providing a sustainable flow of commodities and revenues that could be used to finance restoration programs and support local communities in these provinces.

The Role of Nonfederal Land

The Plan addressed management only on federal land. Although relation to nonfederal land was considered, FEMAT did not analyze conditions or plans for nonfederal land other than for timber production. The Plan essentially did not assume any contribution of nonfederal land to late-successional goals. The FEMAT did call for working with nonfederal landowners to coordinate management across watersheds and provinces as part of an “integrated approach to ecosystem management for nonfederal lands” (FEMAT 1993: VIII-39). No evidence suggests that this occurred to any large degree, however.

The Plan made several fundamental assumptions about nonfederal forest land.

1. The nonfederal land would contribute little to the late-successional goals.

The inventory data suggest that this is not entirely true. The status and trend report shows that significant areas of stands with medium-sized trees (>20 inches d.b.h.) exist off of federal lands (table 6-1). This is particularly true in the coastal provinces of Oregon and California, where federal lands occupy a minority of the area and where highly productive private forests occur that can grow stands with average stem diameters of 20 inches in 60 to 70 years (McArdle and others 1961). Large-diameter (>29.5 inches) multistoried forest occurs predominantly on federal land, although at least 20 percent occurs off of federal land, probably largely on other public ownerships. On these other ownerships, this older forest is more likely to be in smaller patches or have had a history of logging that reduced other structural elements, such as dead wood. Within the nonfederal land, medium and large multistoried forest covers about 17 percent and 3 percent, respectively, of the forest-capable acres (Moeur 2004).

Some research has also shown that this assumption (No. 1) is not necessarily true (Holthausen and others 1995, Spies and Johnson 2003). In fact, some nonfederal forest management practices have incorporated elements of late-successional conservation objectives. For example, state forests in coastal Oregon have adopted plans that would increase the amount of mature forest in that landscape (ODF 2001) over what it would have been if those lands were managed under an industrial forestry model. Simulation projections showed that indicators of old-growth forest structure and spotted owl habitat will increase strongly on those state forests in the northern Coast Range, although they will not reach the amounts on federal lands in that province (Spies and others, in press). Private forest lands will not contribute much to older forest habitat values, but the area of stands with large-diameter trees may show small increases as a result of stream-side protection rules in Oregon and Washington, and some habitat conservation plans for northern spotted owls are on those lands.

2. The federal land alone could meet the biodiversity needs of focal species and ecosystems without contributions from the nonfederal lands.

This assumption also is not necessarily true. Research in coastal Oregon shows that the highest potential coho habitat is not on federal land, where stream gradients are relatively steep, but on private lands and especially on nonindustrial private lands, where stream gradients are gentler and more conducive to coho habitat (Burnett 2004). Furthermore, in coastal Oregon, about one-third of moderate- to high-quality marbled murrelet habitat is on nonfederal land in the Coast Range of Oregon, and almost 60 percent of moderate- to high-quality red tree vole habitat is on nonfederal land. Some ecosystem types that are regionally threatened, such as oak woodlands, are primarily on nonfederal land as are many large river flood plains and wetlands.

3. Federal land alone could meet Plan goals in spite of contradictory influences from nonfederal lands.

The assumption that activities on adjacent nonfederal lands would not negatively influence desired conditions on federal lands is questionable, but it remains untested in provinces, landscapes, and watersheds dominated by nonfederal lands. This assumption is especially questionable on BLM land. For example, in the Oregon Coast Range, 70 percent of BLM land falls within 3,280 feet of nonfederal land (Spies and others 2002). Here, forests on federal lands may be at greater risk of invasion from nonnative species, diseases, and fires that may originate on other ownerships with higher densities of roads, seed sources for nonnative species, sources of fire ignition from human activities, and fuel configurations that facilitate the spread of fire. The magnitude of these influences has received relatively little study, but it could be high in some areas.

The Plan also made implicit assumptions that emphasis on protecting and restoring late-successional habitats and species would not jeopardize the viability or diversity of other species or ecosystems not directly associated with older forest or, in other words, that a plan that focused on older forest would also provide for other elements of biological diversity. Although it was not stated explicitly, it may have been assumed that nonfederal land would provide for other non-late-successional species that were not provided for on federal land.

This assumption is not necessarily valid. Again, research in the Oregon Coast Range indicates several trends. First, successional diversity will decline on federal land as succession moves stands and landscapes toward dominance of late-successional habitats. This trend will be mitigated by any regeneration harvesting in matrix areas and by natural stand-replacement disturbances from fire, wind, and pathogens. In some provinces, however, stand-replacement disturbances will be infrequent, and many landscapes will become dominated by older forests. Second, some vegetation types will decline on all ownerships because no forest plans will provide for them. For example, hardwood forests in coastal Oregon are projected to decline because federal plans exclusively emphasize late-successional forests and private forest lands emphasize the growth of conifer plantations. Although hardwoods could develop as a result of unplanned disturbances, such as landslides, debris flows, and wildfire, most management plans have worked to greatly reduce the incidence of these disturbances. Third, diverse early-successional forests with old-growth legacies are also expected to decline. Disturbances that create these legacies are suppressed on all ownerships, and postdisturbance practices on nonfederal ownerships typically work to reduce early-successional structural and compositional diversity. Although a goal for the federal land is to achieve high amounts of older forest, forest history studies and simulation modeling suggest that, under natural disturbance regimes, landscapes were not totally dominated by old forest, and forest landscapes were characterized by an intermixing of early-, mid- and late-successional forest types (Nonaka and Spies 2005).

The Plan also explicitly assumed that a comprehensive, integrated assessment of forest ecosystem management could be conducted by focusing primarily on late-successional forests with the federal land. Given the interconnectedness of forest ecosystems and landscapes, this focus means that the ecosystem assessment for the Plan was incomplete. For example, it did not assess the consequences of the development of a bifurcated forest condition across the region in which federal land is dominated by older forest managed primarily for biodiversity goals and nonfederal land is dominated by younger forest managed for timber and other goals. This emerging pattern has implications for regional biodiversity, spread of fire and other disturbances, and protecting biodiversity on nonfederal lands. For example, when considered at a regional scale, the biodiversity protections on federal land may allow for timber production on nonfederal land with minimal habitat protection for some endangered species. On the other hand, landscape- and province-scale analysis shows that because of the mix of forest goals, some habitat types (for example, hardwoods, diverse early-successional vegetation) may strongly decline, with uncertain effects.

Climate Change Effects

Climate change was identified as one of the sources of uncertainties in meeting the outcomes described in the species and old-growth ecosystem assessments. The assessments for option 9 in FEMAT stated the likelihood of not achieving the most desired outcomes at about 20 to 30 percent. Climate change effects on Plan outcomes have not been formally analyzed. The consensus of the scientific community that climate change will occur has probably broadened since the Plan was developed (Oreskes 2004). The significance of these changes to the Plan is still uncertain.

The most recent climate-change scenarios for the Pacific Northwest include (JISAO 1999):

- Increased moisture stress followed by a decline in the area of forest land as a result of drought, and increased disturbances from insects and fire. These would largely be at the current margins of forest and nonforest plant communities (for example, East Cascades).
- An initial decrease in summer moisture stress as a result of higher precipitation, leading to an initial expansion of forests at the margins, followed by increased moisture stress and forest dieback as temperatures rise further.

Keeton and others (in press) pointed out that the second scenario probably is less likely than the first because summer precipitation would have to increase substantially (20 to 30 percent) for it to improve the typical summer moisture deficits. In either case, climate change effects within the Plan area are most likely to be at lower elevations, in drier provinces at ecotones between forest and nonforest areas. Many of these effects would be manifest as increases in disturbance frequency and severity of fires, wind, disease, and insect outbreaks.

Considerations for the Plan

The Plan, whose outcomes were expected to evolve over a century, is already making a difference. After 10 years of monitoring, the status and trends in abundance, diversity and ecological functions of older forest are generally consistent with expectations. Although the total area of older forest has increased, and overall losses from wildfires are in line with what was anticipated, losses to fire are high within the fire-prone provinces. Given the relatively short time for monitoring and the lack of reliable information about future losses from high-severity wildfires and climate change, significant uncertainties remain about the long-term trends in old forests.

Information from implementation monitoring suggests that rates of fuel treatments and restoration of structure and disturbance regimes in fire-dependent older forest types have been considerably less than is needed to reduce potential for losses of these forests to high-severity disturbance and successional change. Restoration activities in plantations are apparently also less than what is needed in moist provinces.

Landscape management strategies that balance reducing fuels with maintaining owl habitat have not been developed, but they could reduce the potential for future high-severity fires that destroy both owl habitat and the large conifer trees that serve as the building blocks of old-growth forest restoration.

Reexamination of the Plan's reserve strategy and alternatives indicates that active management in reserves, both dry and wet forests, would restore ecological diversity and reduce the potential for loss from high-severity fire.

Monitoring trends and reevaluation of Plan assumptions do not indicate a compelling reason for major changes to reserve boundaries in moist habitats at this time. In dry provinces, however, new landscape management strategies could be evaluated to determine if they would reduce risks of loss of older forest and owl habitat compared to what is currently in the Plan.

Given that the Plan has not been implemented entirely as intended (for example, the matrix is essentially being managed similarly to the late-successional reserves) alternative landscape-level strategies to the Plan could be considered in an adaptive management context to determine if other approaches might better meet the goals of the Plan.

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