Concluding Remarks

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The 88-year photo sequences, descriptions of historical changes, and the initial results from ecosystem-based management treatments at Lick Creek portray a dynamic, ever-changing forest. The goals of ecosystem-based management at Lick Creek are to continuously maintain an open forest containing old growth as well as younger age classes of ponderosa pine. Half a century ago, Weaver (1943) and Biswell (1963) recognized that ponderosa pine forests were dependent on frequent low-intensity fires and that forest managers need to substitute prescribed fire for historical fires, often in combination with other fuel treatments and silvicultural thinning.

Evidence from Lick Creek shows that despite repeated silvicultural cuttings since the early 1900's, thickets of understory conifers (ladder fuels), down woody fuels, and litter fuels tend to increase in the absence of fire. Similarly, old-growth ponderosa pine/Douglas-fir stands show dramatic increases in understory conifers and fuel accumulation with fire exclusion (Arno and others 1995, 1997). At Lick Creek, the 1907 to 1911 and 1952 to 1980 partial cuttings were followed by vigorous regeneration of ponderosa pine. The 1990's ecosystem-based management treatments that included underburning have already been followed by natural regeneration of ponderosa pine with fewer Douglas-fir, whereas the cut/no-burn areas have a higher proportion of Douglas-fir regeneration, much of it established before the logging treatments.

In the early 1900's, foresters were concerned that an increase in Douglas-fir at Lick Creek would result in proliferation of dwarf mistletoe. Dwarf mistletoe outbreaks are not evident at the photopoints, probably because of frequent cuttings that deliberately removed a higher proportion of Douglas-fir. In contrast, in some stands at Lick Creek where Douglas-fir became abundant soon after the early 1900's cuttings, dwarf mistletoe has reached epidemic levels. Throughout much of this region, removal of large pines and exclusion of frequent fires has often resulted in second-growth forests dominated by Douglas-fir so severely infected that they appear incapable of producing large, long-lived trees. Dwarf mistletoe infestations produce bushy "witches brooms" that are highly flammable and increase the intensity of fires.

Another result of greater stand densities and increased proportions of Douglas-fir in this forest type has been increased defoliation by western spruce budworm (Anderson and others 1987). Tree mortality from root pathogens such as *Armillaria* spp., *Heterobasidion annosum* (formerly *Fomes annosus*), and *Philinus weirii* shows a similar trend related to the post-1900 structural and compositional changes in the ponderosa pine/Douglas-fir forest (Byler and others 1990). Comparable changes in stand structure and related forest health problems linked to fire exclusion have been identified in ponderosa pine forests throughout much of the Western United States (Clark and Sampson 1995; Covington and others 1997). Restoration treatments have been attempted in many areas, but usually the treatments and their effects have not been monitored and evaluated. Most research studies have examined only a narrow set of treatment effects. Prescribed burning has been studied, but usually not in combination with the cutting treatments necessary to restore a more natural stand structure before burning.

The observations and studies at Lick Creek are useful because they combine a long record of stand conditions and responses to a variety of silvicultural regeneration cuttings and thinnings, different burn prescriptions, and multidisciplinary studies of treatment effects. The 1990's treatments incorporated combinations of silvicultural cutting and prescribed fire carried out over a few hundred acres in an economical manner. The cut/no-burn treatments left large amounts of advanced regeneration of Douglas-fir, which will probably dominate the understory of the future stand. The low-, intermediate-, and high-consumption burns were successful in removing most of the small firs and in achieving significant fuel reduction with low levels of overstory tree mortality. The high-consumption

burns were followed by moderate bark beetle-caused mortality that created additional small openings. The high-consumption burns represent the driest conditions usually acceptable for prescribed underburning.

A flush of available nitrogen followed cut and burn treatments. Some was evidently utilized by the postburn vegetation, which was then heavily grazed by deer, elk, and moose. Resprouting willow was browsed so heavily that it has been unable to grow vertically except where it was protected in wire cages. With so little of this burned lower elevation ponderosa pine forest available, and with high elk and deer populations, browsing use becomes concentrated on areas where nutritious browse is available.

It is a daunting challenge to restore the fire-dependent forest at Lick Creek after nearly a century of fire exclusion and having missed about a dozen natural fire cycles. Fuels have accumulated, trees may be experiencing growth stagnation related to overstocking and lack of sufficient nutrient cycling, and fine roots may be growing close to the soil surface and thus vulnerable to fire damage. Invasive nonnative plants are established and likely to increase with any disturbance. The evidence from Lick Creek and other areas, however, suggests that even well-designed silvicultural cuttings not accompanied by fire are inadequate for sustaining wildland ponderosa pine/Douglas-fir ecosystems. Prescribed fire can control the excessive number of saplings and reduce surface fuels, recycle nutrients in a semblance of natural processes, and reduce the risk of severe wildfire (Scott 1998).

"Preservation," protecting the stand from both cutting and fire, is another alternative, but this approach exacerbates problems of growth stagnation and vulnerability to severe damage from wildfire and insect or disease epidemics. Some people argue that preservation represents a conservative approach to maintaining a semblance of the natural ecosystem, but this fails to recognize that these ecosystems were historically dominated by plants and animals adapted to frequent low-intensity fires, not to fire exclusion. Moreover, preservation will likely eventually result in an unusually severe wildfire, which may have damaging effects, for instance, in triggering accelerated erosion or mass invasion of nonnative vegetation.

Because of the excessive stocking of mid-sized trees, returning fire without a prepatory silvicultural cutting would either be ineffective (failing to thin the stand) or too destructive (causing mass mortality) (Arno and others 1996). Once the initial restoration treatments have been completed, however, it should be easier to maintain the stand in some semblance of natural structure at low risk to severe wildfire or insect/disease epidemics by continuing use of prescribed fire, with or without silvicultural cuttings.

The ecosystem-based management treatments produced an array of changes from significant to subtle, from transient to long-term, some of which would be considered positive and some negative. Considered desirable are the open stand structure and removal of the Douglas-fir understory as designed by the cutting prescription and improved upon by the fire treatments. Natural conifer regeneration appears successful with the burn treatments producing microsites more favorable to ponderosa pine. The fire hazard has been reduced somewhat by consumption of surface fuels, but more important is the reduction of ladder fuels. However, burning of forest fuels means consumption of site organic matter and transformation of mineral nutrients. The short-term flush of available nitrogen following burning may have a brief fertilization effect, but a lessening of available nitrogen may subsequently result. The general increase in understory herbaceous and shrubby plant cover with treatments is also a positive response, with the exception of bitterbrush, a favored browse species that was moderately reduced by the harvesting and greatly reduced with the addition of burning. Regeneration of bitterbrush is now likely, however. Vigorous expansion of knapweed from all treatments could have deleterious impacts on native vegetation although it appears that knapweed increases following forest preservation and eventual severe wildfire as well. As with plant response, some bird species declined with treatments, some were unchanged, and others increased. These changes are likely to be temporary. An esthetic decline was indicated with harvesting and burning, but as the forest recovers, an increase in acceptance is expected.

Each of these individual responses to treatments at Lick Creek have been subjectively evaluated as favorable or deleterious. However, the most comprehensive appraisal of these treatments should look at responses collectively rather than individually. The prominent preharvest stand feature was excessive tree density that had resulted in reduced overstory vigor from competitive stress, diminished health and cover of understory vegetation, and rather continuous ladder and crown fuels that would support a stand-replacing fire. Thinning both the overstory and understory trees was essential for overcoming competitive stress among trees, rejuvenating understory vegetation, and reducing the threat of a severely damaging wildfire. The fire treatments reduced the fire hazard further and eliminated the opportunity for understory Douglas-fir to quickly grow into the overstory. Concurrent impacts of the thinning and burning activities were mortality of understory vegetation, soil disturbance that led to spread of knapweed, reduction of potentially mineralizable nitrogen, lessening of esthetic values, and reduction in habitat of certain birds. Many of these are

temporary, but all are anticipated consequences that accompany activities to improve general health, diversity, and sustainability of this forest. The fire, wind, and insect disturbances that resulted in forest stability during past centuries likely caused temporary changes in individual site attributes that might be considered negative, such as those described in these studies. But in the long term, they created the vegetative and edaphic conditions that produce a forest represented by all aged, well-spaced trees with a diverse and vigorous understory that was resistant to catastrophic change. The seemingly negative specific responses described in the these ecosystem-based management studies can, therefore, be viewed as necessary consequences of forest restoration activities that impact site features in a manner thought to resemble that of historic fires.

It seems clear that ecosystem-based management projects of this scale—a few hundred acres being accomplished over 2 years—are attainable by the Forest Service and acceptable to the public. The ecosystem-based management treatments were well accepted by the visiting public, with the aid of educational efforts to explain the reasons and goals for treatments. This scale of treatment, however, is inadequate for restoring and maintaining any substantial fraction of the ponderosa pine forest on National Forest lands in this region. For instance, if average intervals for maintenance treatments were 25 years for 1 million acres of this forest type in western Montana, 40,000 acres would require treatment each year. The Interior Columbia Basin Ecosystem-Based Management Project evaluation calls attention to the need for large-scale restoration treatments, including prescribed burning (Quigley and others 1996). The long-term records from Lick Creek coupled with evaluations and research on the 1990's ecosystem-based management treatments should provide valuable insight for planning restoration efforts elsewhere in ponderosa pine forests. We suggest that these long-term efforts of treatment application, monitoring, and evaluation at Lick Creek continue into the future to build upon and adapt the knowledge already gained toward the goal of ecosystem restoration.