

# Fire History and Landscape Restoration in Douglas-fir Ecosystems of Western Oregon

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For thousands of years fire has been a major, natural disturbance in the forest landscape from the Cascade Range westward to the coast in Oregon and Washington (Agee 1993; Brubaker 1991). Viewing the landscape of the central western Cascades in Oregon from a high point, one can see that fires of variable intensity and areal extent have created a complex mosaic of forest patches (Morrison and Swanson 1990).

In the past, fire was an integral part of the ecosystem, affecting wildlife habitat, forest stand dynamics, soil properties, and watershed hydrology. Even nineteenth century observers Gifford Pinchot and John Muir recognized the profound importance of fire in these forests (Pinchot 1899). They noted that the most obvious fire effect was the abundance of the west-side Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*). Large Douglas-fir trees are much more fire-resistant than competing species, such as western hemlock (*Tsuga heterophylla*), which gradually replace the fir in the absence of fire or other major disturbance. Large Douglas-fir have often survived repeated low- to moderate-intensity fires over the centuries (Morrison and Swanson 1990). Douglas-fir also benefits from severe fires since it readily recolonizes heavily burned landscapes (Agee 1993).

Fire suppression since the turn of the century and logging since about 1950 have changed the extent and role of fire on public lands in Oregon's west-central Cascades (Morrison and Swanson 1990). In these landscapes, the historic fire regime has generally been replaced by (1) fire exclusion and patch clearcutting or (2) fire exclusion and no logging, as in "natural" areas. This paper deals primarily with restoration concerns in the landscapes with previous patch clearcutting, but some of our findings also pertain to restoration of the fire process in unlogged forests.

Exclusion of fire (Pyne 1982) and its replacement by patch clearcutting (Spies and others 1994) as the major disturbance type have affected forest ecosystems over millions of hectares in western North America. Recently, attention has been focused on effects of the resulting changes in landscape patterns and potential approaches to reduce some of the undesirable effects on habitat (Harris 1984; FEMAT 1993).

Harris (1984) described approaches that include conserving old-growth forests and working to connect it with corridors, but did not try to apply this to a particular landscape. FEMAT (1993) developed a plan based primarily on reserves and rather fixed prescriptions for surrounding lands. FEMAT did not prescribe restoration of natural-fire-created landscape patterns, except to the limited extent that may be accomplished by old-growth forest reserves. Restoration of fire and concomitant benefits to stand structure and composition, fuels, and forest health have received recent attention (Wright and Bailey 1982; Walstad and others 1990). Though restoration ecology has seen significant recent advances focused on the site scale (Jordan and others 1988), landscape-level restoration is not well developed in concept or practice (Baker 1994).

We discuss the range of scales of fire effects and present the Augusta Creek Project as an approach to restoring fire-created landscape patterns to portions of a landscape in which timber harvest is allowed in the Northwest Forest Plan.

## Scales of Fire Effects

Fire affects ecosystems at the microsite to continental scales. We will briefly discuss the stand to landscape scales of fire effects in the western Cascades of Oregon. At the local site scale, fire effects include altered stand composition and structure, nutrient cycling, and other system components. Fire can kill none, part, or all of the plants in different canopy layers, consume varying amounts of the forest floor and heat the soil to a wide range of temperatures, depths, and durations. Vegetation composition and structure of the succeeding stand are controlled by the surviving plants and the organisms that they and other site conditions allow to colonize.

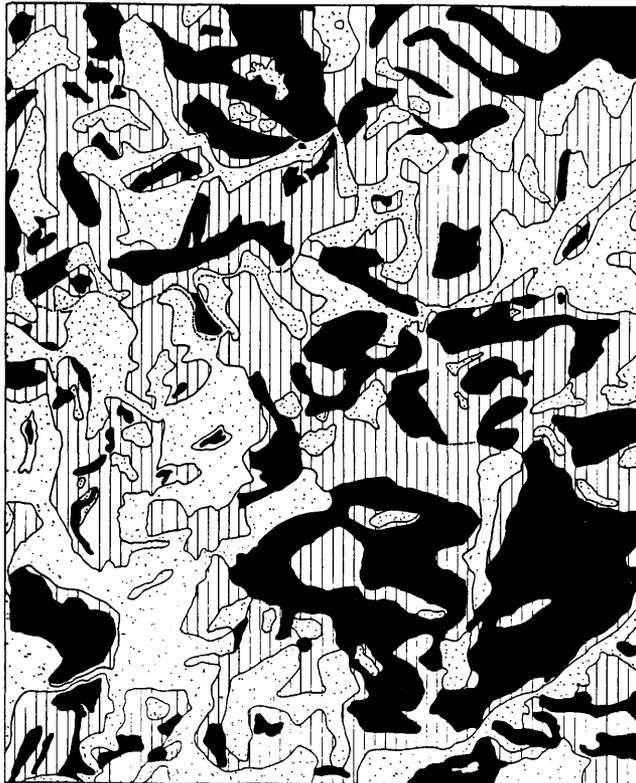
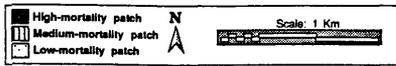
At the hillslope scale, fire may create landscape patterns by leaving many more survivors in a moist riparian zone or north slope than on a drier south slope or ridge, and it may leave no survivors in a steep draw where upslope winds fan flames and convex topography concentrates heat.

At a small landscape scale, fire occurs at varying frequencies and creates a mosaic of patches and corridors of varying amounts of surviving vegetation. Morrison and Swanson (1990) have documented this for the Deer Creek area in the western Oregon Cascades (fig. 1). Similar patterns are found in the Augusta Creek Project area.

At a large landscape scale, we know little about the spatial age patterns in stands created by the natural fire regime. At

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**Figure 1**—Spatial variation in fire severity as reflected in tree mortality, 1800-1900, in the Cook-Quentin study area of Morrison and Swanson (1990).

this scale in the Pacific Northwest, fire regimes probably vary significantly. Examples would be across part of the Cascades from the foothill forests adjacent to the Willamette Valley to the crest of the Cascades.

Patterns at all these scales are important to wildlife habitat, stream habitat, biomass productivity, and landscape susceptibility to future disturbances such as floods. Baker (1994) has examined ways in which fire could be reintroduced to create landscape patterns similar to the natural ones, but reintroduction of fires of large historic sizes (100-10,000+ ha) is not possible outside wilderness areas and parks in this region. Even within the larger parks where prescribed natural fire policies have been adopted, fire size and severity are greatly constrained. The Augusta Creek Project examined one way tree cutting can be used in place of fire to produce a dynamic landscape with some of the important natural landscape features obscured by fire suppression and lost by the pattern of clearcuts. We do not claim that timber cutting can fully or adequately replace the role of fire. Broadcast burning in conjunction with harvest cutting can return some of the effects of fire, but we have not yet considered this option. Perhaps if land managers begin applying fire to more of the landscape, as suggested by Williams (1995) and Mutch (1994), this treatment can be added.

## The Augusta Creek Project

A landscape analysis and management plan, based on the disturbance regime prior to Euroamerican settlement, were developed for the 7,700 ha Augusta Creek area (Cissel and others 1994; Cissel and others, in preparation; Wallin, in press). About 50 percent of the project area is protected as Wilderness, Roadless Area, Wild and Scenic River Corridor, lands having unstable soils, and special elk management areas in the Willamette National Forest Plan. We did not consider changing their designation or cutting in these areas. We developed an alternative management plan for the remaining area including changes to the riparian reserve system designated in the Northwest Forest Plan (Espy and Babbitt 1994). This landscape design includes a mixture of approaches—wilderness area management, species conservation, landscape restoration, and commodity production—distributed in various combinations across the landscape.

### Goals and Assumptions

There is a growing awareness that to sustain human uses of an ecosystem, the ecosystem itself must be sustained. Our main goal in the Augusta Creek Project was to develop a landscape management approach that used past landscape conditions and disturbance regimes to provide key reference points and design elements for future landscape objectives (Swanson and others 1993), while meeting the objectives of the Northwest Forest Plan (Espy and Babbitt 1994). A premise of this approach is that native species have adapted to the dynamic changes of habitat patterns resulting from disturbance events over thousands of years, and the probability of survival of these species is reduced if their environment is maintained outside the range of historical conditions. Similarly, ecological processes, such as nutrient and hydrologic cycles, have historically functioned within a range of conditions established by disturbance and successional patterns. Management activities that move structures and processes outside the range of past conditions may adversely affect ecosystems in both predictable and unforeseen ways.

A second key component of our management strategy recognizes that existing conditions must be integrated with this historic template to meet long-term objectives. Human uses (for example, roads in riparian areas, widespread clearcutting, a major dam, and portions of a designated Wilderness and unroaded area) have substantially altered conditions in the project area and in the surrounding watersheds.

### Analytical Process

Our analytical process involved four sequential phases as summarized below. Results from any one phase, however, could trigger a return loop to a preceding phase. Work in each of these phases was conducted in the context of the larger surrounding watersheds and was designed to link to management activities.

In the first phase, past and current conditions, processes, disturbance regimes and human uses were analyzed. The larger context of the surrounding watersheds was taken into account. This watershed analysis was similar to watershed analyses being implemented as part of the Northwest Forest Plan (Espy and Babbitt 1994).

In the second phase, results from the first phase of the analysis were used to develop landscape management objectives and prescriptions for specific portions of the planning area. Landscape management objectives are qualitative and quantitative statements that describe conditions we wish to see across the landscape in the future. These objectives were based on the range of "natural" variability of forest conditions as interpreted from fire and other disturbance history studies, and modified where current conditions were outside the range of past conditions. In areas where timber cutting was allocated, landscape objectives were translated into prescriptions that established cutting frequencies, intensities, and spatial patterns. These objectives were based largely on natural fire frequency and severity and the resulting spatial patterns. General prescriptions for low-severity fire were also developed.

In the third phase, landscape objectives and prescriptions were used to develop spatially and temporally explicit portrayals of potential future landscape and watershed conditions. Spatial pattern objectives were used to map blocks, termed "landscape blocks," where timber cutting and prescribed fire will occur. These blocks were used for long-term timber harvest scheduling according to the prescribed frequency and intensity of cutting for each landscape area. Maps of forest composition and structure were then projected for 400 years, using a 20-year time step.

In the fourth phase, these maps were used to evaluate a wide range of ecosystem processes and indicators including landscape composition and pattern, plant and animal habitat, and human uses. A combination of quantitative and qualitative methods were used to compare the new landscape design to conditions that would result from application of standards, guidelines, and assumptions in the Northwest Forest Plan (Espy and Babbitt 1994) prior to adjustments based on watershed analysis.

## Phase 1—Analysis of Conditions, Processes, and Uses

A fire history study revealed fire patterns within the planning area over the last 500 years. Plot-level dendrochronologic data collected with the methods of Morrison and Swanson (1990) were used to map 26 fire events (fig. 2). The fire-event maps and field observations were used to describe and map fire frequencies, severities, and spatial patterns of nine general, fire-regime mapping units (fig. 3). The fire event maps were also used to reconstruct and analyze vegetation patterns within the same 500-year period so they could be compared with managed patterns.

Several approaches were used to analyze the aquatic system and hillslope-to-stream connections (Cissel and others, in preparation). Past landslides and debris-flows and relative potential for future occurrences of these events were mapped from aerial photographs, existing maps, and field surveys. Relative susceptibilities of the landscape to rain-on-snow peak flows and contributions to summer base flows were mapped. A time-series analysis of aerial photographs spanning the past 40 years were used to assess riparian vegetation dynamics and disturbance history.

Both prehistoric and contemporary human uses were described and mapped (Cissel and others, in preparation). Prehistoric and historic data for the general area were employed to construct a map showing probability of past use by native people. Current human uses include hiking (two trails), camping (three campgrounds), angling, hunting, and harvest of timber and special forest products (for example, ferns and other greenery for the floral industry).

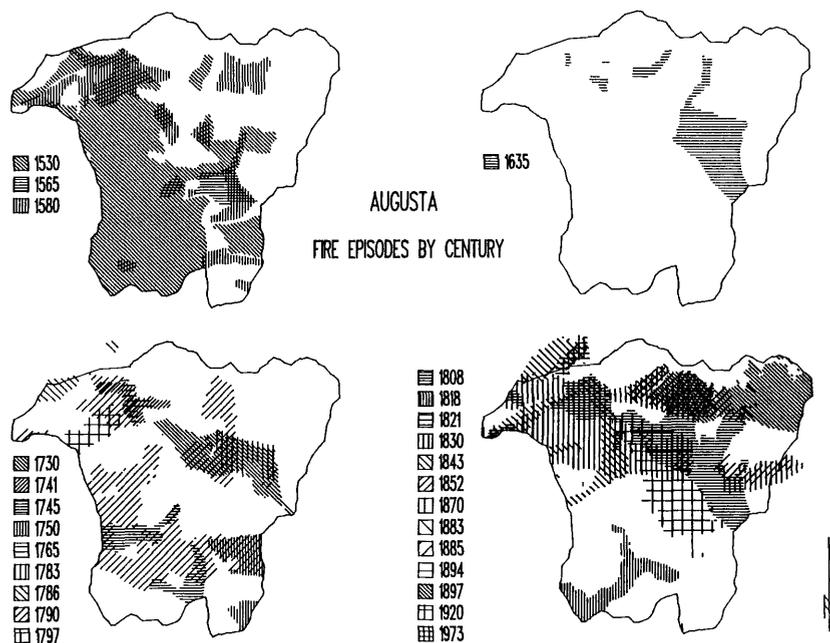


Figure 2—Fire episodes by century in the Augusta Creek study area (Cissel and others, in preparation).

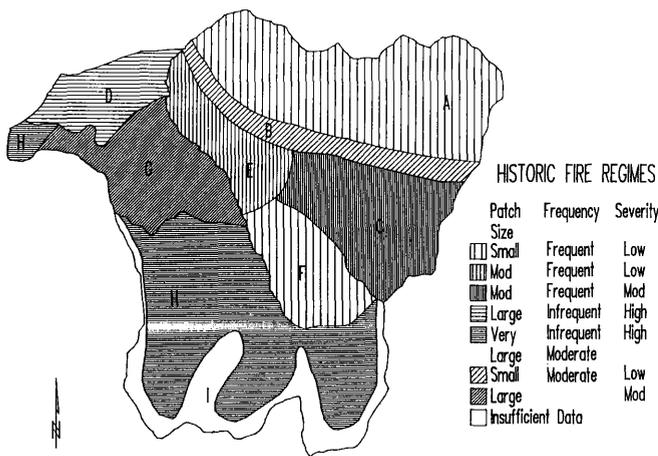


Figure 3—Fire regimes from the fire history study (Cissel and others, in preparation).

## Phase 2—Landscape Objectives and Prescriptions

The planning area was subdivided into three general categories so that specific landscape management objectives and prescriptions could be developed: (1) large reserves as specified by the Willamette National Forest Plan, (2) landscape Management Areas where timber harvest was prescribed, and (3) an aquatic reserve system.

**Large Reserves**—Several reserves were established in the Willamette National Forest Plan and they comprise about 50 percent of the Augusta Creek Study Area. Objectives and prescriptions for these areas imply a “natural” succession approach, with the exception of part of the unroaded area where active management was prescribed to maintain high-elevation meadows. Prescribed natural fires were encouraged where feasible.

**Landscape Management Areas**—Four Landscape Management Areas were established at the small landscape scale to reflect different fire regimes (fig. 4) in areas where timber harvest was allocated. Management objectives and prescriptions were described based upon the range of historic conditions. Rotation ages (100-300 years) were derived from fire frequency information; retention levels of trees to remain after treatment (15-50 percent) were based upon fire severity interpretations (fig. 4). Prescriptions for low-intensity fires were derived from fire regime descriptions and integrated with timber harvest patterns and schedules.

**Landscape Blocks**—Landscape blocks that reflect hillslope scale of the natural disturbance regime were established within Landscape Management Areas to provide a link to project (harvest unit) planning. Block size, boundaries, and the amount of green tree retention reflect natural fire patches (surviving trees) in those areas. Since all of one block is treated in one time period, large block size results in more interior habitat and reduced edge in comparison to the small cutting units of the dispersed cutting system used in the past decade.

**Aquatic Reserves**—Aquatic reserves were then established (fig. 4) based upon the likely frequency, intensity, and spatial pattern of future timber harvests, watershed processes, the larger surrounding context, and the degree to which the landscape has been altered by past human use (for example, dams, roads, timber cutting). These reserves were meant to be zones of minimum disturbance. We chose a reserve-system design that complemented the landscape objectives and was consistent with interpreted “natural” patterns. Small-watershed reserves comprised of both riparian and upslope habitats were positioned throughout the basin, such that different habitat types and topographic/disturbance regions were represented in headwater, mid-basin and lower portions of the drainage, and such that species of concern (for example, torrent salamander) were protected. Aquatic reserves included large riparian corridors along both sides of all major, valley-bottom streams (fig. 4). These

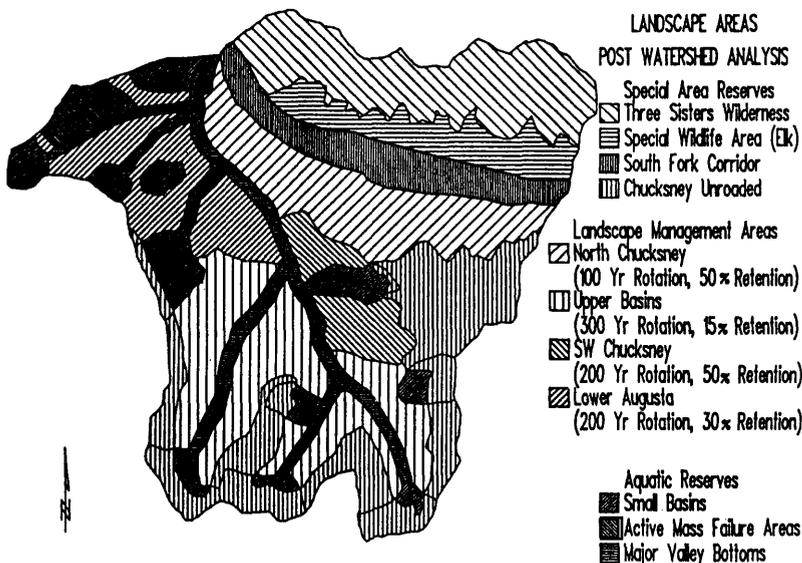


Figure 4—Landscape management areas under the Post-Watershed Analysis Approach (Cissel and others, in preparation).

areas, in which older forests survived past fire events, parallel the stream and include the stream, adjacent floodplains, and riparian vegetation. These corridors link the small-watershed reserves.

### Phase 3—Projection of Future Conditions

Maps of future landscape and watershed conditions were developed by simulating the growth of existing forest stands using a simple stand-age model in a Geographical Information System (GIS). Following timber cutting, blocks were reset to specific stand conditions, according to a timber harvest schedule determined by the landscape objectives and prescriptions for the area, and growth was simulated again until the next scheduled cutting. A set of maps depicting future landscape conditions for each 20-year time interval was generated for the next 400 years. These maps show a gradual change in the landscape from the relatively fragmented forest of today to one dominated by larger blocks and containing a wider array of stand types, as described in the landscape objectives. By year 100, the future landscapes appear significantly different from the existing landscape, and continue to gradually change before reaching a dynamic equilibrium in year 200.

### Phase 4—Evaluation

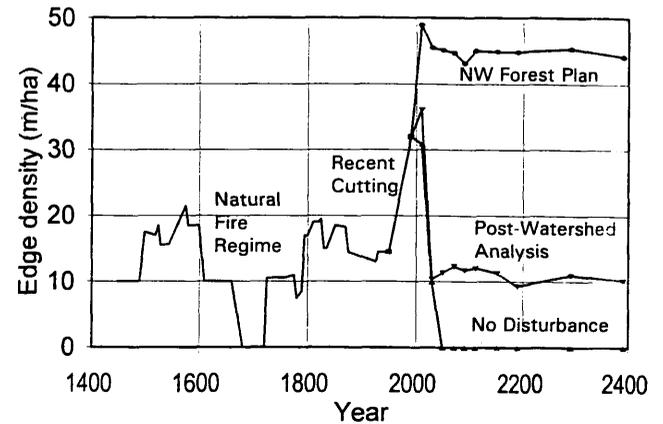
We evaluated this landscape design, which we termed the Post-Watershed Analysis Approach, by comparing it to a future landscape generated by application of standards, guidelines, and assumptions in the Northwest Forest Plan (Espy and Babbitt 1994) prior to adjustments based on watershed analysis (Cissel and others, in preparation). This contrasting landscape design was dominated by the extensive Riparian Reserves buffering all streams, and an 80-year timber harvest rotation on most upland areas. Harvest areas maintained a relatively light level of green tree retention (15 percent). We evaluated landscape composition and pattern; amphibian, bird, mammal, fish, and aquatic processes; peak and low stream flows; disturbance processes (fire, wind, landslides, insects and diseases); and long-term timber yields using quantitative and qualitative techniques.

### Effects on Landscape Pattern

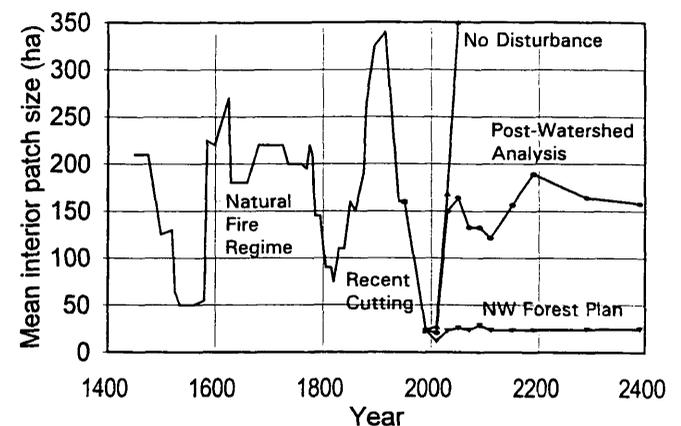
Most differences between the two approaches resulted from the strikingly different landscape patterns. Larger patch sizes with a greater amount of interior habitat (lower amounts of edge) characterize the landscape developed under the Post-Watershed Analysis Approach in the area subject to timber cutting (figs. 5 and 6). This landscape pattern remains within the range of natural variability in terms of edge density and interior habitat whereas that of the Northwest Forest Plan Approach and a No Disturbance Approach (no logging and continued exclusion of fire) do not. This reflects treating relatively large landscape blocks and managing on long rotations in selected landscape areas in the Post-Watershed Analysis Approach to approximate, respectively, patch size and mean fire interval of the natural fire regime.

The No Disturbance Approach produces a landscape outside the range of natural variability by these measures (figs. 5 and 6). In a few decades it would provide no early successional or edge habitat. The No Disturbance Approach is shown only to compare landscape patterns and was not otherwise evaluated.

These graphs reflect only the 50 percent of the landscape outside of protected areas (wilderness, etc.) to better show differences in approaches. The management plan is for the whole study area and this is the scale at which organisms



**Figure 5**—Temporal variation in edge density between open-canopy (0-40 years old) and closed canopy (>40 years old) forest over the last 500 years of the natural fire regime (pre-1970), during recent clearcutting (1970-1990), and under three potential future management approaches. This figure depicts changes only for the 50 percent of the study area outside of protected areas (wilderness, unroaded, etc.).



**Figure 6**—Temporal variation in interior habitat (inside a 100 m buffer) between open canopy and closed canopy forest as further defined in the caption for figure 5. Mean interior habitat for the No Disturbance Approach reaches 1,170 ha in 40 years and is not shown on the graph. This figure depicts changes only for the 50 percent of the study area outside of protected areas (wilderness, unroaded, etc.).

and processes with larger ranges and scales will perceive it. When the whole study area is included, the edge density of the Northwest Forest Plan and Post-Watershed Analysis Approaches equilibrate to about 36 and 17 m/ha, respectively, within 40 years. Note that the Northwest Forest Plan Approach is still outside the range of natural variability (as high as 50 m/ha). When the whole study area is included, mean interior habitat per patch under both approaches reaches 300 ha or more within 40 years. The large areas of reserves raise interior forest habitat to the upper end of the range of natural variability.

## Effects on Forest Structure and Species

The Northwest Forest Plan and Post-Watershed Analysis Approaches were evaluated for effects on features in addition to landscape patterns. Under the Post-Watershed Analysis Approach, higher levels of habitat features, such as green trees, snags, and downed logs, would be found in patches where timber harvest occurs, and a greater range of habitat conditions would be distributed throughout the planning area. This results from the larger blocks, longer rotations, and higher levels of green-tree retention in areas where timber harvest is allocated, and less land in linear aquatic reserves. Greater numbers of microhabitat features in areas harvested for timber, greater landscape connectivity, more interior habitat, and more refugia were felt to benefit many amphibians, birds (including the northern spotted owl), and mammals in the Post-Watershed Analysis Approach.

In contrast, the Northwest Forest Plan Approach leads to a two-toned forest pattern in the 29 percent of the analysis area subject to timber cutting. Here old forests develop along all lower slope positions, while most upper slope positions contain relatively young, structurally simple stands. This results from an intricate network of sharp-edged Riparian Reserves, relatively short rotations, and relatively low levels of green-tree retention in the upslope areas. Maximum protection of aquatic systems from timber harvest was provided by Riparian Reserves along all streams. Edge-using species were found to benefit from this design.

Little difference between approaches was evident for many processes and species. Disturbance processes (for example, landslides and flood events), stream flows, aquatic processes, species that use a wide range of habitats, and long-term timber yields were very similar between the two approaches.

The Augusta Creek example incorporates important features of the natural disturbance regime and landscape pattern into a management plan. We did not attempt to recreate all features of the natural disturbance regime, however; to do so would have been impractical. Under the Post-Watershed Analysis Approach there will be less variability: riparian corridors will not be harvested and old-growth will not vary from 5-80 percent, as occurred under the natural fire regime. The large wildfires (>10,000 ha) that occurred occasionally will not be mimicked. Timber harvest will produce many fewer snags and downed logs than did natural fires. Also, minimal use of fire will occur, but that could change if manager capabilities and funding for prescribed fire improve.

## Implementation Status

Project-level timber sale planning and watershed restoration projects have been initiated in the Augusta planning area. The interdisciplinary team is using this landscape analysis as a starting point and expects to implement as much of the Post-Watershed Analysis Approach as possible within the guidance of the Northwest Forest Plan (Espy and Babbitt 1994). It appears that full implementation may require amending the Northwest Forest Plan. The Blue River Ranger District is now working on a watershed analysis and plan for the Blue River watershed, similar to the one we describe here for Augusta Creek, for the Central Cascades Adaptive Management Area where no amendment will be required.

## Conclusions

Clearly it is possible to incorporate important features of the natural disturbance regime, landscape pattern, and stand structures into management plans. We offer the Augusta Creek Project as an example, and a great variety of plans different from ours are possible. The basic concept is that management choices, such as frequency of silvicultural treatments, can be based to a significant extent on the corresponding attributes of the natural disturbance regime. The objective is to retain habitat with stand structures, spatial arrangements, and disturbance frequencies within the range of natural conditions. This, we assume, would retain native species if applied over adequately large areas.

The concept of managing landscapes within the range of past conditions and the associated implications for landscape pattern restoration have not been subjected to public discussion. Acceptance may be more likely where fire suppression has caused the greatest undesirable ecosystem changes. This could be indexed as the period of effective fire suppression divided by natural fire recurrence interval. In the near-term we need more landscape analyses and management plans, such as the Augusta Project, with follow-up implementation to test operability and effectiveness of these concepts.

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