

Prescribed Burning in the Kings River Ecosystems Project Area: Lessons Learned¹

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Abstract

The prescribed fire program on the Sierra National Forest is in its infancy. Prescription burning was initiated in 1994 in two 32,000-acre watersheds in the Kings River District of the Sierra National Forest. Primary objectives are to return fire to a more historical role in forest ecosystems and to provide opportunities for scientists from the Pacific Southwest Research Station, and elsewhere to study various effects of these fires. Approximately 11,900 acres of prescription burns were completed by the end of 1999, and documents required by the National Environmental Policy Act have been completed for burning on about 23,000 additional acres. A Draft Landscape Analysis Plan has been prepared and reviewed, and a final draft is presently in preparation. Two fuels-reduction projects are nearly completed, using small-group selection, thinning of conifers, conversion of brush patches to conifer stands, and prescribed burning. A second fuels-reduction project is currently being planned. Many lessons have been learned that relate to needed equipment, crew size, lighter experience, and ignition methods; indicators of appropriate times and places to burn; weather patterns; indicators of desirable flame lengths and fire intensities; indicators of the effects of burns on fuels, duff layer, and soil; and measures of the extent of brush, surface fuels, and ladder fuels removed by burns differing in intensity.

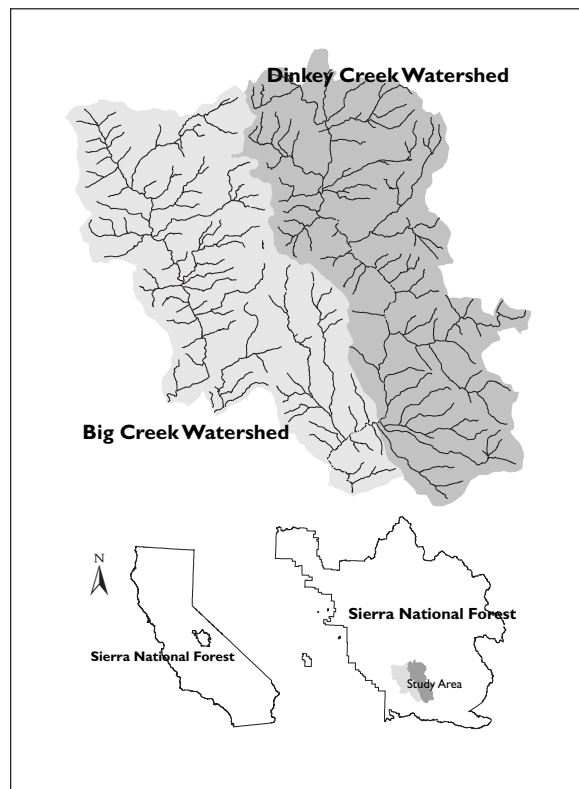
Past efforts to underburn with prescribed fire on the Kings River Ranger District of the Sierra National Forest consisted of isolated, 100- to 1,000-acre projects spread over the district during the 1970's. The main objective was to improve summer forage for mule deer (*Odocoileus hemionus*) of the North Kings herd (Eaton 1978). These projects were single-entry burns done mainly during fall in mixed-conifer and red fir (*Abies magnifica*) vegetation types, although some burning in the ponderosa pine (*Pinus ponderosa*) type occurred during spring months. Opinions varied about whether these burns were successful forest management practices. Some evidence indicated improved forage for deer (Bertram and others 1978), although several fire-salvage timber harvests were done in the area immediately after the prescribed burns in the 1980s. We have no records of underburning between 1980 and 1989.

With the exception of a 60-acre underburn in 1990 in the area covered by the Kings River Sustainable Forest Ecosystems Project, the current underburning program began in 1994. We presently have 23,000 acres of underburning covered by National Environmental Policy Act (NEPA) documents for the Kings River District, and all but 3,000 of those acres are within boundaries of the Kings River Project (fig. 1). Prescribed burning has been completed on 11,900 acres during the past 6 years, 3,900 acres of which are second-entry burns (that is, burned twice). Most of the prescribed burns are routinely accomplished without thinning or other mechanical pretreatment of fuels. Much of the landbase has not seen fire of any type for over 100 years.

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Figure 1—The Kings River administrative study area in the Sierra National Forest in Central California includes the 64,000-acre Big Creek and Dinkey Creek watersheds (indicated by shading).



Objectives

Initial underburning was tied to Environmental Assessments for helicopter salvage sales, and objectives were to remove activity fuels and natural fuels to protect wildlife habitat, mainly for California spotted owls (*Strix occidentalis occidentalis*) using funds from Knudtson-Vandenburg (KV-natural fuels, KV-wildlife) and brush disposal (BD) collections from timber sales. In an effort to reduce dead-and-downed fuels remaining, sale administrators attempted to yard whole trees killed by insects. This effort failed, however, because most of the trees were brittle from dessication and fractured during felling operations.

New NEPA documents later changed objectives to include restoration of fire as a functional part of forest ecosystems and to minimize the damaging effects of wildfire; a sense of urgency was associated with these objectives. Brush species comprise a large part of the understory in the ponderosa pine and mixed-conifer forests in the area. During wildfires, increased fuel loads from brush, litter, logging slash, and conifer reproduction add fuel, increasing fire intensity and damaging the overstory. Brush is generally easy to kill with fire and, considering the short fire-return interval in the area (an average of one fire every 5-10 years; Drumm 1999), probably did not exist historically in its current volume and arrangement. In recent years, patterns of wildfire in the Sierra Nevada pointed to increasing damage to forest environments from unhistorically high fire intensities.

Our burning philosophy is based on the concepts of Biswell (1989), which call for light underburns twice within 5 years. This reduces brush competition in the understory, especially from species that are obligate seeders. Thereafter, maintenance involves reentry with fire every 5-10 years.

General Methods

Two underburning projects were developed for 16,000 acres in the Dinkey Creek, Big Creek, and Rush Creek drainages. Large-scale (1,000-2,000 continuous acres) fuels-reduction projects were planned that combined treatments of thinning from below, mastication, pile and burn, herbicide, and underburning in ponderosa pine and mixed-conifer vegetation types. The main objectives were to reduce the fire hazard and reintroduce a historic fire regime. Defensive fuel profiles zones (DFPZs) were established to reduce the effects of potential wildfires on key resource values and/or urban areas. Following NEPA regulations, Environmental Assessments were developed for these projects, and they were categorically excluded from further analysis under Category 31.2(6).

Three portable, automated weather stations on the District are used to monitor and collect hourly weather data from burn sites. These are tied into the daily fire-danger weather reporting system, and they can be accessed from the District office via computer with radio and/or phone hookups. The stations are queried daily at 6:00 a.m., and the weather for the past 24 hrs is waiting for the burn bosses when they get to work. The outputs are faxed to the National Weather Service, where a Spot Fire Weather Forecast and a Smoke Dispersal Forecast specific to the burn site is produced.

Most control points on the burns are roads and running streams. Firelines are constructed around private property where we lack agreements with landowners. Both handlines and dozer lines are constructed. In addition to roads and streams, control points in the winter and early spring months consist of snow banks, north slopes, and brushfields. The pure chaparral stands on the District do not burn well outside of fire season because grass is the main carrier of fire, and this is green or damp and beaten down then. Burning during fire season requires that control lines be constructed to wildfire standards.

Burns ranging in size from 130 to 1,500+ acres are planned for all aspects at elevations from 3,000 to 7,000 ft. Most burn units are adjacent to other units. In several areas on the District, continuous burn units now cover several thousand acres. Under suitable burning conditions, several areas may be grouped together as one unit and ignited aurally. Units are ignited to burn down from their upper elevations. Backing fire downhill in this way tends to result in lower flame lengths, lower fire intensities, and slower rates of spread. Such a fire is easier to control than those that run uphill.

Burning takes place when burn units come into prescription. This may occur at any time of the year, often even during dry spells in the winter. The 10-hr-lag-time, fuel-moisture stick has proven to be the best indicator of when a unit's fuelbed is in prescription and how it will burn. These sticks are produced to set standards, using wood with known attributes for absorbing and evaporating water. The stick "index" is based on the percentage of its weight comprised of water, so a "stick of 8" is 8 percent water. Large areas covered for burning by NEPA documents provide considerable flexibility. With many acres covered on different aspects and elevations, usually one or more can be selected and burned when conditions are appropriate.

We generally do not apply cut-off dates for burning, as weather patterns fluctuate widely from year to year. For example, burning in 1997 was curtailed by mid-May because conditions were too dry but, in 1998, we could not begin burning until June because of a wet spring, and burning continued into August that year.

Restricting burning to seasons that are thought to have been "historical burning seasons" (summer-fall) has several disadvantages, particularly high smoke emissions and potentially severe fire effects. Because of the heavy fuel

loads in the southern Sierra Nevada, burning in the summer and fall months, when fuel moistures are low, can cause unacceptable resource damage. Flame lengths are apt to be longer and scorch heights higher in the trees than desired. Complete consumption of snags and downed logs is more probable. Soils are more likely to be adversely affected over a larger area. The chance of spot fires, which can turn a controlled burn into an uncontrolled wildfire, is higher at that time of year. In addition, often the Sierra National Forest's fire suppression resources are at minimum levels (draw down) due to fire suppression activities in other areas of California.

Members of the burn crew are instructed to not attempt ignition over every square foot of the burn. For example, wildlife logs and snags are not intentionally ignited. Ignition does not occur in riparian areas, although fire is allowed to back through them on its own, within prescription. To maintain roadside screening for wildlife, burns are generally not brought down to roads, but they are allowed to back down and go out naturally. Unburned patches are left throughout a burn. If an area will not burn for whatever reason, burners do not waste time trying to ignite it. These patches may burn out eventually when burning is done during a drying trend. To assure no risk of escape, burns must be patrolled until smoke has not been noted for several days. The patrolling phase of a burn may last longer than the ignition and holding phases.

Underburns are done with as few fire-fighting resources as possible. Maintaining unneeded personnel and equipment on standby at a burn, to serve as a security blanket, is costly. Moreover, too many firefighters carrying torches on a burn may lead to rapid ignition and undesirable fire effects. The burn plan calls for a minimum staffing level, leaving it up to the burn boss to add forces as needed. This does not mean that burns are understaffed, as we have experienced no escapes of any consequence. We have learned, however, that fewer lighters improve the quality of burns, as the fires are often just tended. Add more lighters to lengthen the fire line but not to speed ignition.

In January, it is not uncommon to have two or three burns active with two or three people and maybe a patrol truck on each burn. In May or June, however, two or three fully staffed wildland engines and patrols stay out until after sundown on each burn. Depending on wildfire activity and the Forest's ability to maintain an aggressive initial attack force, several burns may be active simultaneously. The bottom line is simply common sense: burns are staffed adequately in direct relation to fire and weather conditions.

Strategy and Tactics

The San Joaquin Valley, which is downslope from the Sierra National Forest, is in nonattainment regarding the Clean Air Act, with mid-August to mid-November being the worst period for air pollution in the valley (Guerra, pers. comm.; Martinez, pers. comm.). Acceptable burning periods do occur during the summer and fall months, but they are typically too short to implement slow underburning in conifer forest types, where only about 50 acres of underburning can be completed in a day. However, burn windows then are adequate for short-duration burns in chaparral, where it is possible to complete a 1,000- to 2,000-acre burn in one day. Moreover, we have learned that chaparral on the District does not burn well, if at all, in any season except summer and fall. A complete cycle of two cool-weather burn entries, or a mechanical treatment coupled with a cool-weather burn, needs to be done before it is feasible to ask the Air Regulators to accept long-duration underburning in the summer or fall.

Burn plans typically call for meeting resource management objectives with multiple entries. It is not necessarily the intent of the prescribed fire program to meet all objectives in one entry. Repeated burns allow burning at cooler prescriptions, consuming a little more of the fuel profile each time and increasing

the distance between the ground and tree crowns. This is safer, results in fewer escapes, requires fewer firefighters, and costs less. Lower burn intensities allow ecosystems to change over a longer period of time and have less impact on wildlife, allowing them to move easily out of the way of slow-moving fires. Multiple entries reduce fuel loads over a longer period of time, producing less smoke per burn entry. Finally, repeated entries allow more time to monitor the effects of the burns so that managers are better able to learn from their experience.

Once a burn has been completed on a unit, it is scheduled for reentry in 3 to 5 years. This not only kills freshly sprouted shrubs (Biswell 1989) but also reduces the fire-caused accumulation of dead woody fuel from the first burn entry (Mutch and Parsons 1998). It is clearly a waste of time, money, and effort to burn once and not come back to reburn at an appropriate interval.

Burning in winter and early spring months is an on-again-off-again proposition. Careful monitoring of weather stations, consultation with meteorologists and air regulators, and frequent visits to the burn site are needed to assure that burn windows are not missed. As the drying trend begins in spring, burn windows become more consistent, and possibilities develop to burn on cooler aspects and at higher elevations. As one unit goes out of prescription because of dryness, another on a different aspect or at a different elevation comes into prescription.

Ideally, underburns have slow rates of spread. On first-entry burns, it is common to burn only 10-50 acres per day. Second-entry burns will burn two to three times faster because the reduced canopy cover allows more sunlight on the forest floor, resulting in drier ground fuels and higher fuel temperatures.

Strip-head ignition patterns are used when a fire will not back downhill by itself (*fig. 2*). This creates small uphill runs of 50-100 ft, depending on strip width, but long uphill runs do not occur because the fire is constantly burning either into a control line or into a previously burned strip. Fire intensity and flame length are controlled by the width of the strip. If the fire spreads downhill, we allow it to do so and make additional ignitions only along control lines. Often the best burn results occur when a fire burns downhill on its own, with little or no additional igniting from the burners. This is more typical with second- or third-entry burns (*fig. 3*), when fuel loads are considerably reduced (*fig. 4*).

Not all fire managers accept this style of burning. The thought of having a fire burn through the woods for several weeks at a time is unsettling to them, especially when a burn window occurs during fire season. Consequently, we believe that confidence, patience, and experience with underburns are significant traits to look for in burn bosses and lighters. The success of a burn is in the hands of the drip-torch operators, just as the success of a silvicultural prescription is in the hands of the tree markers (Hurley, pers. comm.)



Figure 2—First-entry burn on the west-facing slope of Patterson Mountain, Dinkey Creek Watershed, January 1998. The burn was aerially ignited using a strip-head ignition pattern, starting below the snow line and proceeding downhill. Snowfall on the third day suppressed the burn.

Figure 3—Second-entry burn on Patterson Mountain, Dinkey Creek Watershed, December 1999. This burn was aerially ignited at the top of the unit and allowed to burn downhill on its own. Some hand ignition was done to maintain a straight line of fire across the slope. This ignition pattern, together with the reduced fuel loads left after the first burn, helped control fire intensities. This burn was suppressed by precipitation on 15 January 2000.



Figure 4—Results after the second-entry burn on Patterson Mountain, Dinkey Creek Watershed, photographed in May 2000. A third-entry burn is planned for sometime between 2008 and 2012.



Results: Lessons Learned and Some Indicators

From 1994 through 2000, we were able to burn substantial acreages during January in 4 years—200 acres in 1994, 200 acres in 1997, 1,400 acres in 1998, and 2,500 acres in 2000. Obviously this burning is low intensity. It occurs on south- and west-facing slopes and usually at elevations below 5,000 ft. Pine needles and bear clover (*Chamaebatia foliolosa*) burn, as do the 1- and 10-hr time-lag fuels. These fuels create enough heat to break the bark on whiteleaf manzanita (*Arctostaphylos viscida*), which successfully kills the stem. Flame lengths are typically 18 inches or less. Duff, medium to large logs, and snags are rarely totally consumed, although large stumps will completely burn out. Readers need to keep in mind the location of the Kings River Ranger District, its climate, and its vegetation types, as some of our results are not likely to apply everywhere.

Our burns have cost about \$70 per acre. The few burns that escaped cost twice that amount. One project in January, involving a helicopter equipped with a chemical ignition device (CID) and five personnel, underburned 1,400 acres in 2 days and cost \$6.50 per acre. Ignition occurred 2 days before a predicted storm, which arrived on time. By burning during the moist seasons, little to no mop up is needed, resulting in a significant cost savings.

For our first underburn in 1994, we used a fuel-moisture stick index of 8 as too dry to burn safely. With more experience, however, we learned that acceptable burning can be accomplished at readings of 7 and even 6. In mixed-

conifer forest, the prescription on the dry end now allows for a stick of 6 on south and west aspects. A prescription using a stick of 8 was validated to help protect white fir (*Abies concolor*) stands that are predominantly on north- and east-facing aspects, because white fir is less fire tolerant than the pine found on hotter aspects. Prescription burns are not feasible with fuel-stick values of 12 or 13—conditions are simply too wet. Lighting a strip at the top of a burn area when the fuel-stick value was 8 allowed us to get a fire to back downhill by itself through bear clover and pine needles. When sticks get to 6, watch the burn like a hawk and consider putting it out if it goes below 6 for much of the day. This will probably occur in late spring or early summer and last for a day or two. It may be prudent not to conduct ignitions at this time and to patrol for a few days until the weather changes. It is possible to get fuel-stick readings of 6 or below in the winter months of some years.

Flame length is the key indicator of fire effects above the ground on trees and brush. Our prescriptions allow for flame lengths of about 4 ft. Combined with other prescription parameters, this equates to scorch heights at about 20 ft, meaning that it is acceptable to kill everything below 20 ft. This occurs at the hot end of the prescription, but underburns are seldom ignited at this end. Usually the hot end is reached, if at all, only after several weeks of burning, and most of the burning occurs at the lower intensities. It is common to have flame lengths of 18 inches or less over the majority of a burn. Higher flame lengths occur in patches of slash and insect kill, where the intent is to have 4-ft flame lengths and 20-ft scorch heights so that those patches will be consumed. If the unit is burning with consistent flame lengths of 4 ft, however, it is probably too intense and needs to be put out or the ignition pattern altered.

An inventory of the brush on the Barnes Mountain Underburn showed that 33 percent of the area was covered in brush before the burn. The initial underburn left only 16 percent of the area still covered by brush (*table 1*) (Ballard 1998).

The desired condition for vegetation taller than 6 ft ranges from 5 to 20 percent of the area covered, which is intended to provide hiding cover and forage for wildlife, minimize fuel ladders, and maintain growth of seedlings and saplings. *Table 1* may suggest that the desired condition has been met with the first burn entry, but it is important to understand that the vegetation described in

Table 1—Percent cover and height of various species of shrubs before and after prescribed underburning in the Kings River Sustainable Forest Ecosystems Project Area

Species	Percent cover		Mean height (feet)	
	Preburn	Postburn	Preburn	Postburn
<i>Arctostaphylos mariposa</i>	26.89	10.55	10.60	10.80
<i>Arctostaphylos mewukka</i>	0.14	0.14 ^a	5.80	(¹)
<i>Ceanothus cuneatus</i>	3.66	3.45	8.10	8.10
<i>Cercocarpus betuloides</i>	1.93	1.21	10.30	9.90
<i>Ceanothus integerrimus</i>	0.38	0.17	9.10	9.00
<i>Rhamnus californica</i>	0.13	0.10	6.70	6.30
Totals	33.13	15.62	8.40	8.76

¹ Fire top-killed the shrubs; all resprouted.

the desired condition includes all vegetation, not just brush. A second fire entry is needed to kill off new obligate seeders and to avoid an over-abundance of brush by the third entry. At some point in the near future, conifers should begin to fill space now occupied by brush.

The color and amount of ash are indicators of fire effects on the soil and root systems. The Sierra National Forest's Land and Resource Management Plan specifies that most of these burn units should retain 50 percent ground cover. In the present case, we defined ground cover as any vegetative material (duff, dead limbs, trees, burned stems, etc.) that will break the fall of a rain drop before it hits the dirt. Commonly lower portions of the duff layer are retained after an underburn, but this depends to a large extent on the season of the burn, which influences the moisture content of the duff layer. Burning in January removes the litter layer but retains most or all of the duff layer. A fire then usually makes one run over the area, barely penetrating the duff layer. On the other hand, when the duff layer is in a drying trend, as in May and June, burns will make an initial pass over the area and smolder in a log or in the duff until the duff has dried out sufficiently to allow the fire to smolder through the area again, and again, until remaining fuel is insufficient to carry the fire another time. This process has been repeated up to three times on some burns in early summer. Because it can cause holding problems if the burn is not patrolled properly, this problem should be anticipated.

If the fire quickly passes through each time, the ash will be black, indicating low-intensity, short-residence time, and resulting in little if any damage to the soil or tree roots. If the fire smolders through the area, burning from the top of the duff to the soil, the ash will be white and the soil will be reddish brown and powdery. The soil may have been damaged and feeder roots on large trees may have been killed (Sackett, pers. comm.). Deep white ash is an indicator of high heat areas. This occurs on many burns, especially as the drying trend continues and/or in areas where large fuel accumulations burn out. This should be expected and monitored to determine whether the burn is meeting management objectives.

Postscript

The prescribed fire component of the Kings River Sustainable Forest Ecosystems Project is moving ahead rapidly and yielding much useful information. Although we are experiencing some resistance to the program as a result of Air Pollution Control Standards, our working relations with the local Board have been excellent, and the public has generally supported our efforts. This is a result of regular, open communication among groups and a growing realization by the public that unnatural levels of fuels have accumulated in Sierran forests and need to be reduced. Indeed, we expect the full scope of the management proposed for the Kings River Project to benefit all resources—water and watersheds, wildlife, air quality, recreation, timber supply, and so on. We must continue efforts to inform and educate the public about the need to strike a balance between full fire suppression and fuels management if we expect to attain our ultimate objectives.

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References

- Ballard, Keith E. 1998. **Surveying vegetation on the Barnes Mountain underburn.** Prather, CA: Kings River Ranger District, Sierra National Forest, Forest Service, U.S. Department of Agriculture; 3 p. [Unpublished internal report.]
- Bertram, Ronald C.; Ashcraft, Gordon C.; Cook, William P. 1978. **Prescribed fire to generate mountain whitethorn.** Fresno, CA: California Department of Fish and Game; 13 p. [Unpublished internal report.]
- Biswell, Harold H. 1989. **Prescribed burning in California wildlands vegetation management.** Berkeley, CA: University of California Press; 255 p.
- Drumm, Mary K. 1999. **Fire history of the mixed conifer series in Kings River adaptive management area, Sierra National Forest, California.** Arcata, CA: Humboldt State University; 32 p. M.S. thesis.
- Eaton, Jack. 1978. **Hoffman, Brush Meadow, Patterson Mountain, Hall Meadow, burning plans.** Prather, CA: Kings River Ranger District, Sierra National Forest, Forest Service, U.S. Department of Agriculture; 47 p. [Unpublished internal report.]
- Guerra, Hector. 1995. Environmental Planner, San Joaquin Valley Air Pollution Control District, Fresno, CA. [Personal communication]. September 1995.
- Haase, Sally M. 1998. Research Scientist, Pacific Southwest Research Station, USDA Forest Service, Riverside, CA. [Personal communication]. August 1998.
- Hurley, Jerry. 1999. District Fire Management Officer, Mt. Hough Ranger District, Plumas National Forest, Quincy, CA. [Personal communication]. January 2000.
- Martinez, Jose. 1995. Senior Air Quality Inspector, San Joaquin Valley Air Pollution Control District, Fresno, CA. [Personal communication]. September 1995.
- Mutch, Linda S.; Parsons, David J. 1998. **Mixed conifer forest mortality and establishment before and after prescribed fire in Sequoia National Park, California.** *Forest Science* 44: 341-355.
- Sackett, Steven S. 1998. Research Forester. Pacific Southwest Research Station, USDA Forest Service, Riverside, CA. [Personal communication]. August 1998.

