Summary

Past practices of fire suppression in the western United States have resulted in the overaccumulation of timber and undergrowth in forest and rangeland habitats. This overaccumulation of biomass has caused a degradation of forest habitat, wildlife habitat, forest health, and biodiversity; has reduced watershed water quality and quantity; has led to spiraling costs of fire suppression and elevated risks to both public and firefighters; and has increased the occurrence of catastrophic wildfires. For several decades, prescribed burning has been the preferred method for addressing fuel load management; however, it also results some adverse impacts. Specifically, in the context of this document, prescribed fire produces emissions that contribute to the increasing air quality problems in the western United States.

In response to this problem, Congress in 1991 created the Grand Canyon Visibility Transport Commission (GCVTC) to advise the U.S. Environmental Protection Agency on strategies for protecting visual air quality at national parks and wilderness areas on the Colorado Plateau. The GCVTC conducted an extensive review of information relating to the problem, collaborating with governmental, business, tribal, and environmental interests and, in June 1996, approved its final report to the EPA. The report made more than 70 recommendations for improving visibility in 16 national parks and wilderness areas on the Colorado Plateau.

The Western Governor's Association (WGA), in conjunction with federal, state, tribal, and local entities, formed a voluntary organization of western states, tribes, and federal agencies. The purpose of the Western Regional Air Partnership (WRAP) is to build on the work of the GCVTC in developing and planning programs that can contribute to reducing emissions and improving visibility throughout the West. Participating states are Alaska, Arizona, California, Colorado, Idaho, Montana, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming. Participating tribal nations include Pueblos of Acoma, Campo Band of Kumeyaay Indians, Cortina Indian Rancheria, Hopi Tribe, Hualapai Nation of the Grand Canyon, Jicarilla Apache Tribe, Northern Cheyenne Tribe, Salish and Kootenai Confederated Tribes, Pueblo of San Felipe, and Shoshone-Bannock Tribes of Fort Hall. Representatives of other tribes participate on WRAP forums and committees. Participating federal agencies are the Department of the Interior (National Park Service and U.S. Fish and Wildlife Service), the Department of Agriculture (U.S. Forest Service), and the EPA.

The WRAP is composed of a planning group, a technical group, and several forums tasked with the development of technical and policy options for specific

areas of interest. The Fire Emission Joint Forum (FEJF) is responsible for making recommendations on strategies and methods to manage emissions from prescribed fire. Among the many tasks with which FEJF was charged was the responsibility of investigating the appropriate use of nonburning alternatives to prescribed fire on wildlands.

The use of alternatives to prescribed burning, when such alternatives are feasible, result in fewer emissions than burning. However, practices vary widely from state to state, obstacles are numerous, and there is limited awareness of the existence of viable alternatives to burning. Accordingly, WGA retained Jones & Stokes to conduct a series of interviews with landowners, land managers, and stakeholder group members to examine the use of nonburning alternatives on wildlands. Information developed during the course of the interviews was used to:

- identify nonburning alternatives,
- establish criteria for the use of nonburning alternatives,
- identify barriers to the use of nonburning alternatives,
- investigate approaches to overcome these barriers,
- examine current accountability mechanisms, and
- develop recommendations to promote the use of nonburning alternatives.

This document represents the compilation of the work done during the course of the interviews and other data collection. The objectives of this document are: (1) to provide landowners and land managers with a comprehensive reference document that describes alternatives to prescribed burning; (2) to provide decision makers with the tools necessary to develop cogent nonburning strategies for vegetation and fuel load management; and (3) to assist air quality regulators, environmental organizations, and the general public in understanding the environmental, economic, and practical advantages of nonburning alternatives.

Chapter 1
Introduction

The 2000 fire season was the worst in 50 years. The scale and intensity of the 2000 fire season capped a decade that was characterized by a dramatic rise in the number of large wildland fires, the costs associated with fire suppression, and the values at risk in the wildland-urban interface. In the 2000 fire season, approximately 123,000 fires burned more than 8.4 million acres. More than $2 billion from federal accounts was spent suppressing wildland fires. This amount does not include state and local firefighting suppression costs; direct and indirect economic losses to communities; loss of private, state, and federal resources; or damage to ecosystems.

In August 2000, President Clinton directed the Secretaries of Agriculture and the Interior to develop a response to severe wildland fires, reduce fire impacts on rural communities, and ensure sufficient firefighting capacity in the future. Congress in turn mandated implementation of a National Fire Plan (NFP) through legislation and appropriations. The NFP addresses conditions that have evolved over many decades and cannot, consequently, be reversed in a single year; these conditions will require consistent and ongoing future management efforts. The NFP is a long-term commitment based on cooperation and communication among federal agencies, states, local governments, tribes, and other interested parties.

The 2002 fire season was the second worst season in the past 50 years; approximately 6.7 million acres burned in more than 68,000 fires. Colorado, Arizona, and Oregon all suffered the largest fires recorded in the past century. Early in the season, about 45% of the country reported moderate to extreme drought conditions; nearly 50% remained in conditions of moderate to extreme drought as the season ended. Clearly, with the worst and second-worst seasons in half a century occurring only 2 years apart, the problem of catastrophic wildfire is becoming increasingly critical.

Fire in the West

For thousands of years, periodic fires, ignited by lightning or Native Americans, shaped the ecosystems of the western United States; forests and other western ecosystems supported an abundance of fire-tolerant or fire-adapted species. The historical fire regimes exerted profound influence on the accumulation of fuels, nutrient cycling, patterns of vegetation growth, and distribution of natural communities. Because of the range of these influences, the fire-suppression activities of the twentieth century have had widespread effects, particularly on those systems that were most adapted to or dependent upon their historical fire regimes.

Fire suppression can lead to marked changes in stand density. The increase of small- and medium-size classes of shade-tolerant and fire-sensitive species that can result from suppression is of particular concern. This change produces an increase in the amount and continuity of live fuels near the forest floor that can act as ladder fuels (i.e., fuels that can conduct fire from ground-level or surface fuels into the forest canopy). Moreover, harvest practices of the twentieth century have typically removed the larger overstory trees, accelerating growth in the dense understory and increasing the homogeneity of the fuel structure. The lack of fire has also caused dead fuels on the forest floor to accumulate in excess of their presuppression levels.[1]

In general, today's typical forest stand is denser, contains more ladder fuels, and has a higher surface fuel load than historic forest stands. Contemporary forests contain a greater abundance of species that would historically have been excluded by fire (i.e., nonclimax or invasive species). Nonforest ecosystems have been similarly modified by fire suppression activities.

Restoring the Balance

Only in the past few decades has it become widely understood that the historical practice of fire suppression has had costly and potentially catastrophic repercussions. This new awareness has prompted a strong movement towards the use of prescribed burning, the intent of which is to reduce the risk of catastrophic wildfire and to restore wildland conditions to a more natural fire regime. However, because of the cumulative impacts of prescribed burning on air quality—already compromised by automotive and industrial emissions—as well as on other environmental resources, there is a strong case to be made for the use of nonburning alternatives that have the potential to achieve many of the same results as prescribed burning but without the adverse effects.

Under the auspices of WGA, WRAP, and FEFJ, Jones & Stokes has prepared this manual to foster a greater understanding of the benefits and mechanics of nonburning alternatives. Early in the process, it became clear that a great many answers to the complex issues involved in vegetation and fuel load management already exist, and that the judicious compilation of available knowledge and resources could provide a user-friendly roadmap to the arduous undertaking of developing site-appropriate strategies. Accordingly, Jones & Stokes conducted extensive interviews with a wide array of individuals involved in vegetation, fuel

[1] Sierra Nevada Ecosystem Project, Final Report to Congress, vol. II, Assessments and Scientific Basis for Management Options (Davis: University of California, Centers for Water and Wildland Resources, 1996).

load, and land management. Interviewees included federal land managers, state land managers, tribal land managers, researchers, timber industry representatives, and environmental interest group representatives.

How to Use This Manual

Because of the enormous complexity of the issues involved and the rather daunting variability of conditions throughout the western United States, it was not possible to create an exhaustive "how-to" manual that would address all the contingencies that might face decision makers. Accordingly, this document has been developed to address the categories of considerations that decision makers are likely to confront, the range of options available for development of nonburning fuel management strategies, and the approaches to finding the best solutions to each land manager's particular situation. It must be understood that every situation is unique, and that a "one-size-fits-all" approach to development of a strategy for management of fuel loads is never appropriate. It is therefore the intent of this manual to provide decision makers (e.g., resource managers, landowners) with the tools to reach an informed decision.

Chapter 2 (*Vegetation Management: To Burn or Not To Burn*) considers the scope of variables that must be weighed in developing a vegetation or fuel load management strategy. Chapter 3 (*Nonburning Alternatives: Variables, Criteria, and Definitions*) provides an overview of the concepts and vocabulary of vegetation and fuel load management, and summarizes the options available for nonburning treatment programs. Chapter 4 (*Getting to Work: How to Build a Nonburning Strategy*) guides the decision maker through the technical and nontechnical considerations one must navigate in designing a vegetation or fuel load management program. Chapter 5 (*Conclusions and Recommendations*) explores means by which the increased acceptance of nonburning alternatives might be promoted. Appendix A presents a sample worksheet for evaluating the options that might be appropriate for any given set of circumstances, as well as an example of the chain of reasoning used to develop a similar site-specific evaluation tool. Other appendices provide [. . . .]

Chapter 2

Vegetation Management: To Burn or Not To Burn

The Rationale for Treatment

As discussed in Chapter 1 (*Introduction*), the need for management activities to correct the results a century of fire suppression is clear. In considering the approach to developing management strategies, it might be useful to review the concept of fire and fire management in its broadest theoretical context.

Fire in the most basic sense is a chemical reaction, involving the rapid oxidation of combustible material and characterized by the release of energy in the form of heat and light. The familiar diagram known as the *fire triangle* [Figure 2-1; Fire Triangle] illustrates the three components essential to the oxidation process we know as fire: fuel, heat, and oxygen.

In the context of wildland fire, fuel is in reality the only one of these components over which humans can hope to exert any meaningful control. The characteristics of the fuel, considered in the context of topography and climate, determine the manner in which fire is likely to ignite, develop, and spread. This process of ignition, development, and movement through the habitat is termed *fire behavior*.

The approach to reduction of fire risk through management activities involves implementing actions that will modify the behavior of fire. The attributes of fuel that management activities can effectively address are, for all intents and purposes, limited to the quantity and arrangement of the fuel load. On the most basic level, vegetation and fuel load management entails disarranging or reducing the quantity of the fuel load to impede fire's ability to pass through the habitat. Continuity of the fuel load can be disrupted vertically or horizontally; firebreaks can be created; fuel can be removed off site. The optimum strategy is governed by numerous variables, and the body of knowledge concerning fire ecology and fire management is continually expanding. The mechanics of fuel load management are discussed in greater detail in Chapter 3 (*Nonburning Alternatives: Variables, Criteria, and Definitions*) and Chapter 4 (*Getting to Work: How to Build a Nonburning Strategy*).

Development of a reasonable vegetation and fuel load management strategy must be predicated upon an understanding of the *desired future condition*. The desired future condition, in turn, requires an understanding of the disparity between historic conditions (i.e., the conditions that existed before fire suppression activities or other land use practices altered the vegetative conditions of the area under consideration) and current conditions. The management strategy, then, is the roadmap for moving from current conditions to the desired future condition.

Typically, the objective of the management strategy is either to restore forest health or to protect human life and property. While these objectives frequently overlap, such is not always the case. Restoration of forest health generally entails returning the habitat to its *historic fire regime*, defined by the natural patterns of frequency, predictability, seasonality, intensity, duration, and scale with which fire historically passed through the habitat. Protection of human life and property is frequently addressed by restoring the historic fire regime; however, some habitats are naturally subject to severe fire regimes. In such cases, additional treatment may be necessary to attain the desired future condition.

Fire regimes have been classified into five groups; these are summarized in Table 1.

Table 1. Fire Regimes

Classification	Fire Return Interval	Severity	Example Habitats
Group I	0–35 years	Low	Ponderosa pine, other long needle pine species, and dry site Douglas-fir
Group II	0–35 years	Stand replacement	Drier grasslands, tall grass prairie, and some Pacific chaparral ecosystems
Group III	35–100+ years	Mixed	Interior dry site shrub communities such as sagebrush and chaparral ecosystems
Group IV	35–100+ years	Stand replacement	Lodgepole pine and jack pine
Group V	>200 years	Stand replacement	Temperate rain forest, boreal forest, and high elevation conifer species

A corollary descriptor of fire conditions describes a fire regime's extent of deviation from historic conditions. These *condition classes* also measure general wildfire risk; however, it is important to understand that the criterion of fire risk is based upon the loss of key components of the ecosystem. For example, a habitat with a naturally severe (i.e., stand-replacing) fire regime, while potentially posing a serious risk to human property, might be considered to have low risk because the ecosystem is adapted to fire and would be likely to reestablish in accordance with historic patterns.

- Condition Class 1: Fire regimes in this condition class are mostly within historical ranges. Vegetation composition and structure are intact. The risk of losing key components of the ecosystem from fire is low.
- Condition Class 2: Fire regimes in this condition class have been moderately altered from their historic range, either by increasing or decreasing the fire frequency. The risk of losing key components of the ecosystem from fire is moderate.
- Condition Class 3: Fire regimes in this condition class have been significantly altered from their historical return intervals. Vegetation composition, structure, and diversity have been significantly altered. The risk of losing key components of the ecosystem from fire is high.

As mentioned above, treatment of a habitat may be appropriate to restore a habitat's health as well as to protect human resources. Accordingly, areas in any of the condition classes may be suitable candidates for treatment. Conditions that indicate the need for treatment may be divided into two broad categories

- An ecosystem in which the fire regime has been altered, increasing the risk of fire that could result in loss of ecosystem elements as well as in destruction of human life or property.
- An ecosystem in which the fire regime is naturally severe and requires treatment to protect human life or property.

When an ecosystem has been altered from its historic regime, efforts to restore that regime are indicated; in other words, the management objective is to modify a condition class 2 or 3 ecosystem into a condition class 1 system. If ecosystem health is the object, such a strategy is considered to be a restoration activity.

However, whether or not the fire regime has been altered, risk of wildfire must be addressed in areas near human resources. In the case of condition class 1 habitats (presumably those with naturally severe fire regimes), the treatment would assume a different strategic character than a restoration activity; for example, treatment might entail creation of fire breaks or home protection zones.

An Overview of Prescribed Burning

If one accepts the proposition that the restoration of natural fire regimes is a legitimate management objective for the preponderance of western wildlands, then it is important to understand the distinction between prescribed burning and natural fire. Although prescribed burning has been widely used in recent decades as a vegetation and fuel load management tool, and despite the acknowledged virtue of prescribed burning to restore natural fire regimes, the mechanisms of prescribed burning and natural fire are widely divergent. For instance, naturally occurring wildfires tend to occur during fire season (i.e., summer through fall), while prescribed burning is generally implemented under precisely those conditions that would most likely preclude the spread of a naturally occurring fire. This difference in timing is a necessary precaution against the risk of escape; indeed, the disparity between natural and prescribed fire is intimately linked with the fact that it is the unnatural conditions created by past management decisions that necessitates treatment in the first place. It should be borne in mind throughout the ensuing discussions that *those areas that are most difficult to treat are the areas in greatest need of treatment*.

The Functions of Fire

Naturally occurring fire in western ecosystems serves several ecosystem functions. Fire can eliminate invasions of species from outside the ecosystem, thin vegetation to facilitate establishment of young plants, eliminate fuel loads before they attain potentially catastrophic proportions, and recycle nutrients. Fire is an integral component of many western habitat types.

Prescribed fire can accomplish many of the same functions as naturally occurring fire; however, as discussed above, the context of prescribed fire differs from that of naturally occurring fire. Because of its controlled nature, prescribed fire does not entirely duplicate the ecological function of fire in the west, nor does it necessarily address all hazardous fuel conditions.

As suggested by the interviews and literature reviews conducted for preparation of this document, the reasons for implementing prescribed burning can be assigned to three broad categories: hazardous fuels reduction, habitat management, and ecological restoration. The functions listed below are those that land managers are most likely to cite for using prescribed fire.

- Reduction of fine fuels.
- Reduction of surface fuel loading.
- Mortality of ladder fuels.
- Release of nutrients.
- Improvement of wildlife habitat through stimulating regrowth and seeding.
- Control of some invasive species, pests, and diseases.

Use of prescribed fire in wildlands falls into two broad categories.

- **Vegetation management.** Objectives include the reintroduction of fire into fire-adapted ecosystems, stimulation of regrowth of species desired for browse, creation of openings for early successional species, control of invasive species, and nutrient recycling.

- **Fuels management.** Objectives include cleaning up post-silvicultural residues, maintenance or creation of fuel breaks to protect resources, and preventing losses from catastrophic wildfire.

These objectives are not mutually exclusive, and often several objectives can be achieved through a single treatment strategy. For example, treatments designed to make natural stands of forestland more fire resistant can facilitate the return of fire into the ecosystem while protecting houses or other adjacent resources.

Challenges to Burning

Because fire is such an integral component of many western ecosystems, and because a key objective of many vegetation and fuel management programs is to restore habitats to an approximation of the ecosystem's natural fire regime, it is often assumed that prescribed burning is the most natural method to achieve such an objective. However, as mentioned above, the conditions under which prescribed burns are implemented differ significantly from the conditions under which naturally occurring fires enter the ecosystem. For example, naturally occurring fires are likeliest during the summer or fall under conditions of low humidity, high temperatures and, frequently, high winds; prescribed burns, to the contrary, are generally implemented under carefully monitored conditions of specific levels of fuel moisture, higher atmospheric humidity, moderate temperatures, and relatively low winds to minimize the risk of escape.

Despite the virtues of prescribed burning for vegetation and fuel load management activities, it must be recognized that fire carries negative impacts and risks as well. Disadvantages of burning include:

- smoke and other emissions that contribute to air quality problems and visibility impacts,
- potential loss of resources from escapes, and
- loss of material that might otherwise be utilizable.

Some of these impacts violate the regulatory requirements of the Clean Air Act, while others entail risk to resources and to the safety of landowners and firefighters. Moreover, there are logistic disadvantages to the use of burning, many of which can be avoided by the use of nonburning alternatives.

Air Quality

The Clean Air Act (CAA) of 1970 established national ambient air quality standards (NAAQS) for six pollutants, known as *criteria pollutants*: carbon monoxide (CO), ozone, particulate matter with a diameter less than 10 microns (inhalable particulate matter or PM10), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and lead. Most standards were set to protect public health; however, for some pollutants, standards are based on other values, such as protection of crops, protection of materials, and avoidance of nuisance conditions. Except for ozone, NAAQS represent short-term (24 hours or less) concentrations that may be exceeded no more than once per year and annual concentrations that may never be exceeded. NAAQS for ozone may be exceeded no more than 3 days in 3 years.

In July 1997, EPA promulgated a NAAQS for PM2.5, making it the seventh criteria pollutant. EPA asserts that these fine and ultrafine particles are closely related to significant adverse health effects. Accordingly, EPA has established a 24-hour average limit of 65 micrograms per cubic meter and an annual average limit of 15 micrograms per cubic meter. Controls for PM2.5 will probably not be established until 2005–2008.

The smoke released by wildland fires contains large quantities of fine particulate matter, as well as many of the same chemical constituents found in urban smog. Wildfire smoke also contains organic compounds, known as polycyclic aromatic hydrocarbons, some of which are toxic and potentially carcinogenic. Because fine particles are readily inhaled and retained in the lungs, and because wildfires release *fine* and *medium* (i.e., <2.5 micron and 2.5–10 micron) particles, these emissions represent a potential to human health and the environment.

Moreover, authorities estimate that every 1,000 acres that burn in a wildfire generate a quantity of fine particulate emission equivalent to that produced by all the motor vehicles in southern California in a day. Accordingly, the contribution of prescribed burning to preexisting air quality conditions can be seen to be significant.

Risk of Escape

Fire by its very nature is characterized by an inherent lack of control. This is of particular concern when using fire as a vegetation or fuel load management tool (remember: *those areas that are most difficult to treat are the areas in greatest need of treatment*). While this characteristic of unpredictability can contribute to results that mimic natural processes, it can also have serious consequences in the real world of land ownership boundaries, adjacent infrastructure, unnatural fuel load conditions, and political and financial liabilities.

The difficulty of confining fire to a prescribed area bears an associated risk; the degree of this risk is influenced by the nature of adjacent resources that might be susceptible to damage or loss, as well as by the kinds of conditions that influence fire behavior (e.g., weather, topography, fuel characteristics). In recent years several large wildfires have begun as prescribed burns, but upon escaping control they destroyed infrastructure, natural resources, watersheds, and people’s homes. In addition to the costs of these losses, a huge amount of money was expended in fighting the fires. Financial liability can fall in many directions depending on location and jurisdiction; whoever must bear the cost, it is clear that escape of prescribed fire carries the potential for serious calamity.

Loss of Materials

Burning of material that might be used as a source of fiber for pulp, particleboard, or energy generation may not be the most efficient or judicious use of our natural resources. The demand for wood and wood products is becoming increasingly difficult to satisfy due to limitations of timber harvest activities on National Forest System lands. Additionally, the use of such submerchantable material might also offset the demand for material that is traditionally derived from large, merchantable trees harvested on public as well as private lands.

Logistic Disadvantages

Because of concerns associated with the risks of escape, prescribed burning is necessarily constrained by rigorous conditions. For instance, burn plans specify very precise parameters of humidity, wind conditions, temperature, and moisture content of both live and dead fuel within which the burn may be implemented. These parameters, as well as regulatory restrictions, can narrow the window of feasibility for a particular burn plan to as little as several days in an entire season. If for some reason those days are precluded, the window might close until the next season. As such opportunities are missed, fuel conditions can continue to worsen. Furthermore, the local air quality management agency may impose stringent requirements to ensure acceptable levels of emissions. For example, the presence of a stable air mass, which is the safest condition under which to initiate a burn, is also the least desirable condition for air quality concerns. Constraints such as these can combine and overlap to frustrate the most well-conceived projects.

It should be remembered that many areas in greatest need of treatment are areas of condition class 2 or 3; in such areas the vegetation structure and composition have been so modified that fire cannot likely be introduced under uncontrolled conditions. By definition, areas of these condition classes are at risk of losing ecosystem components in the event of fire. Consequently, treatment necessitates a managed burn that is cooler—that is, less intense—than a naturally occurring fire would be. While such a managed burn poses less risk of escape than a naturally occurring fire would pose, it is also unlikely to achieve the desired future condition of the treatment area; to the contrary, such a burn is an intermediate step, presumably establishing conditions that would permit a subsequent entry, or entries, with fire to attain the desired condition. Each entry entails repeated risk of escape as well as additional emissions of pollutants.

Evaluating Nonburning Alternatives

In view of the disadvantages to prescribed burning discussed above, there are strong arguments to be made in favor of a careful evaluation of nonburning alternatives when developing a vegetation or fuel load management strategy. Specific nonburning alternatives are discussed in greater detail in Chapter 3 (*Nonburning Alternatives: Variables, Criteria, and Definitions*); for the purpose of the current discussion, nonburning alternatives can be broadly defined as treatments employing manual, mechanical, chemical, or animal (i.e., managed livestock grazing) methods to address management of vegetation or fuel loads.

Nonburning alternatives must, if they are to be satisfactory treatments, mimic at least some of the effects for the achievement of which prescribed burning is typically implemented. Table 1-2 shows a comparison between the effects of potential nonburning alternatives and the effects of prescribed fire.

In assessing nonburning treatments and the relative reasonableness of various alternatives, one must consider a spectrum of criteria to evaluate the potential impacts on fuels, the environment, and society. Often, an initially promising idea can have unforeseen consequences. The practice of fire suppression is a case in point: for many years, fires were suppressed with the objective of protecting forest resources. However, as current understanding teaches, this practice has instead produced an increase in catastrophic wildfire, thereby threatening the very resources it was intended to protect.

Accordingly, it is important to evaluate the *reasonableness* of potential nonburning alternatives. Reasonableness can be taken to reflect the likelihood of a treatment to achieve desired results; the relative absence of risk that unanticipated adverse effects will ensue; and the alternative's conformance to practical, technical, political, and economic constraints.

A variety of criteria can be applied during the evaluation process. This document emphasizes those criteria that identify generalized effects of specific treatment types. Criteria that can be evaluated only when considering site-specific information are not useful for the generic assessment of reasonableness that falls within the purview of this document. For example, potential impacts on wildlife, while extremely important to consider, are far too site-specific to address generally. All treatment types impact wildlife habitat; the degree and character of the impact, however, varies with existing conditions, desired future conditions, and the community of species that occurs on the target site.

A myriad of factors must be considered in developing any vegetation or fuel load management strategy. This document adopts a simple division of the issues that land managers must address; however, as in all activities involving resource management, it is important to remember that the different issue areas are interconnected and that systems of organization are merely tools for the convenient processing and assimilation of information. The four issue areas used in this manual are:

- technical considerations,
- environmental considerations,
- economic considerations, and
- sociopolitical considerations.

The evaluation of nonburning alternatives should include a comparison of the effects of the nonburning treatment method under consideration with the effects that would be achieved through the use of burning.

Finding Innovative Solutions

The interviews conducted in preparation of this report suggested three broad trends regarding the choice of prescribed burning versus that of nonburning alternatives. Respondents inclined towards burning when cost was the determining factor; nonburning alternatives gained support in situations where burning could not be conducted safely, such as in the urban-wildland interface and in areas where pretreatment activities must be carried out prior to burning. Another consideration was the potential marketability of materials on the site.

Traditionally, vegetation and fuel load management has been accomplished by one of two methods: harvesting and burning. Each method has gained staunch adherents and dedicated opponents; consequently, the entire issue has become tangled in emotional response and highly charged rhetoric. Nevertheless, it is generally understood that action must be taken to address a problem that has been a century and more in the making and that is becoming yearly more critical. It will be necessary for groups on all sides of the issue to suspend their preconceptions and examine possible alternatives objectively if the fuel load crisis is to be addressed in a safe and timely manner. It must be borne in mind that the situation as it exists in much of the western wildland habitats is *not* a natural situation; it will, consequently, require decisive actions to correct it. However, with creative thinking, good will, and clear intentions, there is no reason that all parties concerned cannot arrive at mutually acceptable approaches to address acknowledged problems.

Chapter 3

Nonburning Alternatives: Variables, Criteria, and Definitions

The task of restoring natural communities to a semblance of historic conditions is one that cannot be accomplished by the simple reintroduction of fire into the ecosystem. In many western ecosystems, in fact, such a reintroduction is no longer an option due to the overaccumulation of fuel loads. While it is important to recognize that fire is an integral component of ecosystems in the western United States, it is equally important to recognize the merits of nonburning alternatives to address vegetation and fuel load management issues. At the same time, it must be emphasized that implementation of a nonburning alternative does not preclude subsequent use of burning; indeed, prescribed burns are often predicated on preliminary nonburning pretreatments.

The need to reduce fuels increases every year, and proper use of mechanical equipment or other nonburning alternatives can be instrumental in reducing the impact of wildfires in the west. Many of these alternatives have a broader window of opportunity and a much lower level of associated risk than prescribed fire.

In developing the appropriate strategy for any proposed treatment area, it is necessary to proceed through a multilayered evaluation of the issue areas introduced in the previous chapter. Moreover, it is critical to establish the criteria by which one must evaluate various treatment options in order to make an informed decision. Again, it must be emphasized that every situation is unique and that superficially similar treatment areas may be subject to markedly differing constraints. Preparation of a worksheet or checklist similar to that presented in Appendix A should assist decision makers in reaching an informed decision regarding the most appropriate treatment method for the area under consideration.

Technical Considerations

Technical considerations entail the activities that can be conducted within the parameters of physical conditions (e.g., topography, habitat type, fuel conditions), regardless of other considerations. For example, if the terrain is too steeply sloped to use heavy equipment safely, then the range of treatment options that depends on the use of such equipment is clearly excluded.

When options have been screened on the basis of feasibility, it is important to consider the effects that the various treatment options will have on fuels and fire behavior. The evaluation of nonburning alternatives should address:

- changes to be made to the fuel structure;
- whether the treated area will exhibit increased resistance to fire;
- a comparison between the anticipated results of the nonburning alternative with the results of prescribed burning.

Land managers should become conversant with the habitat types in their areas of responsibility, as well as with the basic concepts and common terminology relating to fuel structure and characteristics. Only with a basic working knowledge of the technical aspects of fuel load management can reasonable strategies be developed.

Physical Conditions

Habitat Types

As Map 1 shows, the western United States is a complex amalgam of vegetative communities. These communities have evolved in response to varied characteristics of topography, climate, soil conditions, hydrologic regime, and other physiographic as well anthropogenic conditions. Each community is characterized by a suite of fuel conditions and fire-related traits and responses. For the purposes of the generalized approach of this document, many of these communities can be grouped into broad categories that share common fuel characteristics and types of resources that can be exploited for similar uses.

Map 2 shows the simplified categories that this document uses to address the issues of vegetation and fuel load management. The habitat categories that might be candidates for vegetation and fuel load management strategies are:

- grassland,
- shrubland, and
- forested habitat.

These three habitat categories can be roughly correlated with appropriate equipment types and material resources with utilization potential. As has been discussed elsewhere, site-specific characteristics will have to be addressed in some detail for each proposed treatment project.

Grassland: The dominant fuel type and predominant carrier of fire is grass or forbs. This category includes many oak woodland and savanna communities; because these communities generally exhibit no vertical continuity of fuels, fire is usually limited to surface grasses.

Shrubland: The primary carrier of fire in these vegetation types is a fairly contiguous shrub layer. Fire behavior tends to be more intense than in grassland habitats because the vegetation is typically characterized by greater height and density, larger diameter stems, and (frequently) higher levels of volatility resulting from resins and oils. Surface fuels are limited because the shrubs' density inhibits growth of other plants and the vegetation type does not produce large quantities of litter. Some trees can be present, but not usually in sufficient density to inhibit the growth or continuity of the shrubs.

Forested habitat: The primary carrier of fire in this vegetation type is litter from the trees in the form of needles/leaves and dead branches. Younger trees, shrubs, or low branch growth can provide vertical continuity of fuels. In the case of severe wildfire, dense canopies can become carriers.

[2 Sets of photos showing historical changes in fuel conditions]

[1 photo of excessive fuel load in grass]

[2 photos of excessive fuel loads in shrub]

[3 photos of excessive fuel loads in forest]

Fuels

Fuels can be defined as both living and dead vegetation that is available to burn during a fire. The difference between vegetation type and fuel is that while a vegetation community is defined by species composition, a fuel type is determined by how a given area will burn. The manner in which a given area will respond to fire is a function of the continuity of living and dead vegetation, the height and layers of vegetation, the volume and availability of different sizes of fuels, and weather conditions.

Three categories of fuels are critical in understanding fire behavior and the theory of vegetation and fuel load management:

- surface fuels,
- ladder fuels, and
- aerial fuels.

The role of each category in fire behavior must be understood, and the treatment selected must be appropriate to the category or categories of fuels that represent the primary risk in the treatment area.

Surface fuels are those fuels that are in contact with the surface of the ground. They can, depending upon the particular vegetation community, extend up to 5 feet above the ground. Surface fuels include detritus such as fallen leaves or needles, twigs, bark, cones and small branches, heavier branchwood, and downed logs. Surface fuels can also include understory growth such as grasses, forbs, low and medium shrubs, and tree seedlings. These fuels are important because they are the primary carrier of fire. Their specific characteristics influence such aspects of fire behavior as rate of spread, flame length, and residence time.

Ladder fuels include taller surface fuels. These fuels generally lie between 5 and 15 feet above the ground. They provide vertical continuity between vegetation layers, conducting fire from surface fuels into the crowns of shrubs or trees. Ladder fuels can initiate and spread crown fires, which lead to increased resource damage, pose high levels of risk, and are very difficult to contain.

Aerial fuels include both live and dead material in the forest or shrubland canopy. These fuels are typically more than 15 feet above the surface. They include tree branches, twigs and cones, snags, moss, and high brush. Aerial fuels are the fuels available for supporting a crown fire.

All fuel types have characteristics that are important to evaluate when developing the most appropriate strategy for any given area. These characteristics include fuel volume, fuel size, arrangement and continuity of fuels, and fuel compactness.

Fuel volume is the quantity of a given fuel type, typically measured in tons per acre. This measure is meaningful only if is contextualized; for instance, it can be compared with a historical or natural condition, or a desired target volume.

Fuel size affects the rate of spread and residence time of fire. The size of the material determines the speed of ignition and rate of consumption. For example, in selecting kindling for a cooking fire, smaller, lighter materials are used to start the fire and to generate enough heat to ignite the larger, longer-lasting material. Fuels are normally categorized into two size classes: fine and heavy. Fine fuels are generally those less than ¼ inch in diameter; these include grasses, pine needles, twigs, and smaller branches. Heavy fuels have larger diameters, are more difficult to ignite, and are consumed much more slowly. In general, fine fuels determine how easily a fire ignites and how fast it spreads, and heavy fuels determine how long the fire persists in a given area (residence time).

Arrangement and continuity describe how fuels lie in relation to one another on both horizontal and vertical axes. On the horizontal axis, conditions are described as patchy or uniform. On the vertical axis, conditions are described in terms of the presence and condition of ladder fuels. Uniform distribution of fuels facilitates a complete, rapid burn. Laddering creates conditions for fire to spread into the crowns, where it can move faster and be more difficult to control.

Fuel compactness generally refers to surface fuels. Fire burns more rapidly in loosely compacted fuels because of the availability of oxygen. Compacted fuels, such as piled logging debris or duff, burn more slowly due to lack of available oxygen.

Topography

Topography is the relief of the proposed treatment area. It describes the angle of slopes, the narrowness of canyons, and the elevational variations within a given area. Topography affects fire behavior in several ways; it can influence regional airflow patterns, and fire itself can respond to steep slopes because of heat's propensity to rise. Moreover, the character of the terrain serves as a criterion to evaluate the reasonableness of treatment options. For instance, slopes steeper than 40% are considered (in the context of this document) too steep to use mechanical equipment safely; accordingly, mechanical treatment must be excluded as a treatment option.

Accessibility

Accessibility generally addresses the existence of roads in or near the treatment area as well as the degree to which the area admits movement within it. Roads are necessary for transportation of mechanical equipment, workers, and any materials that may be transported offsite for utilization or disposal. While presence of a road system does not automatically qualify a mechanical treatment option as reasonable, the absence of roads generally precludes mechanical treatment as a viable option. Moreover, particularly rugged terrain or extremely dense vegetation must be considered in determining whether specific kinds of equipment, or even work crews, can navigate the treatment area.

Theory of Fuel Load Management

The fundamental objective in developing a vegetation and fuel load management strategy is to modify the behavior of fire that may enter the proposed treatment area. As discussed in Chapter 2 (*Vegetation Management: To Burn or Not To Burn*), the fuels can be modified by either removing them or redistributing them.

Initial activities are generally directed towards the surface and ladder fuels, because these are the fuel types where fires typically ignite and spread. Treatment of surface fuels can reduce risk of ignition, particularly in areas of high levels of human use or where the surface fuels exhibit a high degree of continuity. Treatment of ladder fuels helps to decrease the risk of a more dangerous crown fire. However, the sequence and methods of treatment are wholly dependent on site-specific conditions.

In any case, the initial target of any treatment program will typically be the fine fuels, because these pose the highest risk for ignition and spread of fire. Whether material is modified and left on site or removed depends upon site-specific conditions, both technical and financial; however, it should be borne in mind that fuels left on site remain fuels, and may require additional treatment to achieve the desired future condition. For example, if ladder fuels require aggressive treatment and are cut and scattered on site, they are merely transformed into surface fuels. Depending on the preexisting conditions, additional treatment might be required to alleviate the resultant excessive surface load.

Treatment Options

Four categories of treatment options are available: manual/hand, mechanical, grazing, and chemical. These four categories are not mutually exclusive, and treatments frequently entail a combination of methods. Each category includes specific techniques appropriate to various conditions and situations.

Manual/Hand

Hand work involves picking up and moving limbs and brush, as well as cutting downed and standing materials using hand tools or chainsaws. The required levels of skill range from unskilled to skilled (e.g., the ability to use a chainsaw safely). Manual methods usually entail a fairly large crew. Constraints on manual methods are: fuel size (up to 9 inches in diameter); accessibility of the site (e.g., slope, density of understory, rocks, safety); limited opportunity to utilize materials; slow production rate (defined as the acreage that is treated per unit of time—for example, acres per day); and needs (support, safety, sanitation) of personnel.

Manual work—lifting, cutting, and carrying forest materials—is generally limited to materials of roughly 9 inches or less in diameter. Larger materials can be handled, but efficiency, production rate, and safety decrease rapidly as size increases. If the fuels requiring treatment exceed the 9-inch-diameter threshold, hand work is not a good option.

Although hand crews are not subject to the same constraints of access and mobility as mechanical equipment, such constraints must nevertheless be considered. Steeper slopes become decreasingly efficient and increasingly hazardous. Density of vegetation can impede access to the work site and movement within it.

Hand work rarely generates material for utilization. It is difficult and inefficient to carry material to a location where it can be transported off site. Firewood is often collected manually, but most other types of utilization require machinery to enter the area being treated.

Hand treatments usually address rearrangement as opposed to removal of fuels. While this can be an effective treatment in certain conditions, it is typically a short-term solution. Alternatively, it can be used as a primary treatment that is followed by burning to consume residual material; the site is subsequently managed by prescribed maintenance burns.

Production rate is determined by the structure of the fuels being treated; for example, a dense stand takes much longer to treat than an open stand. Moreover, a fairly large workforce is required to treat areas in excess of a few acres; a larger workforce, if it is to be efficient, requires close coordination and a structured organization system.

Advantages of hand work include the low level of ground disturbance, the ability to work on steeper slopes than is feasible for many kinds of mechanical equipment, and the ability to treat sensitive habitats such as riparian areas.

Cut and Scatter

Hand crews cut and scatter material to change the vertical and horizontal continuity of the fuel load. This technique increases the surface fuel load by redistributing ladder fuels onto the ground surface. It is appropriate where stand density is generally low and existing surface fuels are shallow. An upper depth limit for scattered material is generally prescribed.

Pile

Cut material can be piled either by hand or using mechanical equipment. As in the cut and scatter method, the fuel load is redistributed rather than reduced. Piling of materials disrupts horizontal continuity to a greater degree than does scattering; it is frequently used as a secondary treatment for material left from a primary treatment method. Piling can be used in denser stand conditions than can scattering because the piles can be situated to avoid fuel loading problems. Because continuity of the surface load is disrupted, increased surface loading is of less concern than it is with the scatter method. However, there are drawbacks to the piling of cut material: piled material decomposes more slowly than scattered material, piling can be quite labor intensive, and dense stand conditions can result in a high number of piles.

Mechanical

Mechanical treatments employ equipment as the primary method of modifying or removing fuels. Mechanical treatments include mowing and masticating as well as traditional harvest operations. A common feature of mechanical treatments is the need for access. Generally, treatment areas must be within approximately ¼ mile of an existing road system.

In general, mechanical equipment consists of two components: the *prime mover* and the *head*. The prime mover is the power source and carrier; it can be rubber tired, rubber tracked, steel tracked, or stationary. The head is attached to the prime mover; heads can be fixed mounted, limited movement mounted, or attached to an articulating arm. A wide variety of permutations are available for use on different kinds of terrain and to address different fuel types and structures; a detailed catalogue of specific equipment types is provided in Appendix __.

In recent years the array of equipment available for vegetation and fuel load management has expanded dramatically. Many innovative methods and designs have evolved from technology that was developed for the logging and heavy construction industries. For example, an excavator developed for heavy construction is often employed as the prime mover for a head designed to shred or chip large-diameter fuels.

Pile

Material can be piled mechanically as well as by hand. See the discussion above for a description of this technique's advantages and disadvantages.

Fuel Modification

In this suite of techniques, machinery is used to process the material into smaller pieces that can then be redistributed on the ground surface or removed from the site. Because materials processed in this fashion can be much more densely packed than materials that are scattered by hand or piled, the available oxygen supply is reduced, thereby inhibiting spread of fire and flame height.

Fuel modification falls into three broad categories. The first, *Masticate/Mow*, involves the reduction of material on site and in place; such material is intended to be left. The second, *Chip/Grind*, involves a piece of equipment into which material is placed for processing, and from which material is discharged through a chute. Chip/grind methods are more appropriate for biomass removal because the system lends itself to placing processed material directly into a conveyance vehicle. The third, *Crush*, involves crushing and compaction of smaller materials (e.g., brush, slash, small trees) on site.

Masticate/Mow

Mastication involves the processing of standing or downed material where it occurs; generally a blade or other mechanism is applied to the fuel. This approach is suitable for denser stand conditions than is scattering or piling, and the redistributed fuel load decomposes more rapidly than scattered or piled materials. It is most appropriate for treating both green and dead ladder fuels and the higher surface fuels; however, it should be borne in mind that mastication is generally constrained from operating with a foot or two from the ground. Like other mechanical treatments, mastication is restricted to areas with suitable access and slopes less than 40%. The distribution of masticated material may inhibit plant growth. The effects of fire on areas that have been treated with mastication are not well documented; it is possible that such areas may be subject to increased residence time if fire does occur.

Mowing is primarily appropriate to treat grassland and light shrubland habitats. It is grouped with mastication because, like mastication, mowing processes the vegetation material on site and in place.

Chip/Grind

Chipping/grinding, like mastication, reduces materials into small pieces. However, as mentioned above, in this group of methods, material is placed into a piece of equipment and discharged, often through a chute; because of this feature, material can be processed more selectively and transported off site for either disposal or utilization. Chipping/grinding can be employed in conjunction with other treatment methods, both manual and mechanical, that create smaller materials as a byproduct (e.g., tree removal, hand cut and pile). It is the method of choice when utilization of biomass is an option.

Crush

Crushing is another form of mastication; this technique is useful primarily in shrubland habitats dominated by brittle species, such as some of the manzanitas. Some specialized applications have been developed facilitating treatment on steep slopes, making this option particularly suited for habitat types that occur in arid and semi-arid portions of southern California.

Tree Removal

Numerous approaches to tree removal have been developed as the timber industry has evolved to operate in a variety of habitats and under myriad political and economic constraints. This document addresses three broad categories of tree removal for possible inclusion in development of nonburning fuel management strategies: bole removal, whole tree yarding, and cut-to-length logging.

Bole Removal

This is traditional harvesting. Trees can be felled either by hand or mechanically; the bole is then removed by a variety of mechanical systems, depending on the conditions, and transported off site for processing. Bole removal eliminates the vertical continuity of the fuel load, but increases surface fuels with the addition of leaf/needle and limb materials. Overall biomass is reduced. Bole removal, because of its dependence on mechanical equipment, is restricted to areas near roads and on relatively shallow slopes. Moreover, this technique removes that portion of the forest structure that is at least risk from fire, while leaving the components normally addressed by fuel management programs (i.e., leaf/needle and limb material). However, a wide variety secondary treatments can succeed bole removal as fuel management activities. The critical point is that the subsequent treatments determine the efficacy of bole removal as a component of a fuel management activity. Accordingly, although bole removal in and of itself can in some instances be employed to accomplish specific fuel management objectives (e.g., creation of firebreaks, home protection, disruption of canopy continuity), it is not generally accepted as a vegetation or fuel load management technique, and is not addressed as such in this document.

Whole Tree Yarding

Trees can be felled either by hand or mechanically; the entire tree is then brought intact to a staging area, where it is processed into a variety of products. This method removes the vertical continuity of the fuel load, removes biomass, and adds very little to the surface fuel load; moreover, the removal of leaf/needle and limb material is more important than bole removal in the context of fire behavior. Material more than 9 inches in diameter can be utilized. However, because branch scarification resulting from removal of larger diameter materials (e.g., >18–24 inches, depending on species) can damage soils and adversely affect water quality, this technique is only appropriate for trees of moderate diameter (e.g., 9 to approximately 18 inches).

Cut-to-Length Logging

Cut-to-length logging utilizes specialized equipment to cut and process entire trees on site in the forest. While much of the biomass either remains onsite or must be addressed through secondary treatments, an important advantage of this technique is its efficacy in treating material of very small diameter. Moreover, the nature of the equipment renders it less likely to inflict ground damage in treatment areas, and the removal of small, dense trees can be conducted to improve health and vigor of remaining trees. While cut-to-length logging is more expensive than whole tree yarding, it is suitable for stand conditions that preclude use of the latter method.

Chemical

Chemical treatments entail the application of herbicides. It should be emphasized that chemical treatments do not remove fuels, but either kill existing vegetation or inhibit growth. In general, chemicals are appropriate to treat flashy, understory growth such as the weedy vegetation under power transmission lines or along railroad rights-of-way. Alternatively, chemical treatments can be used in conjunction with other treatment types, including prescribed burning, to extend the period between necessary management activities.

A widely-used chemical treatment in vegetation and fuel management programs is called *brown-and-burn*. In this technique, pesticides are used to kill target species of understory vegetation, converting live fuel to dead fuel. The chemical treatment can be applied in spring, when nontarget species remain green, thereby facilitating a prescribed burn to remove the vegetation that has been rendered flammable. However, because this technique is properly a preburning procedure, it cannot be considered a nonburning alternative.

The utility of the growth-inhibiting function of chemical treatment types is exemplified in the maintenance of *defensible fuel profile zones* (DFPZs). DFPZs are shaded firebreaks, typically along ridgetops, where mechanical or manual treatments have been applied to reduce fuel loads and create an area where, in the event of a wildfire, the decreased fuel load will retard the spread of the fire and fire crews can work at containment and control of blaze. Periodic chemical treatments could be used to maintain the desired fuel characteristics within the DFPZ, obviating mechanical or prescribed burning treatments for many years.

The drawbacks to chemical treatment methods include very stringent regulatory requirements, the possibility of adverse impacts on water quality, destruction of species that are not target species, toxicity levels, and negative public opinion.

Because chemical treatments have limited efficacy in directly addressing existing fuel load management problems, they are not discussed further in this document. However, under certain site-specific conditions they remain potentially useful options.

Grazing

Grazing involves the use of livestock—primarily cattle and goats—to manage the growth and composition of brush and grasses. While it is of limited utility in forested habitats, it can be an effective technique in rural residential areas, in the urban-wildland interface, and in selected grassland and shrubland habitats. Moreover, research has shown that in some habitats, carefully managed grazing programs can be used to restore degraded ecosystems to historical conditions. For example, in dry rangeland areas, grazing has been used to convert nonnative annual grassland habitat to perennial bunchgrass communities. While the applications of grazing are limited within the scope of habitats addressed in this document, it is nevertheless a technique that enjoys little political resistance and requires a minimum of financial investment.

Environmental Considerations

The primary goals of promoting nonburning alternatives for wildland regions are to avoid the environmental impacts of burning on visibility and air quality and to eliminate the risk of escapes, which can threaten human life and property as well as natural resources. While nonburning alternatives may achieve the desired results in terms of air quality, attention must be given to other environmental impacts. For example, use of heavy equipment on sensitive soils can result in soil compaction, and the resultant erosion can lead to ecosystem damage as well as degradation of water quality. Consideration of such potential impacts should constitute part of any analysis of alternatives.

The criteria by which to evaluate potential environmental impacts are frequently too site-specific to fall within the scope of this document. However, environmental impacts should be examined in the context of the resource areas listed below. It should be borne in mind that any given criterion might be decisive in a given situation; in a different situation, however, the same criterion might be irrelevant.

- **Adverse impacts on air quality.** Although a primary motivation for selecting nonburning over burning treatment options is the vast reduction of adverse impacts on air quality, it must nevertheless be understood that even nonburning alternatives may create some adverse effects. For instance, mechanical equipment produces vehicular emissions, and the movement of heavy equipment can give rise to fugitive dust emissions. These effects should be considered during any environmental review process necessary to approve a vegetation and fuel management plan.
- **Soil compaction.** Soil compaction is of particular concern when conducting mechanical treatments. Passage of heavy equipment can compact soils; compaction can impede permeability, which in turn can reduce groundwater recharge and increase surface runoff. Moreover, the removal of air spaces in the soil can impair the soil's ability to support root development.
- **Water quality degradation.** Soil compaction can increase runoff, posing potential threats to water quality. Additionally, removal of vegetative growth can, by eliminating demand for surface and shallow subsurface water, also increase surface runoff. Increased surface runoff can exacerbate erosion, degrade riparian habitats, and discharge damaging quantities of sediment into watercourses.
- **Removal of nutrients from site.** An important component of any ecosystem is the recycling of nutrients back into the soil. In fire-adapted habitats, periodic naturally occurring fire is a significant mechanism of nutrient recyling; the complex processes of decay and deterioration are also important. Prescribed burning can mimic the role of naturally occurring fire in nutrient recycling; however, nonburning alternatives that remove substantial quantities of biomass can interrupt this cycle. It is important to

consider the impacts of various treatment options on nutrient recycling when developing a vegetation or fuel management strategy.

- **Undesirable impacts on wildlife habitat.** Many materials that constitute potentially problematic fuels can also serve as important components of wildlife habitat. For example, snags provide breeding habitat for a variety of species; surface vegetation provides cover for birds, mammals, reptiles, amphibians, and invertebrates; and surface litter can provide an important substrate for small vertebrates and invertebrates. Although any habitat modification can adversely affect wildlife habitat, well-designed vegetation and fuel management programs should, in the long term, have generally beneficial effects on habitats on the landscape scale.
- **Threatened and endangered species.** While it must be accepted that any habitat modification will affect plant and wildlife habitat, particular care must be given to habitat that supports or that could support threatened or endangered species. In some cases, even seemingly insignificant modifications can have far-reaching effects on certain species. A careful review should be made of special-status species that could occur in the treatment area, and a thorough evaluation of the impacts of alternative treatments on such species should be conducted.
- **Augmented spread of undesirable species.** Many invasive plant species exploit areas of soil disturbance; such areas can be created by implementation of various treatment methods, especially mechanical methods. Additionally, equipment can transport seeds of invasive species on tires and treads. Practices and procedures incorporated into the vegetation and fuel management plan can reduce the effects of this impact.
- **Augmented disease/pest impacts.** The process of cutting trees and brush precipitates vegetative production of pheromones that serve as attractants to pests such as woodboring beetles. An influx of such pests can cause damage to remaining vegetation, particularly if stands have been compromised by earlier conditions. This potential impact must be carefully addressed in the development of a vegetation and fuel management strategy.
- **Adverse impacts on cultural resources.** The potential of inflicting adverse impacts on cultural resources is largely associated with mechanical treatment options—that is, the risk of mechanical equipment crushing resources that may be present on or immediately beneath the surface. The environmental review process to which most treatment plans (particularly those on public lands) are subject should address the likelihood of such resources being present in the treatment area.

Economic Considerations

Conventional wisdom suggests that, as a rule, nonburning alternatives are more expensive than burning. While there are arguments both to support and to refute this contention, there is another perspective that is perhaps more pressing to consider: namely, that the fuel load crisis facing western wildlands is far too acute to relegate to the marketplace. The management actions that are the subject of this report comprise a response to conditions that have resulted from more than a century of unfortunate management decisions. The condition of the western wildlands will not dissipate if left to its own devices, and each year that passes without significant action to address the problem increases the extent and risk of catastrophic wildlife. While any revenues that can be generated from vegetation and fuel management activities should be welcomed as offsets to the costs, the driving intent of such programs should not be financial but rather should be based upon the desired future conditions of the wildland habitats subject to the management actions.

In examining the question of burning versus nonburning treatments, several financial considerations come to light. First is the direct cost of the treatment method; as stated above, it is generally accepted that burning is less expensive than nonburning alternatives. Second, though, one should consider the indirect costs; for example, the societal costs of impaired air quality in increased health care expenditures, reduced tourist revenues, and resource loss. Third, and perhaps most compelling, is the risk of escape which, as has been discussed previously, can lead to catastrophic and unanticipated costs.

However, such a discussion is beyond the scope of this document, and would likely require intensive data collection and analysis. Accordingly, this report focuses on those financial considerations associated with fuel treatment. These considerations are cost per unit of production, production rate, labor requirements, skill requirements, risks of collateral damage, and the potential generation of revenue from materials produced through the treatment method selected.

Because nonburning alternatives may be more expensive and logistically complex than burning, they can present greater challenges in securing financing. The potential of an alternative to generate revenues, the availability of funding mechanisms, and access to professional advice and guidance should be examined during development of the most appropriate fuel management strategy. After considering the types of fuels present and the treatment options available, the land managers must then consider funding sources and access to technical assistance or expertise.

Costs of Treatment

As discussed above, the direct costs of nonburning alternatives tend to exceed those of prescribed burning. Hand crews can be less expensive than other options, but they tend to be most useful in treating rather restricted areas. The cost of mechanical treatments vary widely; regional availability of equipment and personnel can vary tremendously depending upon a given area's economic base. Techniques such as mastication that require specialized equipment and produce no utilizable material tend to be the most costly, but even conventional tree removal techniques can be prohibitively expensive if it is necessary to transport equipment and personnel from out of state.

Infrastructure Conditions

Infrastructure essentially refers to existing facilities, equipment, labor, and transportation that might be available to implement a desired treatment option. Accordingly, the economic implications of infrastructural constraints are site-specific; if the treatment area is in a region that traditionally supports—or until recently did support—a forest products industry, then the infrastructure will likely be available to support mechanical nonburning alternatives. Perhaps the most critical consideration in this context is the cost of transporting either labor and equipment to the treatment area or generated materials to the facilities necessary to process them. This is discussed at greater length in Chapter 4 (*Getting to Work: How to Build a Nonburning Strategy*).

Utilization

Definition of Utilization

Vegetation management activities associated with fuel reduction can result in the generation of usable materials, which in turn can be sold for profit. For the purposes of this document, *utilization* refers to the use of materials that are generated by treatment activities.

When evaluating the feasibility of utilization as a component of a treatment option, it is necessary to consider the costs of generating the material and transporting it off site, the cost of remanufacturing the material into a form that generates revenue, and the potential of selling the product to the end user. Another consideration can be additional support outside of market interactions, generally referred to as subsidies or price supports; these can be used to offset costs when market prices do not equal production costs. The feasibility of utilization is determined by these costs and by market conditions such as industry capacity, capitalization, and labor. This document addresses the utilization process from the generation of raw material to its sale to the remanufacturer.

Utilization Benefits

As has already been discussed, the primary objective of any vegetation or fuel management program should be achievement of the desired future condition. However, when the appropriate treatment option is likely to produce utilizable material, or when production of such material might be the decisive factor in selecting between alternative methods, then such potential should be considered in the decision-making process. Utilization can be undertaken to generate profit or to offset the cost of the treatment program.

- Profitable transactions occur when (a) useful materials are generated and (b) the resultant transactions cover all extraction and transportation fees and produce a margin of profit for the landowner/manager. Profitable transactions are generally market driven.
- Cost offset transactions reduce the cost of treatment that is undertaken to attain condition goals rather than to generate profit.

When generation of useful material is not the primary motivation, cost offset transactions can be important to implementing the necessary fuels management program. Such transactions can comprise a combination of product sales, cost sharing, price supports, and grants that provide monies to offset the costs of extraction and transportation not covered by market transactions.

In addition to useful products generated directly by fuel reduction activities, indirect benefits, such as increased revenue from recreation (e.g., camping, hunting, fishing), can result from fuel reduction activities. However, because such indirect benefits are difficult to describe and quantify and are generally very case- or site-specific, they are beyond the scope of this document.

Types of Products Generated

Products that may be generated by nonburning treatment activities can be broadly divided into two categories: industrial and nonindustrial. Industrial products are those that are available in large quanitities, consistently, or over large geographical areas. Nonindustrial products are generally associated with lifestyle-related or aesthetic enterprises; these tend to be used in producing specialty or value-added products.

Industrial Products

Below is a general list of industrial products than can be generated by some vegetation and fuel load management programs.

- Whole logs
  - lumber of varying grades
  - molding and finish pieces
  - engineered wood products (e.g., glued laminates, finger jointed material)
  - peeled veneers (e.g., finish veneers, plywood)
- Round wood

  - fencing material
  - vertical support elements (poles)
  - beams, joists, and truss elements
- Cord wood
  - firewood
  - low-grade fencing material
  - pulp for paper
  - extractive products (e.g., mineral spirits, alcohol)
- Clean chips
  - high BTU combustible uses (steam generation for power)
  - engineered wood products (e.g., flake board, oriented strand board)
  - pulp for paper
  - extractive products (e.g., mineral spirits, alcohol, sugars)
- Dirty chips
  - lower BTU combustible uses (e.g., drying operations, heating)
  - mulch
  - animal bedding

Energy-related products include firewood, fuel for drying kilns, and fuel for cogeneration plants. Energy products typically yield the lowest return of the spectrum of forest products that can be produced by vegetation and fuel management programs. In general, market decisions are based on site-specific and regional market conditions.

Nonindustrial Products

Nonindustrial products typically entail a high value-added component because of the skill required to create them, the inherent attractiveness of the material used, or limited availability. Examples include musical instruments, turned wood products, specialty cooking woods or charcoals, canes and walking sticks, and basket materials. While they generally do not produce industrial-scale benefits, these products may cumulatively provide substantial incentive because of the high value added; moreover, they offer some intriguing opportunities for creative entrepreneurial undertakings, particularly in areas that have suffered economic depression as a result of the flagging timber industry.

Utilization Constraints

Although useful material may be generated by vegetation management activities, there are often constraints to successful utilization. For instance, lack of demand or global competition can depress prices beyond the threshold of practicality. The material recovered may not meet industry standards in either the quality or quantity required to warrant commercial exploitation. The infrastructure necessary to extract, transport, or process recovered materials may be lacking due to mill closures, suppression of the lumber industry, or a shortage of skilled labor. Regulatory requirements can create costly and time-consuming constraints to pursuit of management activities. These issues are discussed in greater detail in Chapter 4 (*Getting to Work: How to Build a Nonburning Strategy*).

Funding Sources and Fuel Management Programs

Because nonburning alternatives may be more expensive than burning, greater effort may be necessary to secure funding to implement them. Potential sources of funding for nonburning alternatives generally fall into two categories: utilization earnings and program grants. Utilization has been discussed above. Program grant monies are acquired by applying to agencies or nonprofit organizations for financial assistance with fuel reduction efforts.

The NFP, the most notable grantmaking program associated with vegetation and fuel load management, has significantly changed the nature of fuel management funding. The NFP has in the last few years greatly increased the amount of funding available for firefighting, restoration, hazardous fuels reduction, and community assistance. This availability of funds has in turn increased the number of fuel management projects currently being implemented in the western United States and nationwide.

The USDA Forest Service and the Department of the Interior are currently in the second year of implementing the NFP. Congress provides substantial support, as evidenced by more than $2.26 billion allocated for the NFP in the *Interior and Related Agencies Appropriations Act* for fiscal year 2002. This amount includes $1,590,712,000 for the Forest Service and $678,421,000 for the Department of the Interior.

The NFP facilitates collaboration of federal, state, tribal, and local governmental and nongovernmental representatives for the purpose of improving the management of wildland fire and hazardous fuels, as well as meeting the need for ecosystem restoration and rehabilitation on federal and adjacent state, tribal, and private forest and rangelands. The NFP's 10-year comprehensive strategy outlines a new collaborative framework to facilitate implementation of proactive and protective measures that are appropriate to reduce the risk of wildland fire to communities and the environment.

While NFP funds dominate fuel management funding options, other sources are available. Appendix B provides a partial list of funding sources available for fuel management efforts.

Many programs dedicated to fuel management and other fire-related issues have evolved in recent years, both independently and as a result of the NFP. In addition to national programs such as the NFP and Firewise, many western states have instituted programs to assist private landowners and public land managers in managing and reducing fuel levels. Some communities have also initiated programs to manage local resources (e.g., Kootenai County, Idaho).

National, state, and local fuel management programs offer assistance to fuels managers in a multitude of ways. Fuels management programs may provide technical assistance to land managers. Program representatives can impart knowledge and guidance in project design, financing, and implementation.

Appendix C provides a partial list fuels management programs currently operating in the western states. This list was compiled from interviews with state representatives and from internet research. The list is not exhaustive; rather, it is representative of the array of national, state and local programs available to land managers.

Labor Sources

The availability of labor sources to perform fuel management work is an element of project implementation that should be considered following the identification of fuel conditions and treatment options. Landowners and land managers should assess the availability of manual and specialized laborers. Certain treatments, such as hand piling, require unskilled manual labor by a relatively large work force. Other treatments require specialized skills in operating machinery or equipment.

Some areas may suffer a shortage of available labor; others may have a surplus due to an expanding pool of unemployed loggers or other laborers. In some cases, land managers may need to hire out-of-state contractors to perform fuel reduction and removal activities.

Appendix D provides a list of some labor sources available in western states. While some states may currently rely on only a few of these sources for fuel management labor, all of them should be considered by landowners and land managers when seeking new labor. Land managers of new and future projects are encouraged to consider all potential labor options and to investigate which are available in their local areas.

Nonprofit Organizations

Nonprofit organizations can often provide support to landowners and land managers in planning and implementing projects. For example, local university extension programs may offer technical assistance and professional expertise in developing fuel management projects. Some nonprofit organizations may provide volunteers to participate in labor-intensive activities such as hand piling. There are also opportunities for partnering with nonprofits to secure project financing and to share the responsibility for project implementation and success.

Appendix E provides a partial list of nonprofit organizations throughout the western United States that could have an interest in fuel management projects. In addition to the obvious practical advantages, obtaining nonprofit participation can help to involve the local community in project planning, thus aiding in building popular support for the project.

Sociopolitical Considerations

Social and/or cultural considerations can play a critical role in developing a viable nonburning strategy. Some alternatives may have implications for certain groups, such as small landowners or residents of tribal land. Others are likely to provoke heated responses from certain community groups. Community groups that are predisposed in opposition to a particular type of treatment may have the organizational and financial resources to prevent or delay implementation.

Even when the decision maker has evaluated a treatment option in the context of technical feasibility, environmental appropriateness, and affordability, another suite of potential constraints remain to be addressed. These less concrete but no less real sociopolitical considerations can include:

- Health and safety concerns
- Tribal concerns
- Social justice
- Resistance by resource agencies
- Resistance by environmental groups
- Resistance by industry groups
- Resistance by community groups
- Regulatory constraints

Barriers to Nonburning Alternatives

There are numerous barriers that may discourage or prohibit the use of nonburning alternatives to manage fuels in the west. Table XX in Appendix XX lists barriers that were identified by respondents to the interviews conducted during preparation of this report. For this discussion, these barriers have been categorized in accordance with the four issue areas used throughout this document.

1. **Technical Constraints.** These barriers include inhibited access to project areas due to topographical or climatic conditions or the absence of roads; proximity to residential or other developed areas; and lack of available infrastructure, equipment, or labor.
2. **Environmental Constraints.** These barriers include presence of sensitive natural resources and the potential impacts of fuel treatments on these resources (e.g., sensitive soils, sensitive vegetation communities, presence of threatened or endangered species, water quality concerns); the potential for introduction or spread of invasive nonnative plant species or pathogenic organisms; and the presence of cultural resources.
3. **Economic Constraints.** These barriers include lack of funding to perform fuels management treatments; lack of markets for utilization of material; cost of equipment and labor; cost of transporting utilizable material; and the need to generate profit from activity (required by some jurisdictions).
4. **Sociopolitical Constraints.** These barriers include public opposition to specific treatment types; institutional resistance to new approaches; lack of available staff at relevant resource agencies; regulatory requirements; and non-statutory administrative obstacles to nonburning alternatives (discussed further below.

In its 1996 report to the EPA, the GCVTC provided emission management recommendations for area sources, including recommendations regarding fire. One of these recommendations suggested that the federal land management agencies and their state, tribal, local, and private counterparts should identify and remove non-statutory administrative barriers to emission reduction strategies by the year 2000, to the maximum extent feasible.

The majority of activities on wildlands are regulated by agencies that plan, approve, and implement projects within an administrative framework. The administrative framework includes statutory and non-statutory barriers. Statutory barriers are laws, codes, and regulations. Non-statutory barriers are internal policies defined in an agency's handbooks and manuals or formalized in approved land use or resource management plans or environmental documents. Non-statutory administrative barriers may be influenced by social, economic, cultural, or political factors.

Non-statutory administrative barriers can include requirements for compliance with best management practices (BMPs), mitigation measures incorporated into

National Environmental Policy Act (NEPA) documents or memoranda of agreement (MOAs), and policy-level decisions identified in resource and land management plans. For example, a BMP for use of mechanical equipment on the Plumas National Forest in northern California specifies a slope limitation beyond which use of mechanical equipment is prohibited. However, as new equipment is developed, it might become advantageous to allow mechanical treatments outside the parameters of the BMP, particularly under specific fuel conditions. In another example, BMPs incorporated into the MOA between the USDA Forest Service and the Tahoe Regional Planning Agency prohibit the use of mechanical equipment within the 100-year floodplain. However, if fuel load considerations warrant such work, it might be advantageous to suspend such prohibitions to reduce the greater risk of catastrophic wildfire.

In conclusion, it should be emphasized that despite the many barriers that currently exist, there is great opportunity in the growing field of nonburning alternatives. Many of these barriers can be overcome by the simple expedient of communication and education; others may require adjustments to the administrative and regulatory framework within which fuel management programs must operate. In any case, the increasing degradation of air quality and the continuing crisis of overaccumulated fuel loads clearly warrant concerted efforts in promoting the development and implementation of nonburning alternatives to prescribed burning.

Chapter 4

Getting to Work: How to Build a Nonburning Strategy

Developing Alternatives

There is, as has been asserted elsewhere in this document, no "one-size-fits-all" approach to developing a vegetation and fuel load management strategy. In assessing the array of nonburning alternatives and designing a program, the land manager must evaluate the categories of considerations described in the preceding chapter in light of regional and site-specific conditions. This chapter discusses in greater detail the chains of reasoning that one might follow in proceeding through the analysis of possible alternatives.

Technical Feasibility

When beginning to develop a strategy for vegetation or fuel load management, the land manager must first consider what is technically feasible. Clearly, there is no virtue in navigating the sociopolitical hurdles for activities that either cannot be conducted or will not achieve the desired results. The first step in determining the appropriate methodology is to understand the fundamental relationship between vegetation structure and the various types of treatment options available.

Methodology and Vegetation Structure

Every methodology, burning and nonburning, is constrained by parameters which, in turn, are associated with the physical conditions of the proposed treatment area. To assist in the decision-making process, the authors have developed a conceptual model that illustrates the relationships of various treatment types with vegetation structure and with one another.

This model simplifies the description of vegetation into two components: volume/density (measured in tons per acre) and average stem diameter. For analytical purposes, volume/density is represented on the *x*-axis of a simple graph, and stem diameter on the *y*-axis. It should be understood that the figures illustrating this model are merely schematic, and are not intended to accurately depict real-world situations. Similarly, the designation of *average stem diameter* is a conceptual descriptor; for real-world application, the model must be adjusted to take into account relative densities of various diameters in the context of the specific vegetation types to be treated.

Although there are many exceptions, this model suffices to describe the spectrum of vegetation structures. For instance, grassland habitat measures very low on both stem diameter and on volume/density; it is, accordingly, represented in Figure 4-1 as *Prairie*. A grazed field might be represented at a still lower volume, whereas a pampas of shoulder-high grasses would be depicted higher on the graph. Shrublands exhibit higher stem diameter, although sparse habitats supporting small shrubs might contain less volume/density than a tallgrass prairie. Forested habitats might exhibit dense stands of small-diameter trees (e.g., lodgepole pine) or sparse stands of large-diameter trees (e.g., eastside Sierran pine).

The graphs reflect a schematic representation of the parameters within which treatment types are typically selected. It should be understood that the graphically depicted limitations are not absolute, but can be artificially forced beyond normal bounds. For instance, the lower limit of harvesting is determined by the economic feasibility of carrying out operations within a certain range of density and diameter of materials. It should not be inferred that tree removal cannot be implemented under conditions of lesser diameter or volume; rather, the implication is that such an operation would not be profitable and would, consequently, require a source of funding beyond the revenue generated by extracted materials.

Traditional Treatments

Burning

The two vegetation management strategies traditionally employed on wildlands are harvesting and burning. Harvesting is associated with commodity production; burning is not. The conceptual model can be used to plot the boundaries of desirable, effective, and efficient conditions for each of these strategies.

The plot for burning (Figure 4-2) shows that burning is an effective and controllable method for almost all volumes of small-diameter vegetation arrangements. As stem diameter increases (e.g., ~4–10 inches), the volume for which burning is a reasonable method decreases. This is because fire behavior intensifies; the fire is likelier to escape control and, as temperatures increase, may cause undesirable levels of mortality in the vegetative structure. However, fire regains practicality with further increase of stem diameter because substantially larger stems are likely to survive fire, particularly in more open stands. The upper limit for fire is primarily defined by controllability and potential resource damage, although some areas outside the plot reflect conditions under which burning would be either inefficient or unnecessary.

As mentioned above, it would be possible to implement a burning program above the area delimited on the graph; such a program, however, would necessitate artificial modification of one or more parameters. For example, a burning program under such conditions would likely require multiple entries, with primary treatments being conducted under such restrictive circumstances that only minimal treatment would be accomplished. Subsequent burns would be necessary to achieve desired final conditions, and each burn would extend the time required to accomplish the goals, increase the risk of escape, and further contribute to air quality impacts.

Because the upper limit of the burning plot is essentially a function of risk, this boundary is, in a sense, a “soft” one. Especially in matters as difficult to quantify as natural systems and fire, risk is by its very nature a particularly subjective descriptor. Risk that is acceptable to a land manager might be out of the question to a small landowner. Moreover, a vegetation structure that would be too dangerous to burn under certain weather conditions could be reasonable to burn under others. Such variability and subjectivity can suggest that burning is a reasonable treatment for virtually all vegetation conditions—at least under certain circumstances.

Such a perception can have dangerous implications. Land managers might, by waiting for a certain set of conditions, decide to use prescribed fire on vegetation structures for which such treatment would normally not be indicated. The decision might be driven by short-term financial considerations and could, consequently, have unfortunate results. The requisite conditions could so minimize the effects of fire that only limited benefits would be realized. Alternatively, while waiting for the optimum conditions to align, habitat conditions could alter enough that unwanted resource damage could occur; in extreme cases, such changes could lead to escape. Also, as discussed in Chapter 2 (*Vegetation Management: To Burn or Not To Burn*), the constraints on requisite conditions could be so restrictive that the burn window might never open.

Harvesting

The plot for harvesting (Figure 4-3) is bounded by financial considerations. The bottom threshold represents the volume/density of material below which the mobilization of equipment and labor becomes economically unfeasible. The left boundary represents the weak market for small-diameter materials and, to a lesser extent, the limitations of equipment and technology for harvesting such materials.

The plot illustrates that as diameters increase, the overall volume/density of the material can decrease; this reflects the fact that very large trees have more value per unit of volume than smaller trees. Accordingly, if the land manager chooses to implement a harvesting program on forestland of low volume/density, the financial equation must be modified: the material must have higher than normal value, cost of extraction must be lower, or supplemental funding must be secured.

It should be noted that the left boundary—that reflecting a threshold of smaller diameter stems—has shifted towards the left over the last few decades. This is because the demand for wood and wood products has increased even as the number of available large trees has decreased; at the same time, mills that had been designed for large diameter logs have been retooled to accommodate smaller diameter materials. New harvesting equipment has also facilitated the shift.

The Burn/Harvest Disconnect

Figure 4-4 overlays the plots depicting harvesting and burning. Cursory examination reveals a significant gap in the range of vegetation structures suitable for treatment by the two traditional methods; in many cases, the vegetative structures represented by this gap are those most in need of treatment. The unavoidable implication of this gap is that either the limits of the traditional treatment paradigms must be forced to encompass the deficit, or a nontraditional paradigm must be developed to address those conditions beyond the bounds of traditional methodologies.

Mastication and Biomass Removal

Mastication

Mastication in its simpler forms is far from a new concept. Mowing of grass and even larger shrubs has been used to manage vegetation in situations ranging from lawns and gardens to railroad rights-of-way. Only recently, however, has mastication been applied to forest habitats.

The boundaries of mastication (Figure 4-5), and the factors those boundaries represent, are quite different than those of burning or harvesting. As in the case of harvesting, there is no risk factor limiting the level of volume/density for which mastication is appropriate. Mastication is suitable for even the finest fuels; the upper (right) limit of stem diameter corresponds almost precisely with the lower limit for harvesting. There are two reasons for this correspondence: first, the equipment used for mastication is not designed for large-diameter trees; second, larger trees have greater value when either left in the environment or harvested for market. Because mastication is a treatment option that is not intended to address market considerations, there is no lower limit of volume/density.

Biomass Removal

Biomass removal can be similar to mastication except that the material is removed from the site to be disposed or utilized. It can entail creation of chipping or mulching as well as whole tree yarding and, as discussed earlier, it entails a different suite of equipment. Depending on the particular type of biomass removal selected for the specific site, the boundaries can be the same as those for mastication (Figure 4-5) or can reflect whole tree yarding (Figure 4-6), which accommodates much higher stem diameters than mastication. The critical difference between mastication and biomass removal is that the material generated by mastication remains on site, whereas the material generated by biomass removal is transported from the site for disposal or utilization.

If whole tree yarding is the selected method of biomass removal, and if the treatment is undertaken as a commercial venture, then the boundaries to left and bottom are roughly congruent with the boundaries depicted for harvesting. However, the upper limit of stem diameters is lower, because very large trees cannot be removed intact without causing severe scarification to soils.

Site-Specific Considerations

The general nature of the foregoing discussion, once again, should be used as a filter through which to evaluate available options. Specific project design must begin with site-specific conditions that have been previously discussed: topography, habitat type, fuel load conditions, road accessibility, and existing infrastructure. In the second part of this chapter, *Assessing the Alternatives*, a framework is provided for eliminating inappropriate techniques and making the most informed selection of those that remain.

Environmental Feasibility

When the field of possibilities has been narrowed, the land manager must consider the environmental impacts associated with treatment options that have been found to be technically feasible. Because the environmental considerations are so intimately connected with the location and character of the project site, it is impossible to address them in other than a very general fashion in this document.

The treatment area should be thoroughly reviewed (through both literature reviews and field surveys, as appropriate) to inventory any sensitive resources that might be present on or adjacent to it; the proposed activities should then be evaluated to identify impacts that could result. Clearly, if listed species or other sensitive resources are identified, specific regulatory constraints can come into play; these must be addressed in keeping with the requirements of the jurisdiction that has authority over the site as well as with federal regulatory requirements (e.g., the Endangered Species Act, the Clean Water Act, the Migratory Bird Treaty Act).

In some respects, the regulatory constraints might be more easily navigated than other environmental influences. As has been stated previously, any vegetation or fuel management program will have environmental effects. Some of these will inevitably be adverse effects—at least from certain perspectives. For instance, any mechanical treatment is likely to result in some degree of soil compaction. The land manager must objectively weigh both the short- and long-term impacts and benefits and be willing to make sometimes difficult decisions. Do the short-term impacts of soil compaction and the temporary degradation of local water quality that might result from excess surface runoff outweigh the impact on air quality that would result from prescribed burning? Does the temporary loss of nesting habitat for raptor species outweigh the risk of catastrophic wildfire? In some instances the answer will be virtually self-evident; in others the decision might be driven not by clinical scientific analysis but by local political considerations.

With this in mind, it should be pointed out that environmental have driven the preponderance of the changes in land management in recent decades. Environmental regulation has profoundly altered the timber industry; environmental concerns have also precipitated many of the technological modifications that have increased the range of treatment options discussed in this document. For instance, a shift from wheeled to tracked vehicles has been fostered by concerns over soil compaction (tracked vehicles are less damaging because the vehicle's weight is more widely distributed than that of wheeled vehicles).

In all cases, the land manager must carefully evaluate the options, their relative costs and benefits, and the strategy that may be necessary to promote the desired program. The environmental feasibility is inextricably linked with sociopolitical considerations; this is discussed further in *Sociopolitical Feasibility* below.

Economic Feasibility

The cost of implementing nonburning alternatives is the single most challenging financial consideration to overcome; the previous chapter discussed potential funding mechanisms and fuel management programs, and Appendices _ and _ provide lists of these sources and programs. However, in cases where there is reason to consider utilization as a means to fund or offset the cost of treatment, it is necessary to examine barriers related to industry infrastructure.

In many areas of the western United States, adequate industry infrastructure is no longer available. Mills were at one time abundant throughout the country; now, however, only certain areas remain capable of processing forest products. Mill closures over the last several decades dismantled infrastructure beyond the loss of the mills themselves. Once a mill closes down the equipment is sold, industry experts relocate, associated businesses fail, and the community's ability to reengage in the processing of forest products is severely compromised. Additionally, mechanical equipment used for treatment activities is likely to be sold or relocated to regions where the industry is still viable.

The location of a project area is perhaps the most critical variable in assessing the cost of undertaking the project. The proximity of a treatment site to processing facilities can determine the feasibility of utilizing materials generated by nonburning alternatives. Presence of a pulp mill or cement plant (cement plants represent a potential market for dirty chips) within 100 miles of a project site can encourage the use nonburning methods because generated materials can be readily sold. In areas such as the Pacific Northwest where numerous mills still exist, the utilization of materials tends to be relatively affordable and practical. On the other hand, if processing facilities are not reasonably accessible, the cost of transporting the material can exceed the revenue generated by its sale. Moreover, in regions where mills have been retired or where the forest products industry has never become established, land managers can be forced to hire contractors from as far as two states away to carry out nonburning treatment activities. The cost of nonburning alternatives soars when material must be transported great distances or when contractors must be recruited from outside the region.

One hopeful solution to the financial quandary is the cogeneration industry, which could provide a viable market for biomass removed from treatment areas. Cogeneration entails combustion of biomass to produce both electricity and heat; cogeneration plants are typically designed and built close to the source of fuel and the site where the energy and heat will be consumed. Unfortunately, this industry is still in its infancy; accordingly, it is currently a reasonable option only in certain areas. Other biomass utilization technologies, such as biomass gasification and the production of ethanol, also suggest a promising future, not only in increasing the economic feasibility of nonburning alternatives but also in further reducing air quality impacts.

Sociopolitical Feasibility

The sociopolitical hurdle should probably be the last one crossed, because the outreach, education, and negotiations involved in crossing it would all be wasted if the selected nonburning alternative were found to be impractical or infeasible for some more prosaic reason (e.g., technical constraints or presence of a high-profile endangered species). Nonetheless, the sociopolitical considerations are quite serious, and many projects meet their demise because the proponents fail to pay sufficient heed to the human factor.

Public Management Barriers

The tendency of agencies to endorse only those fuel management methods with which they have experience and knowledge inherently limits the options customarily utilized. A public resource agency that has always used fire to manage fuel loads and that has no desire or incentive to do otherwise is likely to continue to use fire and to neglect the use of nonburning alternatives. At the same time, many agency staffpersons with a knowledge of specific management techniques (e.g., timber sales) have retired or left the field. This emigration of traditional expertise leaves in place a new generation of land managers who endorse land management philosophies that deemphasize the commodification of resources.

Many natural resource agencies lack the funds and staff to treat all the areas and fuels requiring treatment. The shortage of personnel, equipment, and expertise may discourage resource managers from considering more expensive or labor-intensive nonburning alternatives. This shortage of resources forces some natural resource managers to select which areas will be treated and which will be neglected.

Some jurisdictions are constrained by such restrictive operational mandates that deviation from the status quo is virtually impossible. For example, the Montana Department of Natural Resources and Conservation is charged with generating profit from management of the state's natural resources; these profits are an integral funding source for Montana schools. This primary agency goal drives all decision-making and management actions. In turn, the fuel management alternative that is least expensive or that generates the greatest profit is and has to be the technique employed.

The interviews conducted during the preparation of this document suggested that vegetation and fuel management programs undertaken on private lands are subject to minimal regulatory requirements unless some commodity is to be generated. If a commodity is to be generated, some administrative process is likely to be required; however, this process varies greatly from state to state.

On public land, however, the planning and documentation efforts are frequently the most time-consuming portion of any treatment project. The costs of these efforts can weigh heavily in the selection of treatment type; even, sometimes, to the extent of outweighing considerations of ecological outcomes and levels of risk.

Because so much habitat in need of treatment lies on federal lands, NEPA is the regulatory mechanism most frequently addressed by land managers. The interviews indicated that while prescribed burning treatments can generally be implemented with preparation of an environmental assessment (EA) or can even be eligible for categorical exclusion (i.e., a designation exempting projects from the NEPA review process), nonburning treatments usually require at least an EA, if not an environmental impact statement (EIS). Moreover, the general level of evaluation in EAs prepared for nonburning treatments tends to be considerably higher than that in EAs prepared for prescribed burns. In addition to the increased efforts for NEPA compliance associated with nonburning alternatives, the nonburning alternatives are more likely to be appealed by opponents of the proposed action, causing additional delays and increased costs.

These NEPA-related considerations, while anecdotal, have several implications. They support the likelihood of many agencies to be predisposed in favor of prescribed burning over nonburning alternatives. Furthermore, many EAs limit the alternatives analysis required by NEPA to a comparison of the Proposed Action and the No-Action Alternative. This is an important point, because it is in the EA that the purpose and need statement for a Proposed Action is developed. The purpose and need statement can be articulated to limit the scope of alternatives that must be analyzed. If the scope of the EA is narrowed in this manner, potentially feasible nonburning alternatives can be eliminated altogether from the public discourse that is part of the NEPA process.

Public Opinion Barriers

Public opinion regarding fuel treatments varies widely and can be influenced by a myriad of factors. In New Mexico, for instance, the public had long supported fire as the fuel treatment method of choice. In the summer of 2000, the Cerro Grande wildfire, which was caused by the escape of a prescribed burn, swept across the Bandolier National Monument in the Jemez Mountains. Following this event, public opinion shifted in support of nonburning alternatives.

Public opinion is highly localized and can vary widely within a relatively small geographic area. Numerous conflicting opinions may be expressed within the same state, region, or municipality. Public opinion on fuel treatments and their respective effects, particularly those effects related to aesthetics, can exert tremendous influence on the selection process. For example, some communities may resent the presence of cattle grazing on fuels, while other communities find the visual results of mechanical treatment unacceptable. Trends among public attitudes, particularly on a small geographic scale, are difficult to predict; it is therefore advisable to assess the opinions and sensibilities of the local community prior to any fuels management project. When possible, inclusion of the local community in the decision-making process helps to ensure popular support.

Perception, of course, is critical to bridging the gaps between various stakeholder groups in the arena of public opinion. For example, the most environmentally beneficial treatment in a particular situation might be a tree-thinning operation that will, if effectively implemented, increase forest health, reduce the risk of catastrophic wildfire, result in minimal air quality impacts, and potentially generate some revenue to fund the operation wholly or in part. However, such an operation uses similar equipment and techniques to traditional harvest operations, which can be perceived to be environmentally irresponsible. Such perceptual barriers present challenges, but also offer opportunities for innovative collaborative efforts.

Environmental Groups

Local environmental groups can be highly visible and influential in dictating the fuel management methods used in a given area, particularly on public lands.

Such local groups can often be brought into a participatory role through proper outreach and communication efforts. However, fuel management projects that have been developed through such a collaborative process can nevertheless be jeopardized by opposition from outside environmental efforts, particularly those initiated by national organizations headquartered elsewhere. These groups may convey their opinions through the scoping process and public comment requirement specified by NEPA. They may express their opposition through the courts, bringing lawsuits or appeals to delay or kill projects. Legal involvement is frequently initiated long after project development, and can severely limit fuel management options and impede implementation. Often, the level of resistance from national environmental organizations is closely correlated with the visibility and political sensitivity of a given project. Such resistance, when it obstructs projects that have been developed through successful collaboration of stakeholders at the local level, is particularly disheartening because it increases the level of frustration and disenfranchises the participants. In some cases, such reversals can reopen philosophical or ideological rifts that have begun to heal through the advent of a successful local collaboration.

Assessing the Alternatives

For the purposes of this discussion, it is understood that the primary goal of any vegetation or fuel load management action is to treat as many high-priority acres as possible with a minimum of onsite emissions. In examining the constraints on specific treatment options, the following discussion focuses on forested habitats. Once again, because of the very generic nature of this document, the authors have chosen to adopt a convention likely to enjoy the widest applicability. Because the preponderance of areas requiring treatment in the western states lie in forested habitats; because the widest variety treatment methods are potentially suitable to such habitats; and because the more controversial treatment methods—i.e., harvesting and tree removal—are specific to those habitats, shrubland and grassland are excluded from this discussion. Similarly, because grazing and chemical treatment options have rather restricted applications, they, too, have been excluded.

Overcoming Obstacles

This analysis compares burning with four categories of nonburning alternatives: hand work, mastication, tree removal, and biomass removal. The graphic comparison in Figure 4-8 is, like the other figures in this chapter, a conceptual illustration of relationships and not a representation of quantitative data. Rather, the figure illustrates conclusions based on the professional experience of the authors and on the collation of the results of the interviews conducted in the preparation of this document.

The analysis compares the treatment types in the context of five key obstacles:

- **Gross capitalization:** the full amount of expenditures that have to be made before any fuel is treated. This includes equipment and facilities acquisition, staffing, marketing, and planning.
- **Post-treatment fuel residue:** the fuel that remains on site after the treatment action has been completed. This should be evaluated in the context of the residual fuel's conditions and arrangement.
- **Administrative resistance:** the level of resistance exhibited by resource agencies. Administrative resistance can also involve the level of environmental documentation that is required for a particular treatment project.
- **Production inefficiency:** the amount of money/labor required to treat a unit measure of habitat.
- **Interest group resistance:** the level of resistance exhibited by particular interest groups (e.g., environmental and community groups).

Figure 4-8 illustrates the relative weight of these five obstacles in the context of various treatment options. In selecting an approach, one should determine which technique is most appropriate for achieving the desired future conditions and which has the greatest potential to be implemented.

Hand treatments require the least gross capital investment, but are also the least efficient of the nonburning treatment options. They tend to leave high levels of post-treatment fuel residues. Though time-consuming and relatively unproductive, hand treatments face very little interest group opposition or administrative challenge.

Mastication requires specialized equipment that is often less common and more expensive than traditional logging equipment. However, transportation and road systems are not as critical for mastication operations. Additionally, there is no need for markets or the associated infrastructure (e.g., processing facilities, transportation system) necessary to exploit them. These factors combine to limit the gross capitalization requirement for mastication. Because it creates limited environmental impacts, mastication encounters little resistance from the environmental and administrative sectors. Mastication experiences only moderate production inefficiency and produces moderate amounts of post-treatment fuel residue.

Tree removal also requires specialized equipment, much of which is readily available and consequently more affordable than mastication equipment. The gross capitalization requirement is higher than that for mastication, however, because of the dependence upon a comprehensive transportation system (i.e., roads and available logging trucks). Moreover, tree removal produces the highest level of post-treatment fuel residue of any treatment option. Perhaps the greatest hindrance to tree removal is environmental and administrative resistance. Some interest groups are strongly opposed to tree removal and the perceived commodification of public lands. Regulatory compliance requirements and other administrative barriers are significant for tree removal operations.

Biomass removal requires very specialized equipment and operational skills, a well-developed transportation network, and a market for generated materials. This industry, contrasted with both standard tree removal and hand treatments, is in its infancy, suggesting that, to achieve a substantial level of efficiency, development would be necessary on a whole-industry scale. Such expansion would result in a very high gross capitalization requirement; this could, for the present, effectively eliminate biomass removal as a regionally applicable approach to solving the fuels problem.

Comparing Effectiveness

The effectiveness of nonburning treatment techniques can be compared by examining a common goal of land managers: the reduction of fine fuels. A principal indicator of elevated fire risk is the availability of large quantities of fine fuels in particular arrangements.

Hand operations are typically used in treating fine fuels; these operations change the arrangement by moving large quantities of surface and lower ladder fuels closer to the ground surface; hand treatments do not, however, actually reduce the volume.

Mastication (including crushing and mowing,) does not reduce volume, but alters the vegetation structure even more radically than does hand treatment. The use of vehicles to grind the masticated material into the soil surface enhances this effect.

Chipping and grinding, particularly when conducted in concert with biomass removal, transports significant quantities of fine fuels either to a central location or completely off site. Whole-tree yarding, although properly considered a tree removal technique, achieves the same end.

Logging operations are generally focused on extraction of commercial materials and not on treatment of fine fuels. Slash operations (as a post-silvicultural treatment) can include hand lopping; however, the intent is rather to comply with regulatory requirements than to perform fuel treatments, and these operations are not as effective as operations in which fine fuels reduction is the monitored success indicator.

Figure 4-8 shows that mastication/mowing operations may offer the greatest potential for success in the context of both desired future conditions and likelihood of implementation. However, mastication requires an industry that is still in development and does not yet generate useful materials. It is possible that mastication could be the best first step towards other more market-driven methods such as biomass removal. Consideration should be given to developing a subsidized program that effectively builds industry capacity and aids landowners/managers in offsetting planning elements of the gross capitalization element.

Making the Decision

[Diagrammatic representations of the decision-making process are in development. These figures and explanatory narrative will be inserted here for the next iteration of this document. We've experimented with a number of options and have finally focused on an approach that seems both clear and user-friendly; again, as we've emphasized, because there is no "one-size-fits-all" solution to fuel load management, it is also not possible to develop an exhaustive 'decision tree' that addresses the spectrum of variables and site-specific kinds of issues with which land managers must grapple. Accordingly, we are creating a schematic depiction of the sequence and relationships of issue areas; this will be followed by a matrix evaluating the advantages and drawbacks of a range of mechanical treatment types.]

Chapter 5

Conclusions and Recommendations

Discussion

Clearly, there is a need to address with determination the fuel load crisis that has developed in the western United States through a century of fire suppression policies. No less pressing are concerns over the deteriorating air quality that plague urban areas and wildlands alike. Although the promotion of nonburning alternatives cannot alone resolve these issues, the reduction of prescribed burning where nonburning alternatives will adequately address the fuel load situation can certainly contribute to advances in both areas.

The investigations conducted during the preparation of this document suggest several salient points.

1. A sound range of nonburning alternatives to prescribed burning currently exists, and emerging technologies await exploitation. While there are obstacles to implementation of many of these alternatives, few of the obstacles are insurmountable; indeed, the greatest challenge is that of stepping beyond the confines of conventional wisdom to explore innovative and creative solutions.

2. Perceived regulatory and administrative barriers to use of nonburning alternatives, while very real, can perhaps be more readily overcome through education and training on the part of land managers and air quality management officials than through an assault on the existing regulatory infrastructure. For example, as discussed in the preceding chapters, the NEPA process can be initiated in such a fashion that nonburning alternatives are excluded from the onset. However, with a relatively cursory amount of training, proponents of nonburning alternatives could be instructed to use the existing procedural requirements of the NEPA review process to ensure that such alternatives are addressed.

3. Very limited accountability mechanisms are in place to promote the use or ensure the consideration of nonburning alternatives. This has been partially addressed in item 2 above; but the issue of accountability is also tied to the fact that traditional treatment programs are evaluated on the basis of numbers of acres treated—and in many cases, *treated* can be considered as synonymous with *burned*. Such mechanisms obviously preclude consideration of nonburning alternatives. Situations of this sort, however, are more appropriately addressed at the level of agency policy or land

management plan development (e.g., individual forest plans, resource management plans) than at the level of legislative action (e.g., NEPA).

4. Because many of the obstacles to nonburning alternatives are economic, there is a substantial need to develop technologies to encourage use of these alternatives. While capitalization costs may in some cases be high, these costs should be weighed not only against the costs of prescribed burning, but also against the potential savings and revenues that could be realized by development of new industries that produce energy, reduce air quality impacts, create job opportunities, and reduce dependence on imports of fossil fuels.

5. Despite the advantages of nonburning alternatives in the context of air quality impacts, it is evident that prescribed fire will remain a critical component of many vegetation and fuel load management programs. Accordingly, the object should be not to replace burning with nonburning alternatives, but to design programs to include a greater proportion of nonburning techniques, such that air quality impacts are substantially reduced.

Air quality and risk of wildfire are subject to influences far beyond wildland management policies. The energy industry, transportation policy, regional economics, technology, environmental protection, and social justice are all interconnected with both issues and the decisions that are made to address them. Consequently, communities and decision makers should look beyond the immediate boundaries of vegetation and fuel load management programs for comprehensive solutions to the problems.

Finally, the increased acceptance of nonburning alternatives is dependent upon a change of mindset. Resource agencies, industry groups, environmental groups, and community groups must all be willing to reassess their preconceptions if significant progress is to be made in combating the dual problem of air quality and fire risk.

Recommendations

A number of recommendations emerged from the process the authors followed in preparing this report. Although some of these recommendations arguably lie outside the initial scope of this document, they have nevertheless been included because the authors feel them to be germane to the matter at hand. Because the recommendations in many cases cross the organizational structure followed in previous chapters, that structure has been forgone for this discussion.

- **Promote consideration of nonburning alternatives within agencies.** This should be undertaken at the agency policy or land management plan level. For instance, every federal agency as its own set of guidelines for NEPA compliance; proponents of nonburning alternatives could suggest relevant agencies to adopt measures requiring consideration of nonburning alternatives in the process of developing vegetation and fuel load management plans.

- **Promote proactive participation in the NEPA review process.** The WRAP could disseminate educational materials to proponents of nonburning alternatives to enable them to engage in the NEPA scoping and review process early on. Where appropriate, the purpose and need portion of the project description should be broadened such that nonburning alternatives are not precluded.

- **Initiate an outreach and education program.** This is a two-pronged recommendation. One area of outreach should be directed to the public, promoting acceptance of nonburning alternatives as environmentally responsible; this program should emphasize that protection of air quality, like protection of wildland habitat, is a critical component of responsible environmental stewardship.

  A parallel outreach program should be developed for resource agency staff to promote acceptance of nonburning alternatives and to encourage inclusion of such alternatives in analyses conducted during development of planning documents.

- **Provide administrative and economic support to development of infrastructure.** If nonburning alternatives are to be successful, additional infrastructure will be necessary. As discussed above, this infrastructure need not be a recapitulation of traditional timber industry infrastructure; indeed, the political climate precludes such a course of action. Rather, attention should be paid to promoting the development of local and regional biomass utilization programs. Such programs offer intriguing opportunities for entrepreneurial innovation; economic redevelopment of depressed rural communities (particularly those impacted by the contraction of the timber industry); reduction of dependence on imports of fossil fuels; reduction of increasing waste disposal problems; and reduction of air quality impacts.

- **Encourage nonindustrial utilization programs.** In concert with the preceding item, opportunities for development of value-added enterprises abound. In the Pacific Northwest, where traditional logging communities have suffered mill closures and high unemployment, innovative value-added businesses have offered examples of the potential of this approach. For instance, a small company on Vancouver Island produces spruce and cedar guitar tops. The company anticipates gross revenues of $Canadian 1 million in 2002. It provides 14 year-round jobs utilizing 3,600 cubic meters of timber annually—an amount that would support 2.5 mill workers in the industrial timber business. Moreover, leftover material that is unsuitable for guitar tops is used by another local business to craft gift boxes for exporting smoked salmon.

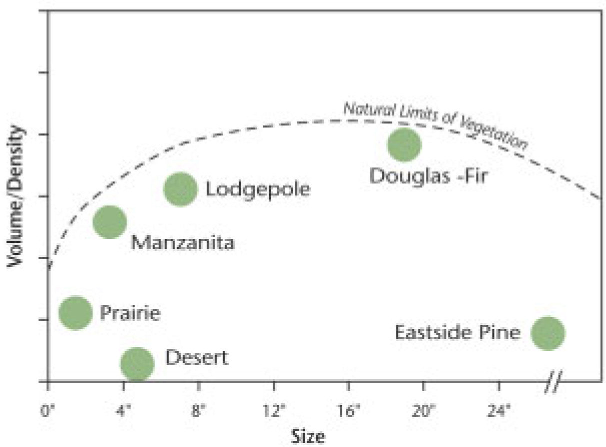
  In another example, homesteaders in a forested region of northern California cut limbs and small trees both to reduce the risk of wildfire and to provide themselves with firewood. However, realizing that much of the hardwood left behind by the previous harvest operations could have intrinsic commercial value of its own, they created a small-scale logging and milling system. Harvesting hardwood trees on the basis of promoting forest health, they market hardwood to local craftspeople, who create value-added products. Their harvest techniques, employing pickup trucks, portable sawmills, and preexisting logging roads, reduce the risk of catastrophic wildfire, minimize air quality impacts, promote forest health, and contribute to the local economy.

Programs such as these, while in themselves not able to address vast tracts of wildlands in need of treatment, can certainly contribute to the promotion of nonburning alternatives. Perhaps more importantly, they can help to bridge the gap between traditional forest practices and those who are unconditionally opposed to any form of commodification of forest products.

- Develop a comprehensive vegetation and fuel management manual. This report fundamentally addresses and promotes nonburning alternatives. However, as has been discussed above, prescribed burning is not likely to be removed from the repertoire of treatment options. With that in mind, it is recommended that the contents of this be expanded, or combined with existing materials, to provide a comprehensive guide to program development. Such a manual would begin with the earliest planning stages and would include prescribed burning techniques, but would emphasize incorporation of emission reduction techniques. It must be emphasized that many of the nonburning alternatives described in the previous chapters can in fact be considered emission reduction techniques, because they are frequently used as parts of larger programs that also entail prescribed burning.

A Final Word

In conclusion, perhaps the most important lesson to learn from the forest management issues that confront us is that single solutions rarely suffice. The present crisis developed because those involved in making management decisions failed to understand the complexity of the natural systems they were attempting to manage, and because they did not consider the myriad consequences of their actions. So, too, we must bear in mind that a great deal remains to be discovered about the mechanics of ecosystems, the interrelationships of seemingly disparate occurrences, and the unanticipated consequences of solutions we undertake. It is imperative, therefore, as both fuel load and air pollution conditions continue to worsen, that we consider a range of solutions as broad and interconnected as the factors that gave rise to the problems in the first place.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Lodgepole
Manzanita
Prairie
Desert
Eastside Pine
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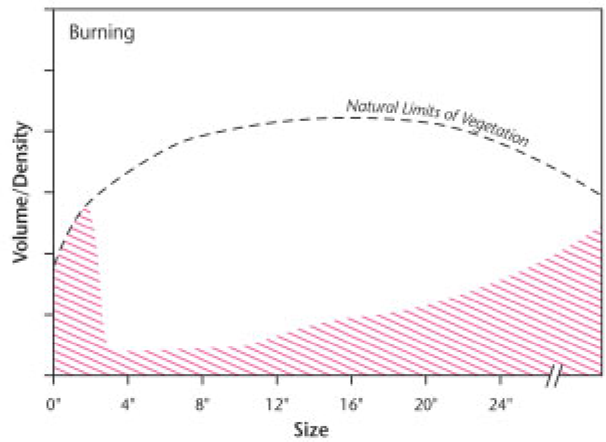
12"
16"
20"
24"
Size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Natural Limits of Vegetation
Volume/Density
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16"
20"
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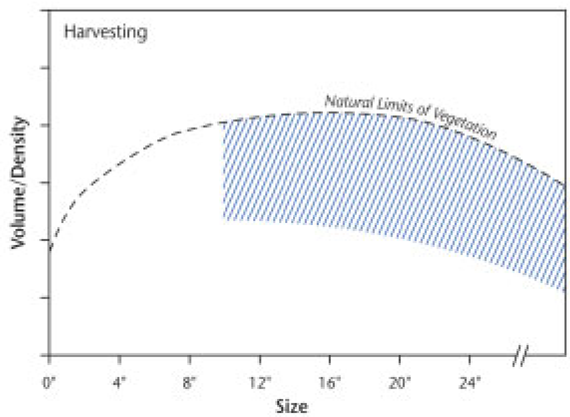
Size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Natural Limits of Vegetation
Volume/Density
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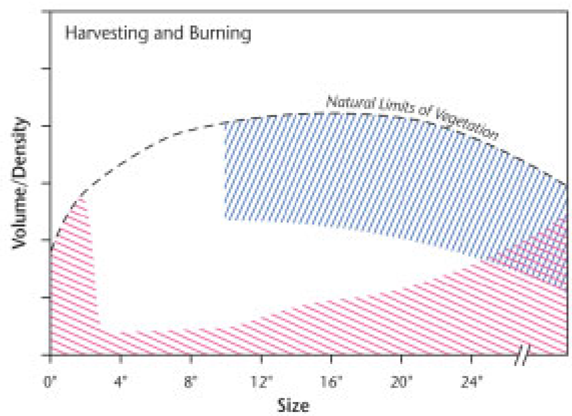
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Natural Limits of Vegetation
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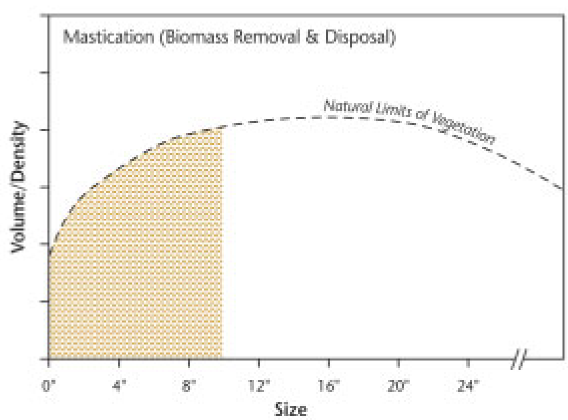
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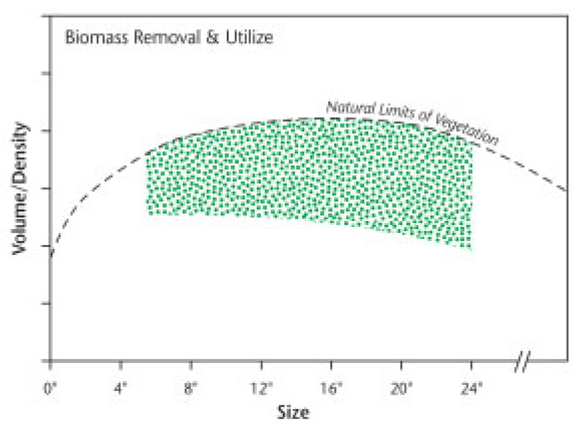
Natural Limits of Vegetation
Volume/Density
0"
4"
8"
12"
16"
20"
24"
Size


Biomass Removal & Utilize
Natural Limits of Vegetation
Volume/Density
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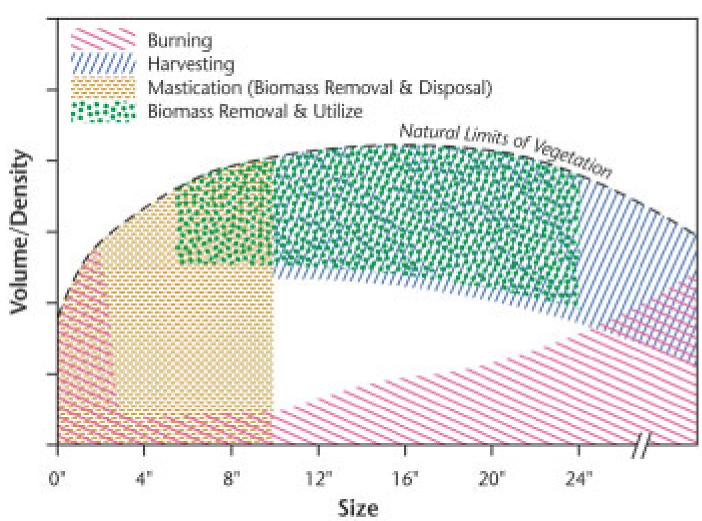
Burning
Harvesting
Mastication (Biomass Removal & Disposal)
Biomass Removal & Utilize
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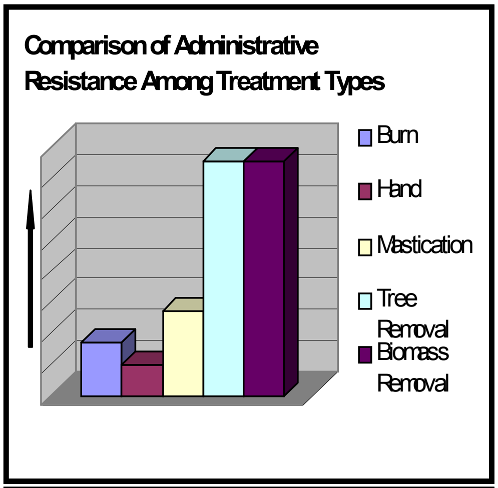
Comparison of Administrative Resistance Among Treatment Types
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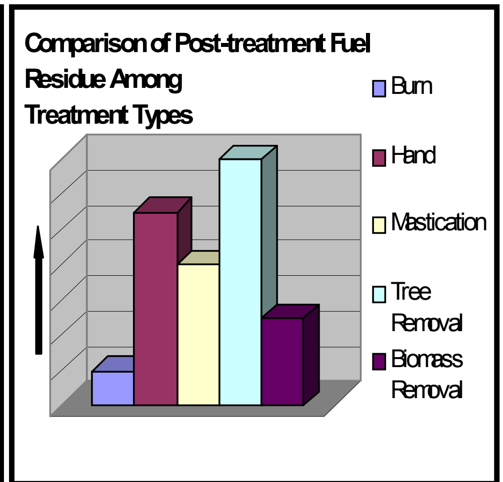
Hand
Mastication
Tree Removal
Biomass Removal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Hand
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Tree Removal
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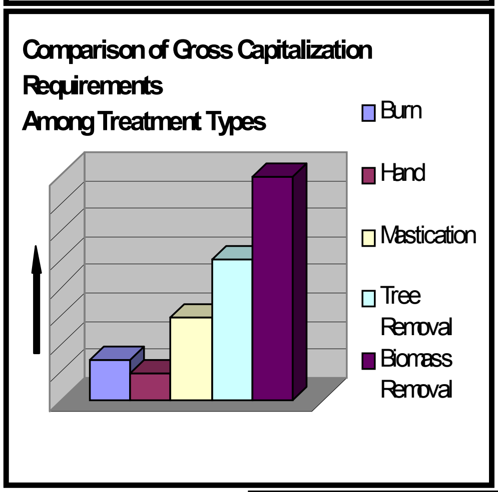
Comparison of Gross Capitalization Requirements Among Treatment Types
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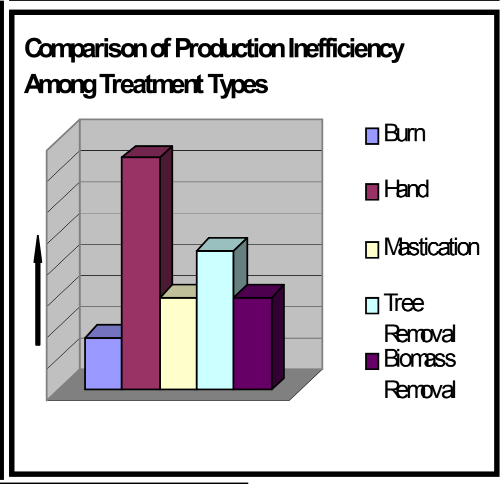
Hand
Mastication
Tree Removal
Biomass Removal


Comparison of Production Inefficiency Among Treatment Types
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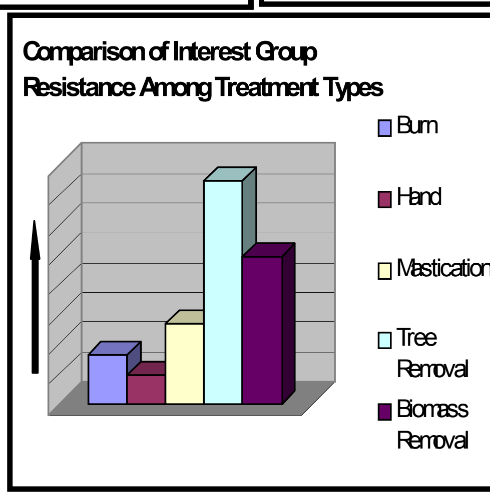
Hand
Mastication
Tree Removal
Biomass Removal


Comparison of Interest Group Resistance Among Treatment Types
Burn
Hand
Mastication
Tree Removal
Biomass Removal