Restoration of Montane Ponderosa Pine Forests in the Colorado Front Range

A Forest Ecosystem Management Plan for The City of Boulder

by Peter M. Brown, Donald R. D'Amico, Alan T. Carpenter, and Diane Andrews

A plan to restore the historical range of variability for more than 3,000 hectares of municipally owned forest.

"Natural resource management should strive to retain critical types and ranges of natural variation in ecosystems. That is, management should facilitate existing processes and variability rather than changing or controlling them. By doing so, ecosystem resilience and the organizing processes and structures of ecosystems will be maintained, thus better serving not only the natural functions and species diversity of those systems but also the long-term (but not necessarily short-term) interests of humanity." (C.S. Holling and G.K. Meffe, 1996)

There is increasing consensus among natural resource researchers and practitioners that human-caused changes in the natural variability of ecosystem processes have often had profound effects on ecosystem behavior, in many cases drastically reducing their viability or setting them on course to develop into an entirely different kind of system (Holling and Meffe, 1996; Landres and others, 1999). A well-known example is the change that has occurred in many low-elevation forests in the western United States because of the absence of frequent, episodic, surface fires during the past century (Mutch and others, 1993; Arno and others, 1995; Covington and others 1997). Fire suppression is the great paradox of management in these forests in recent decades. Fire suppression has led to fuel conditions and forest structures that today result in more intense, catastrophic fires when fires eventually—and inevitably—occur. Furthermore, the loss of fire as a "keystone" ecosystem process (sensu Holling, 1992) has had cascading effects on other ecosystem processes and conditions. Reduced nutrient cycling, lessened stream flows, and loss of species diversity are some of the major changes that have resulted indirectly from fire suppression and forest closure. Many people question the current "health" of forests throughout the West (Covington and others, 1994), and call for restoration of historical variability in fire regimes and forest structure is growing.

The City of Boulder, Colorado owns and manages about 14,600 hectares of open space and mountain parklands, of which about 3,240 hectares are montane forests dominated by ponderosa pine (*Pinus ponderosa* var. *scopulorum*) (Figure 1). Boulder forests occur at the margins of the Great Plains' grasslands, near the growing urban areas of Boulder, Denver, and the rest of the Colorado Front Range. As in virtually all areas of ponderosa pine forest in the West, Front Range forests experienced extensive changes as a result of fire suppression and logging that began in the late nineteenth century. Today, these forests contain mainly young, small-diameter trees with only a few widely scattered and fragmented patches of larger, older trees. Recent catastrophic crown fires, fueled by dense crown structure and

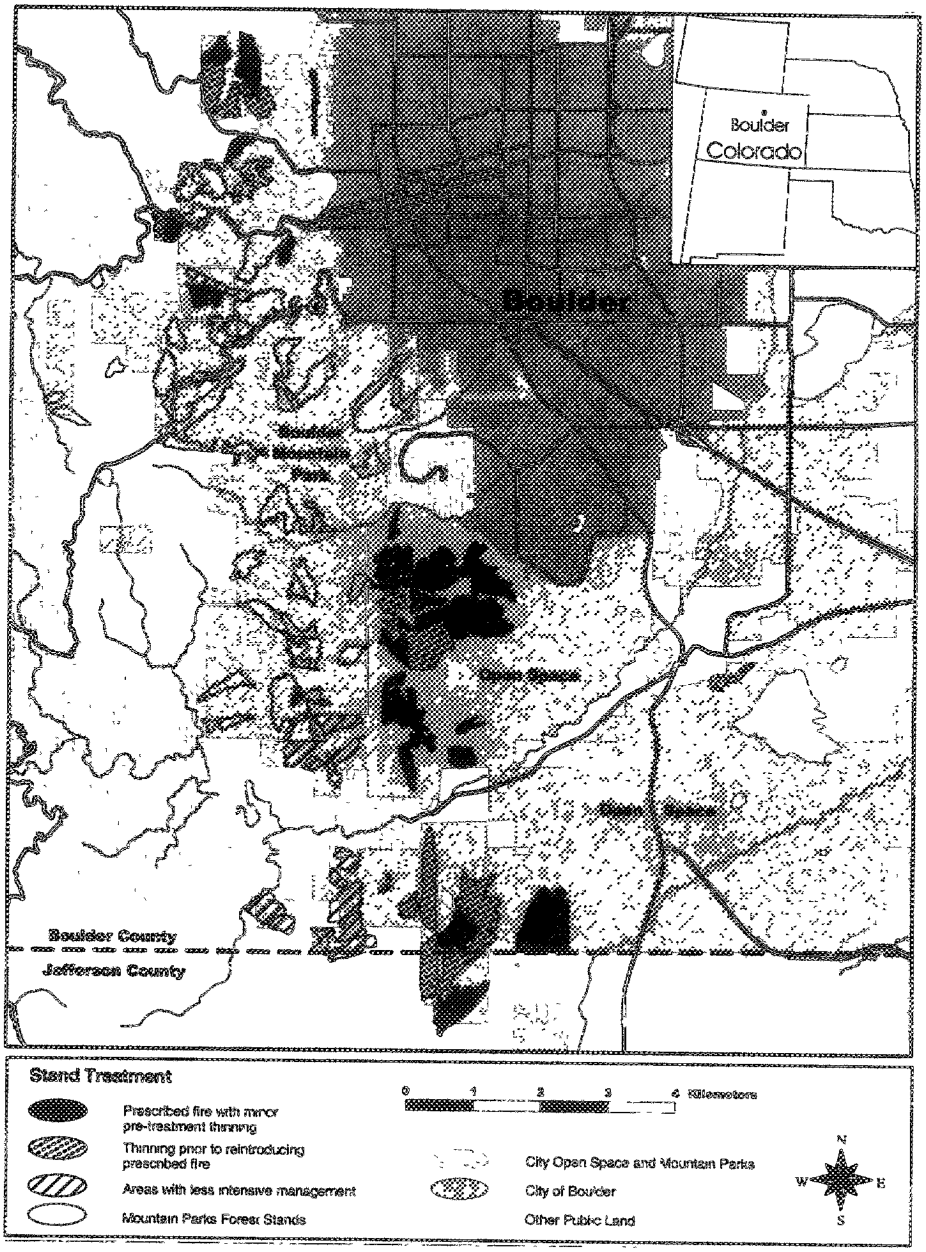


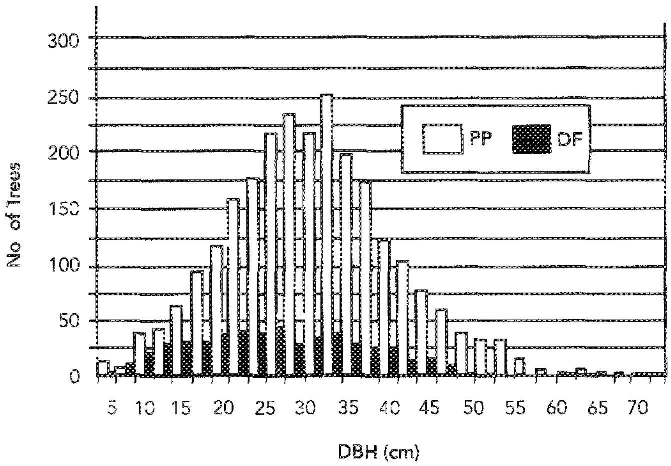
Figure 1: Location of Boulder forests next to urban areas.

"ladder fuels", resulted in losses of homes, property, and large areas of forest overstory. Catastrophic fires have caused erosion and sedimentation problems in watersheds, degrading water quality and reducing reservoir capacities. The presence and expansion of large urban areas and housing developments adjacent to Front Range forests emphasize the need for restoration to more sustainable conditions before additional catastrophic fires and ecosystem damage occur. There is also a need to reinvigorate natural ecosystem processes and to promote biodiversity in order to maintain the ecological integrity of these forested landscapes.

Recently, we and others completed a long-range restoration and management plan for forests owned by the City of Boulder (City of Boulder, 1999). This plan was the result of a cooperative effort between City employees and outside consultants familiar with Front Range forest history (PMB) and management planning (ATC). We expect that the Boulder plan can serve as a model for restoration efforts in other montane forests of the Front Range. The plan is based on explicitly-defined concepts of ecosystem management, adaptive management, and what is known about the historical range of variability (HRV) (Morgan and others, 1994) in ecosystem processes and patterns in lower-elevation Front Range forests. HRV refers to longer-term patterns of ecosystem conditions that prevailed before generally the middle to late 1800s, when widespread non-Native American—primarily Euro-American—settlement in the western United States began in earnest. Although Native Americans are known to have altered ecosystems to a limited extent prior to settlement, their effects do not match the predominance and ubiquity of changes that have occurred during the recent century as a result of population increases and industrialization. Historic Range of Variability was central to the development of this plan since historical conditions provide us with models for viable ecosystem behavior over long time scales (Landres and others. 1999; Swetnam and others, 1999). A central premise in restoration ecology is that ecosystems function best under conditions to which they have adapted in recent centuries. Restoration and management treatments proposed by this plan are not attempts to strictly mimic historical conditions, but instead are an effort to use historical patterns both to guide management planning and to provide justification for management actions to present to the public.

Historic Variability and Current Forests

Characterization of disturbance regimes —including their size, frequency, and ecological effects—provides insights into the ecological processes that sustain species diversity and landscape configuration. Fortunately, disturbance regimes are also some of the few aspects of ecosystems for which abundant historical data exist. The most significant natural disturbance agents that have influenced the montane forests of the Boulder area include fire, insects, various pathogens, and windthrow. Fire has been an especially ubiqui-



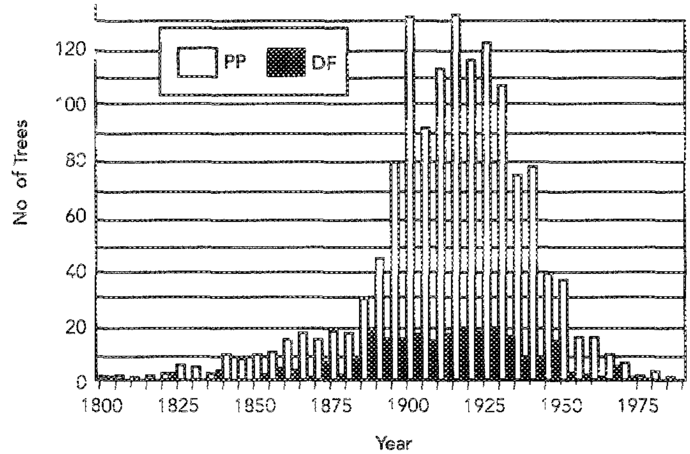
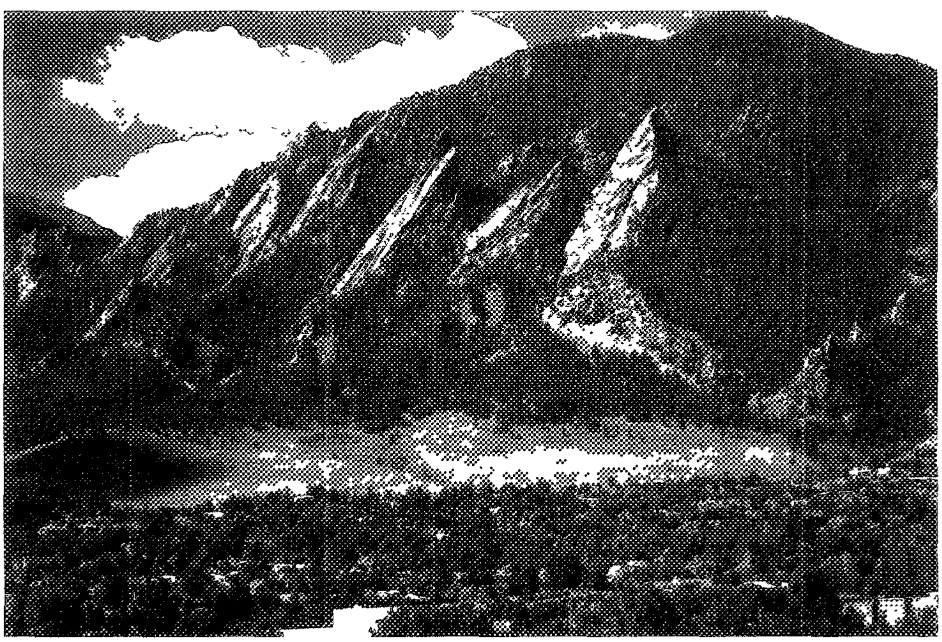


Figure 2: Size distribution (left graph) and date of inside rings (right graph) for trees in Boulder forests. Data shown are mostly for low-elevation forests. PP is ponderosa pine, DF is Douglas-fir. Only a few trees of other species were noted during forest inventories.

tous disturbance in western forests, where rates of fuel accumulation are greater than rates of decomposition and fuel conditions conducive to the ignition and spread of fire are common during long, dry summers. Mature ponderosa pine trees are especially well-adapted to surface fires, having thick bark that protects growing tissues and high canopies that reduce the likelihood of crown scorch.

There is abundant evidence from fire scars recorded in tree rings to document that episodic surface fires were common disturbances in ponderosa pine forests of the western United States in general, and the Front Range in particular, during the past several centuries (Arno and others, 1995; Swetnam and Baisan, 1996; Brown and others, 1999; Veblen and others, 2000). In the Front Range, fire histories document how fire frequency varied with elevation from the margins of the grasslands to the upper limits of ponderosa pine. At a forest stand level (patches less than about 50 hectares in size) prior to the late 1800s, fires burned in the lowest forests about every three to 20 years, while upper-elevation forests burned every 20 to occasionally 60 years or longer. Fires ranged in size from small groups of trees (less than 0.1 hectare) to large areas in "regional fire years" during which fires burned at sites all along the Front Range (Brown and others, 1999; Veblen and others, 2000). Fires were generally low-intensity surface fires that burned through grasses and herbaceous plants at the bases of mature trees, although occasionally large areas of forest at higher elevations were killed by more extensive crown fires.

In virtually all of the fire histories reconstructed from the Front Range, fires disappeared from the landscape during the past century. In the Boulder area, the period of fire suppression followed a period of increased burning during early European settlement when numerous fires were started both accidently, and often deliberately to clear vegetation to reveal ore pockets (Veblen and Lorenz, 1991; Veblen and others, 2000). Livestock grazing, logging, fragmentation of forest stands by roads and



Serried peaks of the Flatiron Mountains rising above the City of Boulder, Colorado, are site of forests that are the subject of a new plan designed to restore the historic range of ecological variability while at the same time reducing the likelihood of catastrophic fires like those that burned over millions of acres in the western United States last summer. Based on historical patterns of disturbance, especially fire, the plan is designed to reestablish variation while at the same time testing ideas about fire and other factors influencing that variability. *Photo courtesy of the City of Boulder* fences, and active fire-suppression by land management agencies are often-cited reasons for loss of surface fires from ponderosa pine landscapes. Grazing contributed indirectly to fire exclusion by reducing grasses and other herbaceous plants that carry fire, while logging and other agents of landscape fragmentation created fuel breaks that limited fire spread.

Cessation of surface fires, in turn, has led to profound changes in forest structure and related ecosystem conditions. Frequent surface fires killed tree seedlings and saplings before they could become established in a forest canopy or on the margins between the woodlands and adjacent Great Plains grasslands. Recent forest inventories in the Boulder forests showed that most trees are small and relatively young, with most trees established since the 1880s and 1890s (Figure 2). Data shown in Figure 2 are from forests at the lowest forest border; higher-elevation forests tend to have more Douglas-fir (*Pseudotsuga menziesii*) and greater tree species diversity, but still have very few old or large trees in contrast to historical conditions. High tree density (often referred to as "dog-hair" thickets) reduces sunlight on the forest floor and results in both low diversity and productivity of ground vegetation and higher potential for devastating crown fires. Increased tree density also results in reduced nutrient cycling and stream flows (Covington and Moore, 1994). And, there is evidence to suggest that loss of natural variability in tree age and size structures and an increase in the homogeneity of forest stands across landscapes has led to more extensive outbreaks of insect infestations, such as the mountain pine beetle (*Dendroctonus ponderosae*) outbreak that occurred during the late 1970s and early 1980s in the Front Range (Schmid and Mata, 1996).

Human disturbances—especially extensive logging—further changed patterns of historical variability in forest structure. Logging during the early settlement period in the 1860s to the early 1900s removed most of the larger trees and dramatically reduced the landscape extent of old-growth forests. The impacts of logging were especially pronounced in the readily accessible foothills that comprise much of Boulder's forested landscapes. In addition, many woodland and savanna areas on the margins of the Great Plains were probably pure grassland in the past. Woody plant encroachment at grassland boundaries is evident throughout the western United States and has been well-documented in the Boulder area (Mast and others, 1998). Reasons for this encroachment may vary (see review in Archer, 1994), but livestock grazing and fire suppression are often cited. Intensive herbivory by livestock changed the competitive relationships between grasses and woody plants by placing greater selective pressure on grasses and certain herbaceous plants and favoring unpalatable woody species.

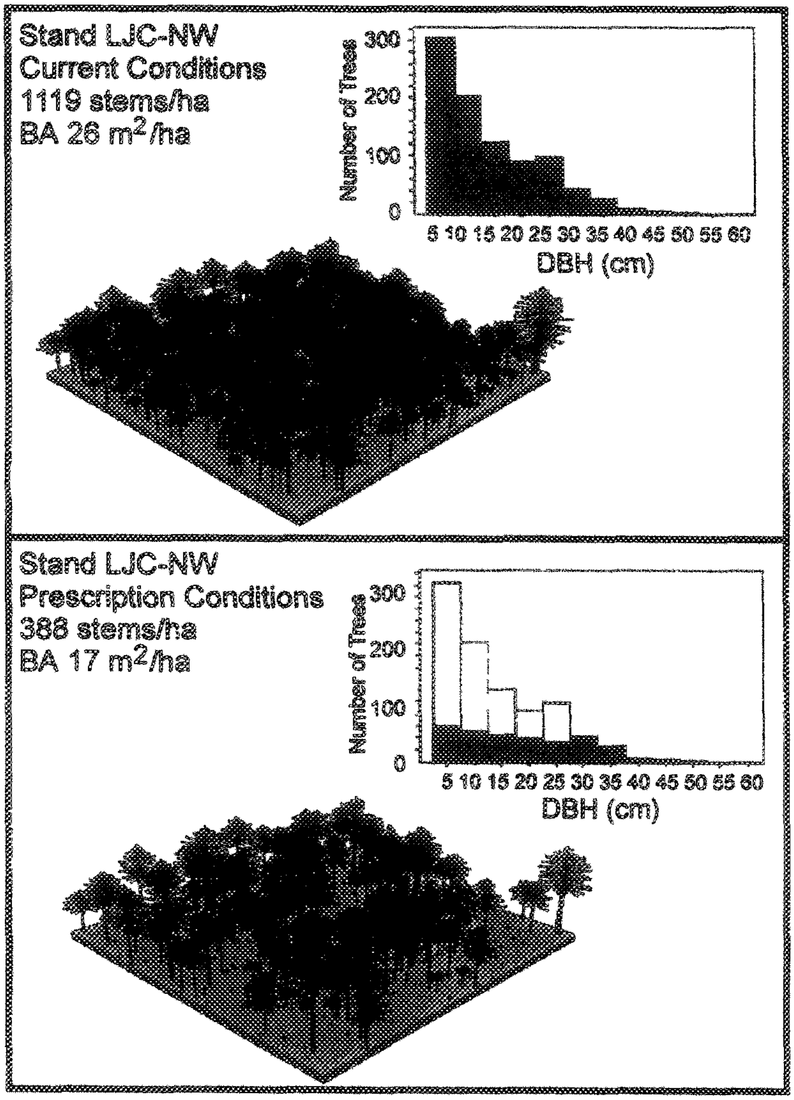


Figure 3. Stand visualizations (McGaughey, 1998) and tree-diameter distributions in present-day forest (upper graph) and prescription conditions after thinning (lower graph) of stand LJC-NW. The open bars in the lower graph show the number of trees in the various size classes that will be cut to achieve the prescribed tree density. No trees larger than 30 centimeter DBH will be cut in this unit. Stand visualizations were done for all stands in the management plan.

Restoration of Forest Structure and Processes

To sustain the integrity of forested ecosystems into the future and to protect the safety of neighbors and users of the Boulder forests, the forest management

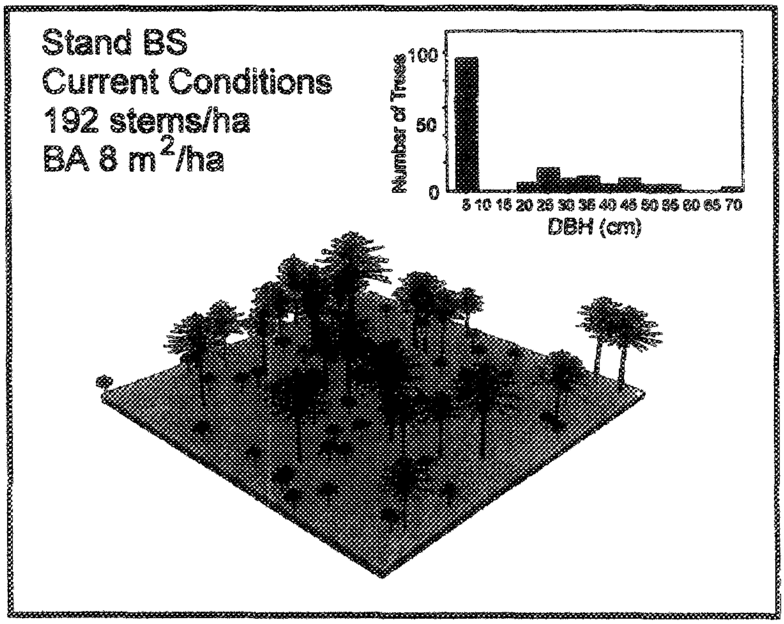


Figure 4. Stand visualization and tree diameter distributions of stand BS, scheduled for prescribed fire treatment. This is a very open stand with vaiable distribuition of tree sizes and a good representation of large tress. We expect that many of the smaller trees will be killed during the initial burn of this stand, and subsequent prescribed fires will continue to maintain open conditions in this unit.

plan that we developed outlines restoration strategies to provide a wider range of historical variability in forest structure and disturbance processes (City of Boulder, 1999). A major component of the plan is to restore variability in landscape and stand patterns, thereby creating what we expect will be greater resilience to future disturbances. The plan proposes to use combinations of silvicultural treatments and prescribed fires to achieve specific objectives for understory and overstory vegetation and wildlife. These objectives are outlined in the plan along with strategies for monitoring success of treatments in an adaptive management framework.

The treatment protocols specified by the plan are intended to provide both short-term restoration and long-term management of forested areas. First, because of abundant tree regeneration during the past century and high tree densities in many stands, we must first restore ponderosa pine forest structure to something more closely resembling its historical condition before surface fires can be reintroduced (Figure 3). We will use silvicultural methods to thin stands to reduce fuel loads and remove sub-canopy trees that promote crown fires. About one-third of the total area proposed for treatment is scheduled for thinning. Silvicultural prescriptions that make use of multi-aged methods (see, for example, O'Hara, 1998) are intended to maintain ponderosa pine regeneration in stands, but at much lower levels than at present. Q-curves were used to quantify ratios between size classes in stands, with a cap on cutting of trees larger than 30 centimeters DBH in most stands. Larger and older trees are generally absent from the Boulder forests, and trees larger than 30 centimeters will be left as "legacy trees" to promote the development of old-growth forest conditions. In addition, Douglas-fir will be removed from some stands in preference to ponderosa pine where the two species co-occur. Douglas-fir is less fire-tolerant than ponderosa pine and probably was not as abundant in presettlement low-elevation forests as it is today. Thinning will be done by crews hired by the City and through contracts with small logging operations in the Front Range area. We will explore markets for small-diameter trees, and will experiment with alternative harvesting methods, such as skidding of logs with horses or tractors, that cause less soil compaction and understory damage.

The second treatment protocol will use prescribed fire both to reduce tree density and to restore fire as a keystone ecosystem process. Prescribed fire is recognized as the best tool available for restoration and management of ponderosa pine ecosystems of the western United States (see, for example, Mutch and others, 1993; Arno and others, 1995; Covington and others, 1997). Many areas with lower overall stand density and fewer small-diameter trees are amenable to immediate treatment with fire (Figure 4). Burning will maintain open stands through mortality of seedlings and occasional small crown fires in the overstory. Prescribed fires also will restore and reinvigorate related ecosystem processes such as nutrient cycling, and promote greater diversity in vegetation and landscape patterning. Prescribed fires on the forest-grassland margins also will reduce tree encroachment and maintain current community patterns in these areas.

Once all stands have been returned to historical tree densities and burned during the first phase of plan implementation, prescribed fires will be used episodically to maintain open stand conditions and to continue to promote related ecosystem processes. At that time, historical variability in fire regimes will guide timing and spatial patterns of burns (Swetnam and others, 1999). Ranges of stand structures resulting from differences in fire behavior will mimic past landscape diversity. Variability in both the timing and amount of area burned during different years will promote heterogeneity in landscape patterns.

In addition to stands recommended for active management intervention, we also have designated a no-treatment protocol for many of the forested areas. These areas are found on the steep and rugged slopes and mountain sides of the Flatiron Mountains immediately west of Boulder, and include some of the most scenic landscapes of the management area. In these stands, short-term, intensive management treatments would not only be difficult to implement, but also more difficult to obtain a consensus from Boulder residents as to what types of treatments to apply. The steep

Thinning of doghair stands of ponderosa pine is a key element in the restoration plan. Since approval of the plan in July, 1999, about 200 acres have been thinned by crews hired by the City and by small logging contractors. The aim is to reduce fuel loads and alter the architecture of the forest in such a way that fires ignited by lightning can burn without going critical and turning into catastrophic firestorms. Shown here is a stand of ponderosa pine in the Lindsay-North unit before (above) and after (below) thinning in the Fall of 1999. *Photos by Rod Moraga, City of Boulder*

areas are not conducive to low-impact silvicultural operations, and it would be difficult to conduct prescribed burns in some of the more inaccessible areas.

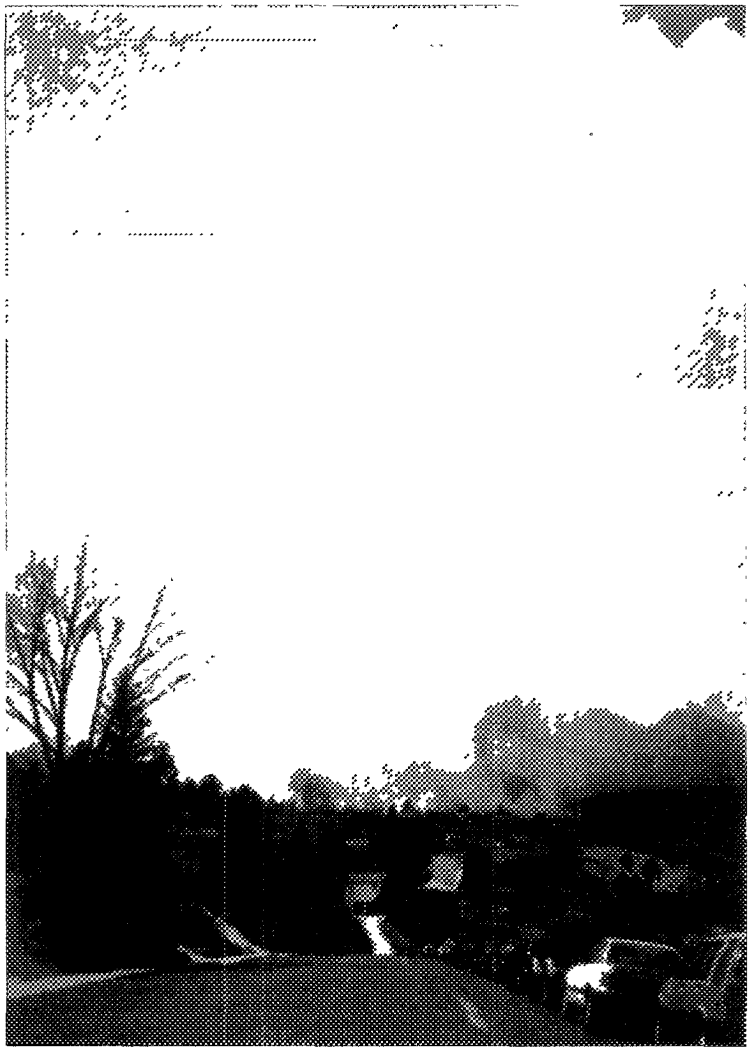
However, we have proposed a longer-term solution in which these areas are to be managed eventually as conditional fire management zones in which naturally-ignited wildfires are allowed to burn. "Prescribed natural fire" (PNF) zones will be established after active treatments of borderline stands have been completed. PNFs are fires started by lightning that are allowed to burn under prescribed weather conditions. After a lightning ignition in this area and as long as prescribed weather and fuel conditions persist, natural fire patterns will be allowed to dominate, even when they include catastrophic crown fires. Treated areas on the margins of the PNF zones will act as buffers for control of wildfires that ignite naturally in the PNF area.

Use of historical patterns as models of longer-term sustainable dynamics in ecosystems must be tempered by constraints imposed on the use of fire and other treatments in the wildland- urban interface. While we believe that the treatments and options outlined in the Boulder plan are both ecologically and operationally sound, we identified two major factors that must be considered before application of the recommended treatments. The first of these is the possible response of Boulder citizens to thinning and prescribed fires in what is essentially many people's back yard (Figure 1). Logging and fires have been very limited in these forests in the recent past, and some people may not want to see the proposed types of management carried out in what they perceive to be otherwise relatively "healthy" forest ecosystems. However, societal perspectives that all fires are "bad" are changing through efforts at education and better scientific information about historical fire processes. For example, public sentiment over the past few years has shifted toward support of prescribed fire as a management tool. A recent survey showed that 72 percent of Boulder residents support the use of prescribed fire as a management option to enhance ecological values and to reduce the hazards associated with wildfires.

The second major consideration in the use of prescribed fire in the heavily-urbanized Front Range is air quality. Smoke management is a concern in all efforts to restore historical fire processes to western forests (see, for example, Ottmar and others, 1995) and may ultimately limit the ability of forest managers to use fire as a management tool. Any fire event has the potential to significantly degrade air quality, impair visibility, and expose the public to pollutants. Plans for burning have to take into account when wind and fuel conditions may produce heavy smoke over populated areas of the Front Range. Smoke management limitations may also preclude achieving historical variation in the seasonal timing of burns, as will limitations of prescribed burning conditions in general.

Adaptive Management and Assessments

While the stand treatments outlined in the plan concentrate for the most part on the general responses of forested ecosystems to management actions, we also recognize that more-specific community and species responses must be taken into consideration when applying treatments. We expect that removal of trees will enhance some wildlife habitats by creating greater structural diversity in forests. Creating snags and downed logs during silvicultural operations and prescribed fires should further enhance habitats for certain rodents and cavity-nesting birds. Thinning stands and creating greater landscape diversity (including old-growth stands) should help to mitigate the impacts of mountain pine beetle outbreaks or other epidemics in the future. Mountain pine beetle and pathogens are part of the natural disturbance processes in these forests and should be expected. However, greater diversity in stand characteristics should reduce the potential for widespread and intensive mortality as has happened in the recent past (Schmid and Mata, 1996). Opening of stands will increase the vigor of individual trees and therefore their ability to withstand attacks



Prescribed burns are also part of the plan. Here a column of smoke rises from an 80-acre burn on the Shanahan Mesa unit in 1999.

by pathogens. Opening of stands also should enhance the visual qualities of the landscape and visitor enjoyment of Boulder forests. Wildlife will be easier to see and we expect bird species and numbers to increase.

These are, however, all inferences we are making at the start of what will be a long-term process. In the plan, we state these inferences in terms of hypotheses that can be tested during application of treatments. We designed the plan around two essential and central concepts of an ecosystem management approach: 1) ecosystems are constantly changing at multiple scales in both space and time; and 2), there is often a great deal of uncertainty when we attempt to define the direction or magnitude of ecosystem changes that may take place (Christensen and others, 1996). These two key features of ecosystems mean that management actions must be flexible to adapt to new data and new theories that further our understanding of how nature works. The basis for an adaptive management approach is that since we do not always know the outcome of a treatment, we must monitor ecosystem response and assess whether goals were, in fact, met or whether unforseen circumstances altered the response. Monitoring guidelines form a large part of the management plan. Each management action is seen as an experiment to be performed with outcomes that can be assessed empirically using various metrics or objective measures. In this manner, future treatments can be refined by past results.

The Long Term

The primary intent of the restoration and management program outlined for City of Boulder forests is to restore historical variability in forest structure and fire processes. Holling and Meffe (1996; see quote above) argue that losses in ecosystem variability can reduce ecosystem resilience, or the ability of an ecosystem to persist in response to shifts in external factors (such as climate change) or internal system events (such as major disturbances). Managers (and forest users in general) must realize that change is inevitable and that our best hope for management efforts is to help ecosystems develop and maintain enough resilience to withstand unexpected events in the future. Not only will fire continue to be a factor in Boulder forests despite our best efforts, but so will other disturbances, such as mountain pine beetle. The Forest Ecosystem Management Plan for the City of Boulder is only a first step in an attempt to mitigate these impacts, but we can never eliminate them. Management must be flexible and adaptable, and managers must adopt a long-term perspective if they are to ensure the viability of the ecosystems under their care.

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Peter M Brown, Rocky Mountain Tree-Ring Research, Inc 2901 Moore Ln , Fort Collins, CO 80526, Phone 970/229-9557, Email pmb@rmtrr.org

Donald R D'Amico and Diane C. Andrews, City of Boulder Open Space. 66 S. Cherryvale Rd , Boulder, CO 80303

Alan T. Carpenter, Land Stewardship Consulting, Inc 2941 20th St., Boulder, CO 80304