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# Fire-Management Policies and Programs

## ABSTRACT

For most of this century the goal of fire management in the Sierra was to control fire. The policy was aggressively and successfully applied, substantially reducing annual acres burned. This goal was based on a fire policy that emphasized keeping wildland fires as small and inexpensive as possible. As the role of fire in maintaining Sierran ecosystems has been recognized, fire has been reintroduced through the application of planned prescribed fire and prescribed natural fire. Despite changes in fire-management policy that have allowed expanded use of fire, relatively few acres have been managed using fire in the Sierra Nevada. This chapter explores options for expanding the role for fire in the Sierra through more liberal application of current fire policy and through changes in existing fire policy. These recommendations are tempered by the knowledge that the number of available fire-fighting resources has been steadily declining since the mid-1970s and that social, economic, and biological factors are making all aspects of fire management more costly and difficult.

## INTRODUCTION

This chapter describes the history of fire management in the Sierra and discusses present programs in the context of changing public expectations of fire organizations and evolving management objectives.

For most of this century, the goal of fire management in the Sierra was to control fire. The policy was aggressively and successfully applied, substantially reducing annual acres burned. Fire-suppression programs, although effective in achieving this goal, are very expensive. The cost of the U.S. Forest Service (USFS) presuppression program in the Sierra, for example, was $30,000,000 in fiscal year 1995, and this amount does not include aircraft contracts and the money spent actually suppressing fires. National fire-suppression costs are increasing at a rate higher than that of inflation. Fire-fighting costs are rising at an even faster rate in the Pacific West than in the rest of the country (USFS 1995b; Schmidt 1995). A USFS study aimed at determining the reasons for increasing fire-suppression costs concluded that the explosive fuel types that have developed across the West have made traditional fire-suppression tactics very expensive and sometimes ineffective, and this expense was a major contributor to the record-breaking fire expenditures during the 1994 fire season (USFS 1995c). A series of reports has highlighted cost increases due to emphasis on protection of private property (USFS 1995d). Rising costs, increasing numbers of firefighter injuries and fatalities, and concerns about the ecological effects of excluding natural disturbance from fire-adapted ecosystems have prompted national review of fire programs and policies. These issues are magnified in the Sierra, where fire suppression has been highly successful in reducing the annual acres burned by wildfire, fuel treatments have not affected enough acres to influence fire regimes, and more and more people are moving into vegetated wildlands adjacent to or mixed with federal and state lands.

Fire-management organizations are more than fire trucks and helicopters. Fire-management programs encompass presuppression activities aimed at reducing the land area burned by wildfire, as well as fire-suppression activities aimed at putting out fires and repairing the damage caused by wildfires that escape initial attack. Presuppression includes reducing the flammability of fuels through removal or rearrangement; engaging in fire-prevention and public-education activities; training fire personnel to fight fires; detecting fires; and operating fire stations, air tanker bases, and other facili-

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ties during the fire season each year. Fire-suppression includes fire-fighting activities and emergency rehabilitation of burned areas.

Five agencies have fire-management responsibilities in the Sierra Nevada: the California Department of Forestry and Fire Protection (CDF), the USFS, the Bureau of Land Management (BLM), the National Park Service (NPS), and several Native American tribes. All the fire agencies cooperate closely. Many dispatch or coordination centers in the Sierra dispatch resources from more than one agency in the vicinity. Wildland fire fighting in the Sierra is conducted using the "closest forces" concept, where the fire-fighting resources closest to the fire are dispatched, regardless of agency. Actual protection boundaries between the larger agencies were set through a process called balancing of acres in 1990. These boundaries redistribute protection responsibilities to ensure that fire-suppression resources are used most efficiently. The balancing of acres also reorganized responsibilities to avoid the need for reimbursement among agencies for initial-attack fire protection. As a result, each agency provides fire protection on lands in the other agencies' jurisdictions. Each agency has responsibility for prescribed burning in its own jurisdiction. Local government, in the form of fire districts and through CDF contracts, is responsible for structural fire protection within their areas within the State Responsibility Area. Many local fire departments also participate in suppression of wildland fires.

Inherent differences in the missions of fire-fighting agencies affect their fire-management programs. The California Department of Forestry and Fire Protection provides fire protection primarily for private lands with roads. CDF has the highest percentage of wildlands mixed with structures (urban intermix or interface lands) in its protection area. CDF protects much of the lower-elevation lands in the Sierra foothills as well as large areas of private timberlands. These lands dry earliest and have the longest fire season (McKelvey and Busse 1996). CDF also protects state parks and other state-owned lands. CDF works closely with the Office of Emergency Services and rural fire departments. Fire-suppression strategies, tactics, and activities are influenced by state statutes, the types of vegetation in the CDF protection area, access, and the need to protect lives and private property. CDF conducts prescribed burns cooperatively with landowners through the vegetation-management program.

The national forests in the Sierra Nevada range from the foothills through the high-elevation zone. The USFS manages most of the publicly owned timber-producing belt in the Sierra Nevada. Fire-management activities are conducted to meet the objectives outlined for the various management areas in each forest's land- and resource-management plan. The forests are managed with many objectives in mind, from recreation, cattle grazing, scenic values, and water quality to late successional forests, wilderness, timber harvest, and wildlife habitat. The varied land uses and management objectives result in a variety of fire-management strategies for each forest. Fire-suppression strategies, tactics, and activities are influenced by vegetation type, management objectives, proximity to development, private/public ownership patterns, elevation, and other factors. The forests have large fire-management programs that include fire-suppression, fuels management, and a small amount of prescribed natural fire.

Four national parks fall within the Sierra Nevada Ecosystem Project (SNEP) analysis area. These four areas—Yosemite National Park, Sequoia National Park, Kings Canyon National Park, and Lassen Volcanic National Park—are managed primarily for their wilderness, ecological, and recreational values. Most of the park acreage is inaccessible by road. The national parks put great emphasis on restoring natural processes, including fire. The parks have complex fire-management programs that include fire suppression, prescribed burning, and prescribed natural fire.

The BLM protects lands on the southern end and the east side of the Sierra Nevada range, outside the core SNEP area. The agency has protection responsibilities east of the Sierra in the Susanville area. Most of the protection area is in Great Basin vegetation types. The BLM has a complex fire-management program that includes fire suppression and prescribed burning.

Native American lands are protected by either the USFS or the BLM through agreements or contracts. None of the tribes in the Sierran area maintain separate fire-fighting organizations. Activities include fire suppression and vegetation management.

## EVOLUTION OF FIRE-SUPPRESSION POLICY

One of the fundamental purposes for establishing forest reserves (the original name given to the national forests) and national parks was to provide organized fire protection for public lands. The Forest Reserve Use Book issued in 1905 listed protection of reserves from fire as one of the three duties of forest officers. Disastrous fires in 1910 claimed eighty-five lives and burned 1,011,750 ha (2.5 million acres) in the northern Rocky Mountains (Cermak 1988). The 1910 fires focused emphasis on fire control nationally. During the same time period, California was the site of a nearly two-decade debate over the application of "light burning" as a management tool in forests and rangeland. This debate was resolved in favor of aggressive fire control. The USFS quantified its fire-protection mission in 1926 by adopting the objective of controlling all fires at 4 ha (10 acres) or less. Wildfires were to be suppressed, minimizing the costs of fire suppression and resource loss. These concepts were the basis of fire suppression in the National Park Service as well. The USFS sought to strengthen its fire-protection policy by adopting the "10 AM Policy" in 1935. If aggressive initial attack did not control a fire, then enough fire-fighting resources would be assigned to control it by 10 A.M. the next day. The policy was simple, was easy to understand, and provided clear direction. The developers of the 10 A.M. policy considered it consistent with the objective of minimizing fire-suppression costs and resource damage because they expected suppression costs to decrease if all fires were attacked aggressively.

In 1971 the USFS adopted a 10-acre control plan for 90% of all fires as a planning objective. Rising fire presuppression and suppression costs and the need to link fire protection with land-management planning led to the replacement of the 10 A.M. policy in 1978. Terminology changed from fire control to fire management. The new fire-management policy directed fire managers to minimize fire-suppression costs and damage consistent with land and resource objectives. It defined appropriate suppression response (ASR) as a range of suppression strategies. These strategies—called contain, confine, and control—were to be employed to accomplish a cost-effective response to fires that escaped initial attack. ASR implies that the most cost-effective response might deviate from a suppression philosophy that emphasized keeping all fires small.

Starting in 1983, ASR was expanded to allow the federal agencies to use confine, contain, or control strategies during initial-attack fire fighting. The NPS requires a rationale for the use of a strategy other than control during initial attack. The USFS requires justification (completion of a fire situation analysis, or FSA) if a fire is managed for more than a single burning period without being considered to have escaped. At a minimum the FSA must include a decision analysis that considers expected suppression cost, damage, and the probability of success or failure. If it is determined that the initial action response does not meet or is anticipated not to meet established fire-management direction minimizing fire-suppression cost and damage from fire, the fire is declared an escaped fire.

## PRESENT FIRE-SUPPRESSION POLICY

The fire-suppression programs pursued by fire-management agencies have limited the number of fires that escape initial attack. Nationally, only 2% of all fires in USFS jurisdiction required large-scale suppression efforts in 1994. Ninety-four percent of the total burned acres resulted from 2% of the fires (USFS 1995a). The California Department of Forestry and Fire Protection estimates a similar success rate in suppressing wildfires in the CDF protection area.

The National Park Service, Bureau of Land Management, and national forests have similar fire policies. These policies are likely to be further standardized in response to the recent federal wildland fire policy review recommendations. The objective of fire suppression in the NPS is to "suppress wildfires at minimum cost consistent with values at risk while minimizing the impacts from suppression activities" (NPS 1990b). The BLM policy states that "wildfire losses will be held to the minimum through timely and effective suppression action consistent with the values at risk." The USFS manual states that "the objective of fire suppression is to safely suppress wildfires at minimum cost consistent with land and resource management objectives and fire management direction as stated in fire management action plans" (USFS 1994b). The goal for fire control on CDF lands is "to detect, respond to and control each fire occurring in or threatening State Responsibility Area (SRA) at a size that will hold net damages to resources and exposed life and property to a minimum" (CDF 1986). All four agencies recognize confine, contain, and control strategies as appropriate suppression strategies for managing escaped fires. The NPS and USFS define the strategies slightly differently. ASR is a continuum of fire strategies from monitoring through control. Figure 40.1 contrasts the NPS and USFS definitions of confine, contain, and control. BLM and CDF policy manuals do not include definitions.

Present NPS and USFS directions specifically prohibit the use of wildfire to meet resource-management objectives. This interpretation is based on the philosophy of economic efficiency adopted in 1928, which directed that fires must be suppressed using the alternative that cost the least and most effectively reduced resource loss. Fires are managed to minimize cost and damage without considering their benefits to the resource.

**FIGURE 40.1**

Definitions for confine, contain, and control in the NPS and USFS.

***Confine:***

NPS: To restrict the wildfire within determined boundaries established either prior to, or during the fire. These identified boundaries will confine the fire, with no action being taken to put the fire out.

USFS: To limit fire spread within a predetermined area principally by use of natural or preconstructed barriers or environmental conditions. Suppression actions may be minimal and limited to surveillance under appropriate conditions.

***Contain:***

NPS: To restrict a wildfire to a defined area, using a combination of natural and constructed barriers that will stop the spread of the fire under the prevailing and forecasted weather conditions, until out.

USFS: To surround a fire, and any spot therefrom, with a control line as needed, which can reasonably be expected to check the fire's spread under prevailing and predicted conditions.

***Control:***

NPS: To aggressively fight a wildfire through the skillful use of personnel, equipment and aircraft to establish fire lines around a fire to halt the spread and to extinguish all hot spots, until out.

USFS: To complete the control line around a fire, any spot fires therefrom, and any interior islands to be saved; to burn out any unburned area adjacent to the control line, until the line can reasonably be expected to hold under foreseeable conditions.

## IMPLEMENTATION OF FIRE-SUPPRESSION POLICY IN THE SIERRA NEVADA

The four national parks and the nine national forests in the Sierra Nevada have had the option of applying appropriate suppression response since 1978. The degree to which the flexibility inherent in ASR is exercised is highly variable in the Sierra Nevada, both within and among agencies. The application of fire-management policy by the various agencies in the Sierra Nevada could be summarized as follows: CDF has a rigid fire-suppression policy that is applied flexibly. The USFS and BLM have flexible suppression policies that are applied conservatively. The NPS has a flexible fire-suppression policy applied liberally.

The 1986 fire-management plan for the California Department of Forestry and Fire Protection establishes an objective of controlling all fires during initial attack on CDF's jurisdiction. Appropriate suppression response is allowed on fires that have escaped initial attack.

The forest plans for the Inyo, Tahoe, and Lassen National Forests and the Lake Tahoe Basin Management Unit allow use of ASR on all fires on forest land. The Eldorado, Sierra, Sequoia, and Stanislaus National Forests allow the use of ASR in wilderness and in high-elevation areas of the forests but specify control in other portions of the forests. The Modoc National Forest has used ASR since 1971 in the Big Sage Management Unit. The Plumas forest plan specifically prohibits the use of any suppression strategy other than control anywhere on forest land and at any stage of fire suppression.

The fire-management plans for Sequoia and Kings Canyon National Parks, Lassen Volcanic National Park, and Yosemite National Park allow use of ASR for any fire in any location.

Reading plans and policies alone does not give an accurate picture of how and where fires are suppressed in the Sierra Nevada. Forest plans, fire-management plans, and other documents describe the options available to the fire manager but do not explain how often each strategy is applied. The way in which the plans are carried out varies from place to place. The differences in application of initial-attack strategies are displayed in table 40.1. As can be seen, there seems to be little relationship between what is written in the plans and what is applied. Although confine and contain strategies are allowed, they are not frequently employed, since the manager generally opts for the control strategy.

In discussing the application of policy in the Sierra Nevada, fire managers listed the following reasons for selecting confine and/or contain initial-attack strategy on federal lands in the Sierra:

> Confine or contain is used to reduce fire-suppression impacts and costs, particularly in wilderness. This also reduces rehabilitation costs.
>
> Confine or contain may be selected because of firefighter safety concerns. Fires may be confined or contained when inaccessible to firefighters, such as those located on cliffs or in steep drainages.
>
> Confine or contain may be selected if the fire is confined by natural barriers to a small area of continuous fuels that will burn and go out.
>
> Confine or contain may be selected for some fires when resources are needed for higher-priority fires.
>
> Confine or contain may be selected when no resource damage is expected.
>
> Confine or contain may be selected when fewer fire-fighters can accomplish the job of suppression over more time. The fire gets larger, but fewer firefighters are committed, though they may be on the fire for a longer period. For example, a single crew may take several days to suppress a fire at a larger final size using ASR, as compared to several crews controlling the fire at a small area. This may be chosen either because fire-fighting resources are scarce or to minimize suppression costs.

Federal fire managers listed these limitations to applications of appropriate suppression response in the Sierra Nevada:

> Mixed ownership patterns occur in many areas of the Sierra Nevada. For example, much of the Tahoe National

**TABLE 40.1**

Estimated use of confine, contain, and control strategies for fire suppression during initial attack in Sierran forests and parks, through 1994, listed by percentage of total wildfires (survey of Fire Management Officers of parks and forests conducted for this chapter).

| Unit | Percentage Confine | Percentage Contain | Percentage Control |
|---|---|---|---|
| Eldorado National Forest | 5 | 5 | 90 |
| Inyo National Forest | 35[a] | | 65 |
| Lake Tahoe Basin | 1[a] | | 99 |
| Lassen Volcanic National Park | 10 | 20 | 70 |
| Lassen National Forest | 1[a] | | 99 |
| Modoc National Forest | 23 | 1 | 76 |
| Plumas National Forest | 0 | 0 | 100 |
| Sequoia and Kings Canyon National Parks | 17[a] | | 83 |
| Sequoia National Forest | 0 | 0 | 100 |
| Sierra National Forest | 2[a] | | 98 |
| Stanislaus National Forest | 0 | 0 | 100[b] |
| Tahoe National Forest | 1[a] | | 99 |
| Yosemite National Park | 5[a] | | 95 |

[a]Confine or contain.
[b]All fires are controlled except lightning fires in the Emigrant Wilderness. However, an amendment to the Stanislaus National Forest forest plan allowed use of confine and contain strategies in other areas starting in 1995.

Forest is a checkerboard pattern of sections in public and private ownership. Aggressive initial-attack and control strategies are used because of risk to private land.

Many areas of the Sierra Nevada have continuous, homogeneous fuels with few of the natural barriers or fuel type changes that provide opportunities for application of contain or confine strategies.

Most of the area protected by CDF and much of that protected by the Forest Service is intermixed with or adjacent to homes, communities, and other development. Even a remote chance of an escaped fire is unacceptable because of the dire consequences.

Many areas of the Sierra Nevada are subject to frequent and unpredictable severe fire weather patterns.

The Sierra's Mediterranean-type climate (wet winters and long, dry summers) results in a lengthy fire season with few breaks in the fire danger.

Managers and firefighters do not want to take on additional risk associated with some fire-management strategies.

The concept of appropriate suppression response is poorly understood. Most fire managers have not received training in its application or in matching tactics to any strategy except control.

There is no incentive or encouragement to apply the full range of appropriate suppression response.

Long-term management of wildfires is discouraged because it ties up fire-fighting resources that could be used on other incidents.

Control strategies are generally viewed as the least costly suppression response for fires in the Sierra Nevada, given the restricted definition of cost that fire managers use in selecting fire-suppression alternatives. Many lightning fires start under low to moderate burning conditions and spread slowly. It is consistently less expensive to assign a fire crew to put a fire out when it is confined to a single tree than it is to pay to monitor the same fire for a longer period in a containment or confinement mode. Fires in red fir, lodgepole pine, or upper-elevation mixed conifer forests spread slowly at first. The litter is tightly packed and burns slowly, at low intensity. Dense canopies shelter the fire from the wind and from the direct rays of the sun. These vegetation types are also under snow for a longer period and at higher elevation where the fuels dry slowly and the fire season is shortened. Such fires can be extinguished easily and inexpensively when they are small. Fire managers recognize the lower risk associated with these fires but cannot justify allowing them to get larger because of the requirement to select the least-cost-plus-loss suppression alternative. As a result, most wildfires that burn in locations and under conditions that would produce results most similar to those that occurred under historic conditions are suppressed at small size.

Fires initiate and spread rapidly in fuel types with light, quick-drying fuels or with more-open canopies that allow wind and sunlight to reach the surface litter. In the Sierra Nevada these types include ponderosa pine, eastside pine, grassland, oak savanna, deciduous oak stands, lower-elevation mixed conifer, sagebrush, and chaparral. These are the same types in closest proximity to structures and other development. The risk and suppression cost of managing fires in these types limit suppression action to rapid, aggressive control.

In practice a combination of several fire-suppression strategies may be applied to a single fire. Fire managers and members of specialized Incident Management Teams agree that a single fire-suppression strategy is rarely applied on a large fire. One flank may be allowed to run into rocks, another may be contained by a river, and a third, adjacent to structures, may be controlled by direct or indirect methods. There are, however, only three examples of large fires in which the contain or confine strategy has been selected in the Escaped Fire Situation Analysis (document that describes the selected suppression alternative) on Sierran forests in the last ten years. Control strategies have been used to suppress all large fires on the Eldorado, Lassen, Sequoia, Plumas, Tahoe, and Stanislaus National Forests in this time period. Confine or contain has been used regularly on escaped fires in national parks, especially when prescribed natural fires have been declared wildfires because of national fire emergencies or because of smoke-management concerns.

## FIRE-SUPPRESSION TACTICS

Once a fire strategy is selected, it can be accomplished using a variety of fire-suppression tactics. Minimum impact suppression tactics (MIST) are those fire-suppression techniques that use the minimum tool needed to do the job. They also accomplish fire suppression using methods that produce the least visual impact. Techniques include flush cutting of stumps, use of natural barriers or roads as firelines, retention of snags, narrow firelines, and other techniques that minimize the impacts of fire suppression.

Minimum impact suppression tactics are used in all four parks whenever it is safe to do so. All forests use MIST in wilderness areas. In addition, the Eldorado and Inyo National Forests and the Lake Tahoe Basin apply MIST whenever possible outside wilderness areas. Several fire managers mentioned the cost savings in reduced rehabilitation through implementing these tactics.

## FIRE-MANAGEMENT RESOURCES IN THE SIERRA

There are fewer fire-management resources in the Sierra today than in past decades. For example, in 1963, the Lassen National Forest had sixteen engines, two helicopters, twelve lookouts, nine prevention units, and two air tankers. By 1995 the number of resources had been reduced by nearly half, to nine engines, one helicopter, six lookouts, three prevention units, and one air tanker. Table 40.2 displays the number of USFS resources in California from 1982 to 1995. The table lists all USFS wildland fire-fighting resources in California. Approximately a third of these USFS resources are located in the Sierra. The table illustrates the gradual decrease in the numbers of wildland fire-fighting resources during the fourteen-year period. The number of fire engines, for example, has been reduced by 12%.

Table 40.3 illustrates the number of CDF wildland fire-fighting resources in California. CDF has experienced reductions in some types of fire-fighting resources in the Sierra similar to those displayed for the USFS. The number of CDF fire engines in California has been reduced by 12% since 1970. The number of hand crews available to the CDF has increased substantially in this same period. These fire crews, from the California Department of Corrections, California Conservation Corps, and other sources, are generally not dispatched as initial-attack forces except during high fire-danger periods. They take thirty minutes to an hour to arrive at a fire.

The decrease in numbers of USFS and CDF fire-fighting resources cannot be directly linked to a decrease in the amount of presuppression funds. The presuppression budget for the Pacific Southwest region was $96,200,000 in FY82 and $97,800,000 in FY95, expressed in constant FY95 dollars. Nationally, USFS presuppression funding peaked in 1977 and has not increased or decreased in real dollars during the past twenty years (USFS 1995b). Adjusted for inflation the annual CDF fire-protection base budget has been relatively constant during the period FY84/85 through FY93/94, with an average of $310,551,384 in 1994 dollars. There are a number of reasons for the decline in available fire-fighting resources in both agencies, given the reasonably stable presuppression budget. In the USFS, there has been a decrease in the availability of project funds to pay portions of the base salaries of fire crews when they are not fighting fires. In the past, portions of fire crews' salaries and basic costs were paid to improve wildlife and fisheries habitat, build fences, thin plantations, construct fuel breaks, and clean up slash resulting from timber sales. The impact of declining project funds has been greatest on forests that had large timber-sale programs, where collections for brush disposal (dollars collected to clean up slash resulting from timber harvest) have dropped dramatically. The portion of national presuppression funding used to treat natural fuels accumulations has decreased steadily since the mid-1970s.

Table 40.2 does not fully illustrate the decrease in numbers of fire-suppression resources in the USFS because it does not include brush disposal crews. Districts formerly employed hand crews to complete slash clean up. These crews were also available to fight fires. Most of the Sierran forests had approximately one ten-person crew per district at the height of the brush disposal program in the early 1980s. Fire-fighting ability has also been impacted by the decrease in the number of USFS employees from outside the fire-fighting organization (foresters, administrators, biologists, and others) who are available or willing to fight fires. Currently, only 53% of USFS employees hold red-card qualifications, which certify them to participate on wildfires. In 1994 25% of the red-carded employees accounted for 75% of the fire-fighting efforts (USFS 1995a).

Administrative support costs have absorbed an increasing portion of fire funds because the fire program has become a

**TABLE 40.2**

USFS wildland fire-fighting resources in California during fiscal years 1982–95 (summarized from records on file in the regional office of the Pacific Southwest Region of the USFS).

| Fiscal Year | Air Tankers | Helicopters | Air Attack | Hotshot Crews[a] | Engines | Prevention Units |
|---|---|---|---|---|---|---|
| FY82 | 13 | 19 | 8 | 17 | 240 | 282 |
| FY83 | 13 | 19 | 8 | 17 | 228 | 245 |
| FY84 | 13 | 17 | 6 | 17 | 241 | 251 |
| FY85 | 13 | 18 | 6 | 16 | 254 | 229 |
| FY86 | 12 | 18 | 6 | 16 | 237 | 215 |
| FY87 | 11 | 18 | 6 | 16 | 231 | 228 |
| FY88 | 11 | 18 | 6 | 18 | 236 | 240 |
| FY89 | 11 | 18 | 6 | 18 | 228 | 222 |
| FY90 | 11 | 18 | 6 | 18 | 228 | 222 |
| FY91 | 11 | 18 | 6 | 18 | 228 | 222 |
| FY92 | 13 | 18 | 6 | 18 | 228 | 222 |
| FY93 | 11 | 18 | 6 | 18 | 217 | 205 |
| FY94 | 11 | 18 | 6 | 18 | 221 | 182 |
| FY95 | 11 | 18 | 6 | 18 | 219 | 176 |

[a]Hotshots are organized, twenty-person fire crews.

**TABLE 40.3**

CDF wildland fire-fighting resources available in California from 1970 through 1994 (summarized from statistics compiled by CDF).

| Year | Air Tankers | Helicopters | Crews[a] | Engines | Dozers | Lookouts |
|---|---|---|---|---|---|---|
| 1970 | 23 | 2 | 116 | 367 | 58 | 78 |
| 1971 | 23 | 2 | 114 | 374 | 58 | 79 |
| 1972 | 23 | 7 | 110 | 370 | 58 | 82 |
| 1973 | 21 | 7 | 113 | 370 | 67 | 82 |
| 1974 | 21 | 7 | 113 | 368 | 71 | 83 |
| 1975 | 21 | 7 | 113 | 367 | 70 | 80 |
| 1976 | 21 | 7 | 113 | 362 | 68 | 79 |
| 1977 | 21 | 7 | 113 | 362 | 67 | 78 |
| 1978 | 21 | 8 | 114 | 362 | 67 | 78 |
| 1979 | 21 | 9 | 114 | 355 | 55 | 78 |
| 1980 | 21 | 8 | 132 | 352 | 63 | 76 |
| 1981 | 21 | 8 | 132 | 352 | 63 | 75 |
| 1982 | 21 | 8 | 150 | 344 | 63 | 72 |
| 1983 | 21 | 8 | 148 | 344 | 63 | 72 |
| 1984 | 21 | 8 | 153 | 344 | 63 | 72 |
| 1985 | 21 | 8 | 157 | 344 | 63 | 72 |
| 1986 | 21 | 8 | 177 | 344 | 63 | 71 |
| 1987 | 21 | 9 | 188 | 344 | 63 | 71 |
| 1988 | 21 | 9 | 206 | 344 | 63 | 64 |
| 1989 | 21 | 9 | 217 | 344 | 63 | 64 |
| 1990 | 21 | 9 | 230 | 344 | 63 | 64 |
| 1991 | 21 | 9 | 231 | 338 | 58 | 33 |
| 1992 | 15 | 9 | 184 | 338 | 58 | 24 |
| 1993 | 19 | 9 | 173 | 336 | 58 | 24 |
| 1994 | 19 | 9 | 173 | 334 | 58 | 32 |

[a]California Department of Corrections hand crews, California Conservation Corps, and other crews.

larger percentage of the forests' organization as other parts of the organization have shrunk. Unemployment claims have risen dramatically because many temporary firefighters cannot find jobs during the off-season.

Both CDF and the USFS have experienced increasing module costs (cost to staff and operate individual pieces of fire-fighting equipment). Within CDF, labor costs have risen dramatically as a result of court decisions regarding the Fair Labor Standards Act. Changes in overtime pay policies have also increased costs. USFS module costs have increased because of changes in job classification and grade structure that have resulted in more highly paid employees on modules.

A discussion of the declining availability of fire-suppression resources would be incomplete without focusing on the impact of structure protection on fire-fighting resources. A recent USFS publication (1995a) states, "Forest Service manual direction for planning wildfire suppression strategies prioritizes the protection of life and private property above protecting natural resources. Suppression forces therefore protect urban values at the expense and detriment of forest ecosystem values. The result is even greater acreage of burned wildfires." This statement is echoed in the draft Federal Wildland Fire Management Policy and Program Review (1995) and the Strategic Assessment of Fire Management in the U.S. Forest Service (USFS 1995d). None of these reports have included quantitative estimates of the increased costs or the drain on wildland fire-fighting resources created by increasing demands to protect private property interspersed with wildland. However, the California Department of Forestry and Fire Protection has defined three fire-management environments in California: undeveloped, developed, and mixed interface (CDF 1995). These categories can be used to display the degree to which development affects fire-management programs and decisions. Undeveloped lands are defined as those areas with less than one house per 160 acres located more than five kilometers from areas with a housing density greater than one house per 160 acres and arranged in contiguous blocks of 50,000 acres (20,000 ha). Developed lands include all areas of the state with a housing density greater than one house per five acres plus all areas within two kilometers of such developed areas. Mixed-interface areas are those between the developed and wildland areas. When this classification is applied to the Sierra, approximately 39.2 million acres (15.9 million ha) are undeveloped wildlands, 9.7 million acres (3.9 million ha) are developed, and 34.9 million acres (15.6 million ha) are mixed interface. The three categories are distributed across all ownerships and jurisdictions. Sierran forest fire managers estimate that the efficiency (speed at which fireline is constructed and held) of fire-fighting resources decreases by 20% to 25% in portions of the forests where demands to protect private property are high.

California has one of the most mobile, highly organized fire-suppression forces ever assembled. The pool of available manpower and equipment has, however, declined. An organization that increases its response efficiency but decreases overall manpower would exhibit the patterns we see in the

Sierra Nevada: more-effective average response coupled with exhaustion under extreme circumstances (McKelvey and Busse 1996). To understand why simultaneous ignitions can create problems for fire suppression and how an organization can be effective at controlling single ignitions but fail when faced with multiple ignitions, consult the conceptual model in appendix 40.1.

## FIRE-MANAGEMENT PLANNING

The National Park Service emphasizes understanding fire regimes in developing fire-management plans. Restoring fire to its natural role in park ecosystems is one of the highest resource-management priorities in all four Sierran parks (NPS 1990a). The three plans divide the parks into zones: a high-elevation zone where lightning fires are managed as prescribed natural fire under all but the most extreme conditions; a middle-elevation, conditional fire-management zone where prescribed fire is used to restore fuel conditions to natural range of variability and then prescribed natural fire is employed; and a suppression zone where only fire suppression or prescribed fire is employed. Full suppression zones are found around the perimeter of parks, at low elevations, and around improvements within parks. The use of prescribed natural fire is influenced, in all zones, by the national fire situation, availability of fire-fighting resources to manage a lightning-caused ignition as a prescribed natural fire, the current drought situation, and funds.

Fire is not a central issue in the current forest plans for the national forests in the Sierra Nevada. It is discussed in the context of protection of resources in the various management areas described in the plans. Although acre objectives for wildfire control were superseded by ASR in 1978 and 1984, the USFS has continued to use acre objectives (maximum fire-size objectives) as a convenient method of relating forest-plan objectives for individual Management Areas to Standards and Guides for fire management, as required in forest plans. Most of the Sierran forest plans set different maximum fire-size objectives for different fire-management zones depending on fire-intensity level. For example, the Stanislaus Forest land and resource management plan may have a maximum fire-size objective of 40 ha (100 acres) if the fire intensity is low but a maximum fire-size objective of 4 ha (10 acres) if intensity is high. Maximum fire-size limits of 4 ha (10 acres) are the upper limit for most of the other forests. The size limit is negotiated in the planning process through discussion of fire effects on resources and is based on the objectives of the unit, such as watershed management, timber management, or wilderness management.

The maximum fire-size objective does not exempt the fire manager from selecting a least-cost-plus-loss alternative. This brings up a fundamental point of confusion in USFS fire planning and policy: both planning and future budget requests for presuppression (National Fire Management Analysis System) are based on suppression cost plus the net value change in the resource. Net value change includes consideration of both the benefits and detriments of wildfire. The combination of cost of fire suppression plus the net value change in resources (timber value, watershed values, recreation values, forage, wildlife habitat, and others) is used to justify a level of protection on each national forest, defined by the most efficient level of fire suppression. The future funding tool encourages high valuation of resources to maximize presuppression funding.

There is no mechanism within the current USFS planning system to display the effects of excluding fire from the ecosystem. Fuel management can be considered beneficial only in the sense that a reduction in suppression costs can be demonstrated. Currently, the USFS does not organize fire-management planning units around similar fire behavior types, and the fire-planning model does not allow planning for multiple ignitions.

The statewide CDF fire plan is currently being revised. The new fire plan will be based on a damage-plus-cost analysis of fire-protection performance similar to that used by the USFS. The purpose of the analysis is to provide a fire-protection system that equally protects lands of similar type. The analysis will define a level of service rating that can be used to compare, on a relative basis, the level of fire protection provided for wildland areas in California. The level of service rating will be used to set program priorities and provides a means to integrate various program elements like fire prevention, vegetation management, and engineering. Public input will be used to adjust the level of service acceptable to California residents.

## PRESCRIBED NATURAL FIRE POLICIES AND PROGRAMS

In 1964 the Wilderness Act recommended that fire be allowed, as much as possible, to play its natural role in wilderness. In 1968 Sequoia and Kings Canyon National Parks began a prescribed-burning program that used prescribed natural fire and management ignition. Yosemite National Park started a prescribed natural fire program in 1972. Lassen Volcanic National Park began a prescribed natural fire program in cooperation with the Lassen National Forest in 1983. All three programs were suspended for revisions called for by the Interagency Fire Policy Review Team in 1988 (Fire Management Policy Review Team 1989). The Yosemite and Sequoia Kings Canyon programs were restarted in 1990, and the Lassen program was restarted in 1994.

USFS fire-management policy was amended to allow use of prescribed natural fire in wilderness in 1971. In 1985 it was again revised to allow use of planned-ignition prescription burning in wilderness, under a limited set of conditions and objectives. Before 1988 there were approved prescribed natural fire programs in the Lassen National Forest's Caribou Wilderness, the Stanislaus National Forest's Emigrant Wilderness, and the Jennie Lakes Wilderness on the Sequoia National Forest. The programs were suspended after the 1988 fire season for a review of the prescribed natural fire program and fire policy. The prescribed natural fire programs in the Caribou and Emigrant wilderness areas were restarted in 1993 and 1994, respectively.

Planned prescribed-burning programs are permissible in eighteen USFS wilderness areas in the Sierra. A combination of planned-ignition prescribed-burning programs and prescribed natural fire programs is called for in thirteen wilderness areas. Prescribed natural fire alone is called for in one wilderness area. The Lake Tahoe Basin plan allows only fire suppression in the Desolation Wilderness. The prescribed natural fire program has been taken from the planning to implementation stage in two Forest Service wilderness areas in the Sierra Nevada.

The NPS and USFS have similar wilderness fire-management policies. The fire programs for the two agencies differ in the degree to which the policies have been applied locally. Sequoia and Kings Canyon and Yosemite National Parks have had active prescribed natural fire programs for most of the last twenty-five years. Both parks have used extensive prescribed burning to restore fuel loadings and forest structure to levels within the natural range of variability. Lassen Volcanic National Park has had an active program for almost fifteen years. However, analysis of even the most successful prescribed natural fire programs (Botti and Nichols 1995; Parsons 1995) indicates that these programs fall far short of duplicating the role of natural process in Sierran ecosystems. Acres burned are much fewer than the number of acres burned under historic fire regimes. Smoke-management constraints, risk to adjacent jurisdictions, or improvements and limitations on programs during periods of high wildfire activity are among the factors that have limited accomplishments. The national and state interagency preparedness plans have required that no new prescribed natural fires be managed during periods of high activity and may require that ongoing prescribed natural fires be suppressed during extremely high activity.

The plans for the Sierran national forests authorize the use of prescribed natural fire and, in most cases, management-ignited fire, as shown in table 40.4. Despite program authorization in nearly every plan, only two USFS wilderness areas have prescribed natural fire programs, with a total Sierra-wide burned area of less than 40 ha (100 acres) in the entire period that the programs have been in place. No management-ignited prescribed burns have been conducted in USFS wilderness areas in the Sierra Nevada.

When surveyed, fire managers in both agencies gave the following reasons for the differences in implementation of wilderness fire-management programs between agencies:

The National Park Service has provided consistent funding for the planning and implementation of prescribed natural fire programs. Forests must use scarce project dollars for both planning and implementation. These same funds are in demand for prescribed burning outside wilderness and for other recreation and wilderness activities. There is no indication that additional dollars will be made available for managing prescribed natural fires. As a result, there is little or no incentive to develop programs.

Before 1988, the National Park Service used emergency dollars to manage prescribed natural fires. This practice was suspended in 1988 but is once again in place throughout the Department of the Interior. This mechanism provides the flexibility to allow changes in the size of the prescribed natural fire program from year to year in response to variation in the number of lightning fires. The U.S. Department of Agriculture does not use emergency fire dollars to manage prescribed natural fires, because of the department's interpretation of fiscal policy and allowable uses of emergency funds.

Yosemite and Sequoia and Kings National Parks have developed a strong research basis for implementation of fire-management strategies within the parks. The southern Sierra Nevada have been the focus of most of the dendrochronology / fire history studies conducted in the range. A fire-history study has also been conducted in Lassen Volcanic National Park and the adjacent Caribou Wilderness.

The Forest Service and National Park Service differ in philosophical basis of fire programs in wilderness. The National Park Service focus is on management of fire as a disturbance within its natural range of variability. In Forest Service wilderness, on the other hand, the emphasis has been on allowing natural processes to operate freely, without making judgments about whether the effects of these processes are good or bad. There is a subtle but important difference between managing fire freely and managing it as a process that has a distinct ecological role. The fire-management plans for the NPS areas in the Sierra include use of planned prescribed fire to reduce fuel loadings, prior to reintroduction of prescribed natural fire.

National Park Service wilderness areas are substantially larger than Forest Service wilderness areas. When comparing two areas of similar fuel and fire behavior characteristics, the risk of long-duration fires leaving the prescribed natural fire zones is reduced in a larger area. It is notable, however, that the Emigrant Wilderness, Hoover Wilderness, Yosemite National Park, Ansel Adams Wilderness, John Muir Wilderness, Sequoia and

**TABLE 40.4**

Summary of wilderness fire direction in forest plans and NPS fire-management plans.

| Wilderness Area | Acres | Forest/Park | Fire-Management Options[a] |
|---|---|---|---|
| Ansel Adams | 228,669 | Inyo National Forest (INF), Sequoia National Forest (SQF) | INF 1; SQF 2 |
| Bucks Lake | 21,000 | Plumas National Forest (PNF) | 3 |
| Caribou | 20,625 | Lassen National Forest (LNF) | 2, approved interagency plan with Lassen Volcanic National Park (LAVO) |
| Carson-Iceberg | 160,000 | Stanislaus National Forest (STF) | 2 |
| Desolation | 63,475 | Eldorado National Forest (ENF) | 2 |
| Dinkey Lakes | 30,000 | Sierra National Forest (SNF) | 2 |
| Domeland | 94,686 | SQF | 2 |
| Emigrant | 112,191 | STF | 2, approved plan |
| Golden Trout | 303,287 | INF, SQF | INF 1; SQF 2 |
| Granite Chief | 25,000 | Tahoe National Forest (TNF) | 2 |
| Hoover | 48,601 | INF, Toiyabe National Forest | 1 |
| Ishi | 41,600 | LNF | 1 |
| Jennie Lakes | 10,500 | SQF | 2 |
| John Muir | 580,675 | INF, SNF | INF 1; SNF 2 |
| Kaiser | 22,700 | SNF | 2 |
| Lassen Volcanic | 79,000 | LNF, LAVO | 2, approved plan |
| Mokelumne | 104,461 | ENF, STF, Toiyabe National Forest | ENF 2; STF 2; Toiyabe 2 |
| Monarch | 45,000 | SQF, SNF | SQF 2; SNF 2 |
| Sequoia and Kings Canyon Parks (SEKI) | 736,584 | SEKI | 2, approved plan |
| South Sierra | 63,000 | SQF, INF | SQF 1; INF 1 |
| South Warner | 70,385 | Modoc National Forest | 2 |
| Thousand Lakes | 16,335 | LNF | 2 |
| Yosemite National Park (YOSE) | 677,600 | YOSE | 2, approved plan |

[a] 1 indicates planned ignition only; 2 indicates planned ignition and prescribed natural fire; 3 indicates prescribed natural fire only.

Kings Canyon National Parks, Monarch Wilderness, Jennie Lakes Wilderness, and Golden Trout Wilderness, when grouped, form a 3 million acre unit where consistent prescribed-fire programs could be developed. At the present time, agreements are in place to allow prescribed natural fires to cross agency boundaries between Lassen National Park and the adjoining Caribou Wilderness on the Lassen National Forest and between Yosemite National Park and the Emigrant Wilderness. These agreements have not been used to date.

## PRESCRIBED-FIRE PROGRAM AND POLICY

The objectives for application of management-ignited prescribed fire vary between agencies, but the policies, planning requirements, and implementations are very similar. The Federal Wildland Fire Management Policy and Program Review Team (1995) recommends that policy concerning prescribed fire be standardized for all federal agencies. The revised policy statement reads, "Wildland fire will be used to protect, maintain, and enhance resources, and be allowed to function, as nearly as possible, in its natural ecological role."

Each agency requires the completion of a prescribed-burn plan for each prescribed burn. The plans describe quantifiable objectives for the burn, the burning prescription designed to meet the objective, the organization that will accomplish the burn, the ignition plan, the holding plan, the mop-up plan, and the contingency plan should the burn escape. The burn plan also describes smoke-management requirements, monitoring requirements, and values at risk.

The effectiveness of the prescribed-fire program in the Sierra is limited chiefly by the scale at which it is currently applied. As an example, table 40.5 shows the extent of recent and planned burning in the Sierra Nevada forests. The extent of burning is negligible when compared to the historic fire regimes. Currently, 20,235 ha (50,000 acres) are burned in the Sierra each year using prescribed fire. Evidence suggests that a much greater area burned yearly under historic fire regimes (Skinner and Chang 1996). Further discussion of the prescribed-burning program and fuels-management strategies is included in Weatherspoon and Skinner 1996.

### CDF's Vegetation-Management Program

In 1981 the California Department of Forestry and Fire Protection implemented a vegetation-management program (VMP) on private lands in California. The goal of the program is to reduce large, damaging wildfires by reducing fire hazards on wildlands.

CDF's intent is to realize the best mix of natural resource benefits from these lands, consistent with environmental protection and landowner/steward objectives.

The VMP identifies three broad goals:

1. Reduce conflagration fires.
2. Optimize soil and water productivity.
3. Protect and improve intrinsic floral and faunal values.

The VMP identifies twelve subgoals:

1. Reduce the number and intensity of large, damaging wildfires with corresponding savings of suppression costs.
2. Increase public safety.
3. Increase water quantity and maintain water quality from managed watersheds.
4. Decrease the potential for damage from flooding and siltation.
5. Protect and improve soil productivity, and decrease erosion over the long term.
6. Improve wildlife and fisheries habitat.
7. Improve oak woodlands through fire management and regeneration.
8. Establish and maintain desired plant communities.
9. Propagate rare and endangered plant species that are fire dependent.
10. Improve air quality over the long term.
11. Improve forage and browse for livestock.
12. Increase opportunities for recreation and improve scenic vistas.

The VMP was originally established to reduce fire hazard by treating standing brush. Since its inception in 1981, there have been 61,919 ha (153,400 acres) burned in the Sierra, an average of 4,775 ha (11,800 acres) per year.

The VMP was never intended to replace landowner burning; however, this has been a consequence in some areas. Some private landowners no longer burn vegetation because they would rather let the state assume the liability.

Currently, the VMP is being reviewed with the intent of expanding the program to include fuel types other than standing brush, for example, understory burning. Such expansion would add areas to the program that have not historically been treated. The program may also expand to include methods other than burning to accomplish its goals.

## Costs of Prescribed Burning versus Wildfire Suppression

Table 40.6 displays some examples of costs per acre for implementing planned prescribed burns in forests and parks. A discussion and comparison of the costs of various fire-management activities are beyond the scope of this chapter. Prescribed burning, however, is much cheaper than fire suppression, when the two are compared on a per-acre basis. For example, on the Stanislaus National Forest current fire-suppression costs range from $6,400 per acre for fires up to 1 acre in size to a low of $1,000 per acre for fires 5,000 acres or larger. The cost per acre for underburning is $50 per acre. Average cost per acre for suppression of wildfires in Yosemite National Park between 1970 and 1994 was $216 to $358 per acre compared to $19 per acre for prescribed burning and prescribed natural fire during the same period.

Prescribed-burning costs are difficult to quantify because information collection is not standardized. Costs for differ-

**TABLE 40.5**

Number of acres burned using prescribed fire in 1993 and 1994 compared to planned future acreage per year.

| Unit | Acres Burned in 1993 | Acres Burned in 1994 | Future Acres/Year |
|---|---|---|---|
| Eldorado National Forest | 4,267 | 3,235 | 7,000 |
| Inyo National Forest | 165 | 365 | 800 |
| Lassen National Forest | 9,193 | 6,772 | not available |
| Modoc National Forest | 2,527 | 2,781 | 40,000 |
| Plumas National Forest | 5,099 | 4,443 | 10,000 |
| Sequoia National Forest | 2,452 | 2,280 | 11,000 |
| Sierra National Forest | 1,035 | 3,794 | 6,000 |
| Stanislaus National Forest | 8,353 | 11,587 | 13,000 |
| Tahoe National Forest | 2,725 | not available | 5,000 |
| Lake Tahoe Basin Management Unit | 355 | 355 | 1,100 |
| Sequoia and Kings Canyon National Parks | 2,851[a] | 1,294[a] | 16,000–18,000 |
| Yosemite National Park | 1,075[a] | 3,490[a] | not available |
| CDF | 11,800[b] | 11,800[b] | not available |
| Total | 51,897 | 52,196 | |

[a]Includes both prescribed fire and prescribed natural fire.
[b]Average figure per year for all CDF areas in the Sierra combined.

**TABLE 40.6**

Estimated prescribed-burning costs in dollars per acre for 1995.

| Unit | Underburning, Dollars per Acre | Burning Piles (Hand Piles and Machine Piles), Dollars per Acre | Broadcast Burning of Slash, Dollars per Acre | Brush Burning, Dollars per Acre |
|---|---|---|---|---|
| Eldorado National Forest | | 40–100 | | |
| Inyo National Forest | | 53–111 | | |
| Lassen National Forest | 205–559 | 42–124 | 169–509 | 50–86 |
| Modoc National Forest | 80–180 | 30–75 | 170–420 | |
| Sequoia National Forest | 229 | 45 | | 107 |
| Stanislaus National Forest | 50 | 40–110 | | |
| Tahoe National Forest | 450 | 60–100 | 650 | |
| Sequoia and Kings Canyon National Parks | 22–356 | | | 2.50–52 |
| Yosemite National Park | 19[a] | | | |

[a]Average value for all planned prescribed burns for 1982–88.

ent units are not necessarily comparable because they include different things. In particular, planning and prefire survey costs for endangered species or archaeological values can increase costs. Each forest, park, or ranger unit differs in the amount and degree of planning and public involvement needed for the individual project.

# FUTURE FIRE-MANAGEMENT POLICY AND PROGRAM OPTIONS

Land managers are struggling to reconcile ecosystem management, which emphasizes the role of natural processes in maintaining healthy ecosystems, with the tremendous success of fire suppression, which has all but eliminated the influence of fire on ecosystems. The National Park Service began its program of natural-process management in 1968 after reassessing its policy of suppressing all fires, at least partially in response to the Leopold report (Leopold et al. 1963). Both the USFS and the BLM are reassessing the role of fire in California's ecosystems through ecosystem-management efforts. Manley and her colleagues (1995) have recommended that fire frequency, intensity, size, and seasonality be used as key environmental indicators of ecosystem health in the national forests of California. Two recent reports have dealt with this emerging dilemma on a national, interagency scale. The USFS recently issued a strategic assessment of its fire-management programs (USFS 1995d) recommending a shift from the traditional focus on fire suppression and control to true fire management. A review of the federal wildland fire-management policy and program, undertaken in light of the severe 1994 fire season, highlighted needed changes in federal fire policy. The report recommends that federal agencies standardize their fire-management policies, taking into consideration the role of fire as an essential ecological process and natural change agent (Fire Management Policy and Program Review Team 1995).

Possible changes in fire-management programs in the Sierra Nevada fall into two categories: those possible under current policy, especially if additional funding were made available, and changes possible if policy were altered.

## Changes Possible under Current Policy

The agencies responsible for fire management in the Sierra Nevada must cooperate to take full advantage of the present flexibility in fire-management policy. Under current policy the prescribed natural fire program could be expanded to all suitable wilderness areas and to many high-elevation areas outside wilderness. Consistent prescriptions and programs across jurisdictions for both prescribed natural fire and planned prescribed fire would reduce perceived risk and cost, because fires would not be suppressed along some jurisdictional boundaries.

The four agencies in the Sierra Nevada have the complementary skills in all areas of fire management needed to implement a more effective overall program. For example, the NPS has the most experience managing and restoring natural processes in Sierran ecosystems. The USFS has the greatest experience using mechanical methods to reduce fuels. CDF has experience protecting private lands and structures. BLM has specialized in rangeland burning. They must work together more closely, especially in the planning phase.

The agencies must also consider the organizational structures best suited to the changing role of fire management. Several recent documents have emphasized the difficulty of linking fire-management objectives to resource- or ecosystem-management objectives, if the fire-management organizations specialize in fire suppression and emergency response at the expense of vegetation management, fuels management, or fire planning.

Forests, BLM areas, and parks could reexamine the opportunities to fully exercise appropriate suppression response. It is essential that fire-management planning be organized in ecological units, which emphasize similar fire regimes. McKelvey and Busse (1996) have displayed the relative increase in fire-suppression effectiveness with elevation in the Sierra. Current presuppression planning takes into account differences in fire regimes by dispatching fewer initial-attack resources to fires in dispatch units with lower fire potential and during periods of low to moderate fire danger. However, this approach has not been extended to application of different strategies with increasing elevation, variation in fire behavior, or different values at risk, except in a few areas.

## Changes Possible under Revised Fire Policy

Frustrating for a number of fire managers surveyed is their inability to use wildfire to meet resource-management objectives. The cost-efficiency requirement makes it impossible to allow low- to moderate-intensity fires to burn to significant size, as wildfires. The Federal Wildland Policy and Program Review (1995) approaches this issue by suggesting that "Planning should consider all wildland fires, regardless of ignition source, as opportunities to meet management objectives." Planning documents for all agencies could be revised to prescribe conditions under which wildfires could be used to meet resource objectives, even if fire-suppression costs increased. The basis for applying the proposed policy change is already present in the fire-management plans for the national parks, which contain natural fire prescriptions for most areas. The forests would need to determine the relationship between fire characteristics and resource objectives through landscape-level analysis. One vehicle for such analysis is watershed analysis. The use of wildfire to meet resource objectives is not recommended on private lands, unless the landowner supports the proposal.

Several managers suggested changes in planning methods to take into account the cost of repeatedly suppressing lightning fires in the same watershed, when it could be burned by a single low- to moderate-intensity wildfire at lower cost over time. Small fires on the Stanislaus National Forest cost an average of $6,000 per acre to suppress. Current policy requires that the cost effectiveness of each wildfire be analyzed individually. Again, up-front planning would be needed to contrast the long-term costs and benefits of fire suppression in a watershed.

The risks associated with widespread use of fire throughout the Sierra are daunting, especially given the risks to developed areas. It is essential, however, that fire-management programs are realigned to match suppression strategies and prescribed-burning applications with the known burning characteristics of the different fuel types. The fire-management agencies simultaneously pursue two fire-management objectives, one with the goal of eliminating fire from the ecosystem (fire suppression), and the other with the goal of reintroducing fire in areas from which it has been intentionally eliminated (prescribed fire). In the Sierra Nevada 20,235 ha (50,000 acres) are burned each year using prescribed fire, at a cost of approximately $5,000,000. The average cost of twenty-six large fires that burned in California in 1994 was $2,920,989 each (USFS 1995c). Five of these fires—the Cottonwood, Hirschdale, Crystal, Big Creek, and Doyle—burned in the Sierra, cost an estimated $27,000,000 (charges do not include costs for mobilization and transport and do not include resource damage), and burned approximately 25,496 ha (63,000 acres) of federal, state, and private land.

To begin to influence fire regimes in the Sierra Nevada, prescribed burning and fuel treatments must be increased by at least five to ten times their current levels. It is essential that the costs of the prescribed-burning and fuels-treatment program be put in clear perspective by assessing their value to Sierran ecosystems and contrasting them to the considerable costs and effects of wildfires that do occur.

## REFERENCES

Botti, S. J., and H. T. Nichols. 1995. Availability of fire resources and funding for prescribed natural fire programs in the National Park Service. In Proceedings: Symposium on fire in wilderness and park management, 30 March–1 April 1993, Missoula, MT, technical coordination by J. K. Brown, R. W. Mutch, C. W. Spoon, and R. H. Wakimoto, 74–103. General Technical Report INT-GTR-320. Ogden, UT: U.S. Forest Service, Intermountain Research Station.

California Department of Forestry (CDF). 1986. California Department of Forestry and Fire Protection fire plan. Sacramento: CDF.

———. 1995. Fire management for California ecosystems. Unpublished report. Sacramento: CDF.

Cermak, R. W. 1988. Fire control in the California national forests, 1898–1955. Unpublished report. Tahoe National Forest: National Park Service.

Fire Management Policy and Program Review Team. 1995. Federal wildland fire management policy and program review. Washington, DC: U.S. Department of the Interior and U.S. Department of Agriculture.

Fire Management Policy Review Team. 1989. Final report on fire management policy. Washington, DC: U.S. Department of Agriculture and U.S. Department of the Interior.

Leopold, A. S., S. A. Cain, C. M. Cottam, I. N. Gabrielson, and T. L. Kimbal. 1963. Wildlife management in the national parks. Trans America Wildlife Natural Resources Conference 28:1–18.

Manley, P. N., G. E. Brogan, C. Cook, M. E. Flores, D. G. Fullmer, S. Husari, T. M. Jimerson, L. M. Lux, M. E. McCain, J. A. Rose, G. Schmitt, J. C. Schuyler, and M. J. Skinner. 1995. Sustaining ecosystems: A conceptual framework. San Francisco: U.S. Forest Service, Pacific Southwest Region and Station.

McKelvey, K. S., and K. K. Busse. 1996.Twentieth-century fire patterns on Forest Service lands. In Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, chap. 41. Davis: University of California, Centers for Water and Wildland Resources.

Mills, T. J., and F. W. Bratten. 1982. FEES: Design of a fire economics evaluation system. General Technical Report PSW-65. Berkeley, CA: U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station.

———. 1988. Economic efficiency and risk character of fire management programs, northern Rocky Mountains. Berkeley, CA: U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station.

National Park Service (NPS). 1990a. Fire management plan. Unpublished report. Yosemite National Park: NPS.

———. 1990b. Wildland fire management guideline. NPS-18. Washington, DC: NPS.

Parsons, D. J. 1995. Restoring fire to giant sequoia groves: What have we learned in 25 years? In Proceedings: Symposium of fire in wilderness and park management, 30 March–1 April 1993, Missoula, MT, technical coordination by J. K. Brown, R. W. Mutch, C. W. Spoon, and R. H. Wakimoto, 256–58. General Technical Report INT-GTR-320. Ogden, UT: U.S. Forest Service, Intermountain Research Station.

Pyne, S. J. 1982. Fire in America: A cultural history of wildland and rural fire. Princeton, NJ: Princeton University Press.

Schmidt, G. 1995. Emergency fire suppression expenditure trends in the Forest Service. In Fire suppression costs on large fires: A review of the 1994 fire season, Appendix A. Unpublished report. Washington, DC: USFS.

Skinner, C. N., and C. Chang. 1996. Fire regimes, past and present. In Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, chap. 38. Davis: University of California, Centers for Water and Wildland Resources.

U.S. Forest Service (USFS). 1994a. Fire related considerations and strategies in support of ecosystem management. Unpublished report. Washington, DC: USFS.

———. 1994b. Fire management. In USFS manual 5100. Washington, DC: USFS.

———. 1995a. Course to the future: Positioning fire and aviation management. Unpublished report. Washington, DC: USFS.

———. 1995b. Fire economic assessment report. Unpublished report. Washington, DC: USFS.

———. 1995c. Fire suppression costs on large fires: A review of the 1994 fire season. Unpublished report. Washington, DC: USFS.

———. 1995d. Strategic assessment of fire management in the USDA Forest Service. Unpublished report. Washington, DC: USFS.

Weatherspoon, C. P., and C. N. Skinner. 1996. Landscape-level strategies for forest fuel management. In Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, chap. 56. Davis: University of California, Centers for Water and Wildland Resources.

APPENDIX 40.1

# A Conceptual Model for Fire Suppression

To understand why simultaneous ignitions can create problems for fire suppression and how a suppression organization can be effective at controlling single ignitions but fail when faced with multiple ignitions, a simple conceptual model is useful.

Fire-resource scheduling models are designed to evaluate the effectiveness of suppression response for specific geographic zones. They are, therefore, complex, with detailed descriptions of resource capabilities and travel times (Mills and Bratten 1982, 1988). They have, however, common structural features:

For input they require

- a list of available resources
- the travel time for each resource to each potential fire location
- the rate at which each unit resource creates fireline in various fuel types
- the assumed fuel type in which fires occur
- weather

When fires occur, in the models,

- They spread at constant rates based on fuels and weather, and the fire perimeter forms an ellipse.
- There are rules controlling the suppression response—which resources are dispatched to the fire.
- The fire is contained when the total length of line created exceeds the fire perimeter.

To be useful for evaluating the effectiveness of a suppression organization, each of these inputs needs to be as accurate as possible, and hence these models are complex and extremely data-bound. For purposes of developing a simple conceptual model, however, it is possible to simplify each of these requirements without altering the basic model form.

## SIMPLIFYING ASSUMPTIONS

The model can be greatly simplified by assuming that there is only one type of suppression resource, evenly distributed across the landscape. Travel time is simply the straight-line distance between the resource and the fire multiplied by the rate of speed at which the resource can travel. In addition it is assumed that there is only one fuel type and one weather condition. We will also assume that fire spreads at a constant rate and forms the simplest possible ellipse, a circle. Last, we will assume that all resources are dispatched to the nearest ignition and that resources continue to be dispatched until the fire is contained.

## SINGLE IGNITION

Think of this model as a parking lot with people scattered on it. Suddenly a light turns on (a fire) somewhere in the lot, and everyone runs toward it as quickly as they can (they all run at the same speed and don’t get in each other’s way).

At any time t after the ignition, all resources within a distance r from the ignition will have arrived (figure 40.A1). r is simply the speed (s) at which the resources can travel * t, the time elapsed since the fire started. For instance, if the resources can travel toward the fire at 30 mph, then at time t = 1 hr, all resources from up to 30 miles away will be at the fire. At t = 2 hr, all the resources from up to 60 miles away will arrive, and so on.

If the resources are uniformly distributed on the landscape (one of our simplifying assumptions), then the forces available to suppress the fire at any time $t(S_t)$ will be:

$$S_t = \pi(s^*t)^2 d \qquad (1)$$

that is, the area of a circle of radius r = s*t times the density (d) of resources per unit area. If s = 30 mph and d = 2 firefighters per square mile, then at time t = 1 hr, 5,654 firefighters could be on the scene.

Because the radius of the response circle gets larger at a

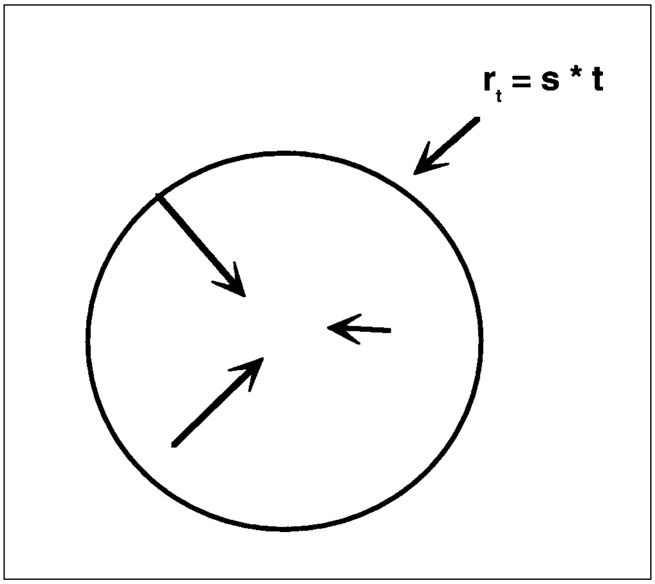



**FIGURE 40.A1**

The suppression response circle at time *t*. All resources within the area of the circle will have arrived at the fire.

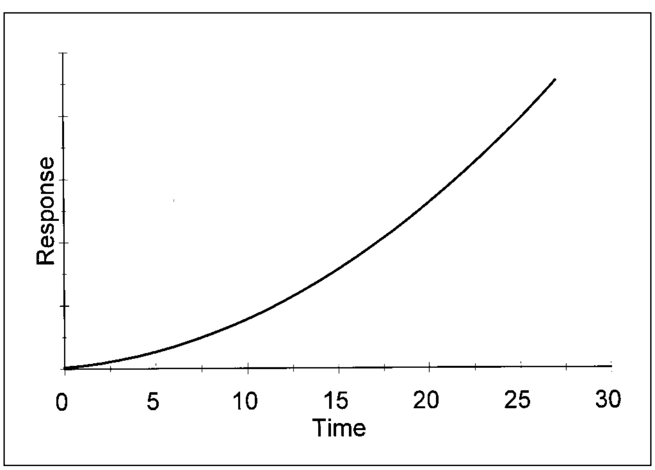
steady rate over time, the number of forces arriving per unit time increases quadratically, leading to a "power curve" in suppression resources at the fire over time (figure 40.A2).

While resources are streaming toward the fire, the fire is spreading according to our simplified rules—rate of spread (ROS) is constant, and the fire expands in a circular manner. Its radius at any time *t*, therefore, is t*ROS. The key to suppression is that the resources don't fight the area of the fire, only its perimeter:

$$P_t = 2\pi(ROS^*t) \qquad (2)$$

**FIGURE 40.A2**

The "power curve" for suppression response to a single ignition.



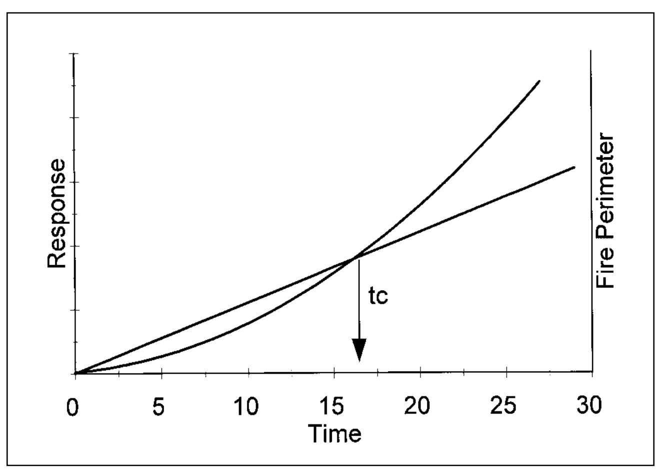

where $P_t$ is the perimeter at time t. Because this is a linear function of time, whereas our response function is quadratic, if we can maintain our power function in suppression resources, we will eventually control the fire (figure 40.A3). The point at which the suppression-resources curve crosses the fire-perimeter curve is the time at which the fire is controlled (tc). The average acreage associated with a fire in a suppression environment is directly related to tc. The important variables controlling when tc is achieved are, on the suppression side, the speed of response and the density of resources. On the fire side they are the rate of spread and the resistance to control—that is, how many resources are required to control a unit distance of the fire perimeter.

Assume that we are dissatisfied with tc and want to shorten the time necessary to achieve it. Should we increase the speed of response (s) or increase our resources (d)? Looking at equation 1, the answer will always be to increase the speed of response. Increases in s are squared, while increases in d are not (figure 40.A4).

This model, while simple, captures the basic dynamics of the suppression process. In reality, resources come in clumps—and some are more mobile than others—they have different suppression capabilities, and they are unevenly distributed. But this doesn't change the basic power-curve structure of suppression response. Fire ROS is also not constant, but that doesn't change the basics of fire perimeter growth. And there will be a tc. When the fire calms down because of a change in weather, if sufficient resources have been gathered, the fire will be contained.

**FIGURE 40.A3**

Where the suppression-response curve (curved line) crosses the fire-perimeter curve (straight line), the fire will be contained, at time *tc.*



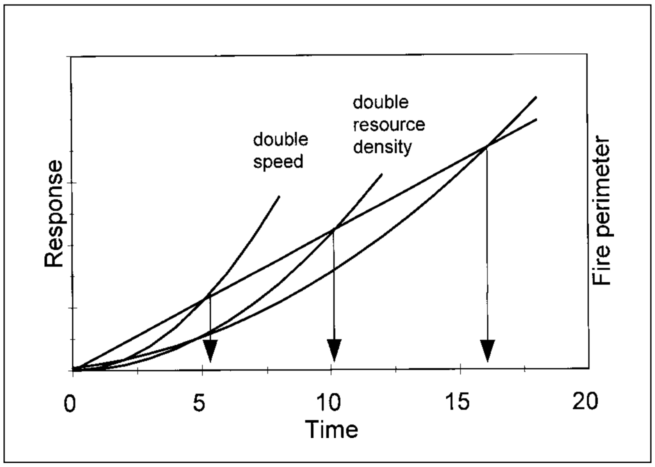



**FIGURE 40.A4**

Curves showing the change in suppression response associated with doubling the rate of speed at which resources can converge on a fire *(s)* or the number of resources per unit area *(d)*. Arrows point to the *tc*, or time at which the fire is controlled, associated with changes in resource availability.

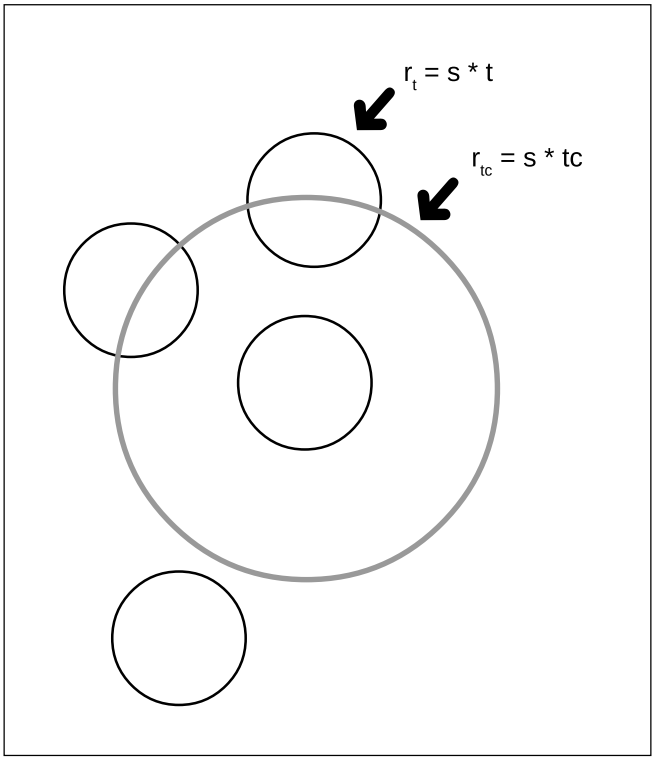
## MULTIPLE IGNITIONS: WHY SUPPRESSION FAILS

If individual ignitions are the expectation, then the optimization will be heavily weighted toward speed of response. Not only is this tactic more effective, but it is generally less expensive than large increases in the resource pool. In many cases (such as by keeping crews fire ready), response time can be shortened at no cost. This happy world begins to come undone, however, when there are multiple ignitions in the same area. Returning to our basic model, assume that tc is known, that is, the resource density, speed of response, and ROS of the fire are all fixed. For a single ignition, tc occurs when all resources in a circle of radius $r_{tc}$ around the ignition are at the fire. Figure 40.A5 shows the problem. Figure 40.A5 shows a snapshot of four closely spaced ignitions at time t. The small, black-outlined circles are the areas whose resources have responded to each strike by time t, and at this time there is no conflict: the responses to all fires are still following their power curves. Unfortunately, *tc* hasn't been reached—$r_{tc}$ will require resources from a larger area, and there will be a resource conflict. Resources necessary to achieve suppression will already have been dispatched to the nearest fires. This conflict fundamentally alters the power curve of suppression response. In the worst case, there will be a gap during which no new resources arrive at the fire. During this period the fire perimeter will continue to grow unchecked.

So, for multiple ignitions, the key to avoiding breakdown is to avoid competition for resources, and to do so the radius of the resource area associated with control should be as small as possible. In figure 40.A5, for instance, if $r_c$ was achieved at time t, when the snapshot was taken, there would be no conflict and hence no breakdown. So the optimization for dealing with multiple strikes is very different from the single-strike model. In the single-strike model a small quantity of resources can be very effective if they are mobile enough. For multiple strikes, the density of resources is much more important. It should also be noted that for any suppression organization, regardless of its structure, there will be a point of resource exhaustion. No suppression agency can guarantee that extreme fire events characterized by multiple strikes will not get out of hand.

**FIGURE 40.A5**

In this scenario there are four fires close together. Each fire requires resources from an area $r_{tc}$ in size to be contained. The resource demands of these fires will overlap and the "power function" cannot be maintained.

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