# Fuel Reduction Guide for Sierra Nevada Forest Landowners

## University of California Cooperative Extension

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***INSIDE THIS GUIDE***



## *The Problem*

**Figure 1. Sierra mixed conifer forest with a hazardous buildup of fuels.**

California's forests have evolved with fire. However, fire suppression along with past forest harvesting techniques have led to the dramatic build up of forest fuel, causing more intense wildfires that are more difficult to manage and prevent. Intense wildfires threaten both homes and the environment and degrade watersheds and wildlife habitat (see Figure 1).

Aggressive fire suppression drastically reduced the frequency of natural fires and the annual area burned throughout the West during the 20$^{th}$ century. A study in the Northwest found that only about 3 percent as much mixed conifer forest burned in the 20$^{th}$ century as in the period before European settlement. Only 10 percent as much red fir forests and 2 percent as much blue oak woodland burned as previously. Areas not burned have accumulated greater flammable

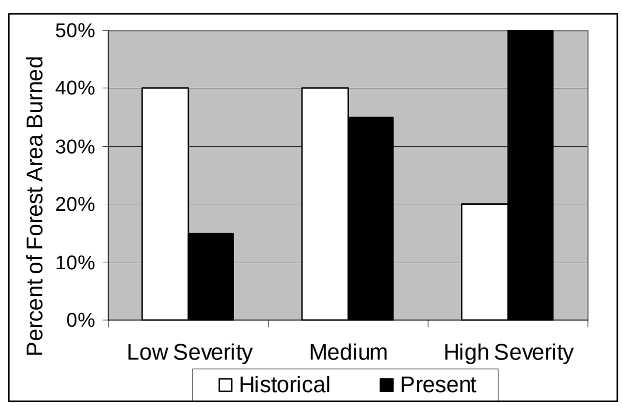


**Figure 2. Current and historic wildfire intensity in the inland Northwest before 1900. Source: Graham et al 2004.**

fuel, causing wildfires that do burn to be more destructive. Before 1900, only 20 percent of wildfires in the Northwest burned at high intensity compared to 50 percent today (See Figure 2).

**Figure 3. Hazardous fuels around a home. Source: Jerry Hurley.**

This trend of increasing fuel loading and fire intensity is occurring in California at the same time as human population in forested areas has been increasing dramatically (see Figure 3).

The population of the Sierra Nevada more than doubled between 1970 and 1990 to 650,000 and is expected to triple between 1990 and 2040 (SNEP 1996). As the number of residents has increased, rural parcels have increased in number and decreased in size. Recent research in Nevada County (Walker et. al. 2003) showed that 85% of rural landowners were new to the county in the last 35 years, and that the median size of rural parcels decreased from 550 acres to 9 acres. Furthermore, rural parcels were found to be more densely vegetated than in the past. Landscape quality was the reason over half the landowners came to the area and many were encouraging re-growth of vegetation on their property.

These trends taken together indicate an increased risk of severe wildfire to a growing population. However, there are steps that can be taken to reduce this risk. Fuel treatment techniques described here can successfully limit the extent and intensity of wildfires. Individual landowners need to work together to best reduce the risk to property and communities. A recent study estimated that nearly 100 million acres of forest lands in the Western United States could benefit from restoring occasional surface fires. Over 66 million acres could benefit from mechanical fuel reduction. Another 11 million acres need fuel treatment to protect adjacent communities from wildfire (Graham et al 2004).

This guide is designed to aid landowners in the Sierra Nevada to lower the risk of wild fire on their forested property. It is aimed at residents who own forested parcels of at least an acre in size. The goal of this guide is to help landowners better understand basic fire ecology and how to modify forest fuel to minimize the risk of destructive crown fires on their property.

*Changes in Fire in Sierran Forests*

Fire frequency, extent, intensity, severity, and seasonality have a great impact on the vegetation that grows in the forest. Before European settlement, fires in most lower-elevation oak woodland and conifer forests of the Sierra Nevada were frequent, covered large areas, burned for months at a time, and were primarily low to moderate in intensity. Dendrochronology studies of fire frequency, known as the fire return interval, have shown that each acre of mixed conifer and ponderosa pine forests burned every 11 to 15 years, on average (See Table 1). In contrast, it may now be almost 200 years before each acre of this forest type burns as a result of fire suppression. During this time, forest fuel continues to accumulate.

**Table 1. Fire Frequencies in Sierra Nevada Forests. Source: SNEP 1996**

| Forest Type | Fire – Return Interval (Years) | |
|---|---|---|
| | Pre-1900 | $20^{th}$ Century |
| Blue oak | 8 | 78 |
| Ponderosa pine | 11 | 192 |
| Mixed conifer-pine | 15 | 185 |
| Mixed conifer-fir | 12 | 644 |
| Red fir | 26 | 1,644 |

**Figure 4. Ponderosa pine with a healed scar caused by frequent, low-intensity fire**

Early accounts of Sierra Nevada forests suggest that the structure was more open. In 1853, William Blake, a geologist, noted the absence of understory vegetation that allowed views of considerable distance on each side of the road while traveling from Yosemite to the Calaveras Grove of Big Trees. In 1894, John Muir described the inviting openness of the mixed-conifer forest as one of their most distinguishing characteristics. Muir wrote that *"The trees of all of the species stand more or less apart in groves, or in small irregular groups, enabling one to find a way nearly everywhere, along sunny colonnades and through openings that have a smooth, parklike surface"*.

Frequent fires cleared low growing brush and vegetation, consumed litter and downed and dead trees and thinned out new seedlings and saplings as well as standing trees. Frequent fires created fairly open forest stands with enough sunlight reaching the forest floor which favored the growth of shade intolerant trees, such as pines. Pines have thicker bark and thus are more fire resistant than shade tolerant trees such as white fir (Figure 4). Stands that are open, with a small number of larger trees, are more resistant to insects and disease. Available fuel was burned more frequently, meaning that although fires were frequent, they were of low intensity, burning mostly along the forest floor, with low flame height. The resulting forests were much more open in many locations (Figure 5).

In contrast, forests in which fire has been removed have vastly increased fuel accumulation, leading to more intense fires that often consume or kill all vegetation including the standing trees. Over time forests become overcrowded with smaller shade tolerant trees that are more susceptible to fire but are not killed because fires have been excluded (Figure 6). These overcrowded forests are more likely to succumb to insects and disease because individual trees, with limited access to sunlight and water, are not as vigorous. Accumulated dead trees and shrubs increase the amount of fuel for wildfires, making it more likely that fires that do burn will be of high intensity and will damage or destroy more trees (Figure 7).

**Figure 5. East Branch North Fork of the Feather River under snow, 1890. Source: Gruel 2001.**

**Figure 6. Same Feather River location in 1993. Note the vast increase in vegetation cover over the 100 year period. Source: Gruel 2001.**

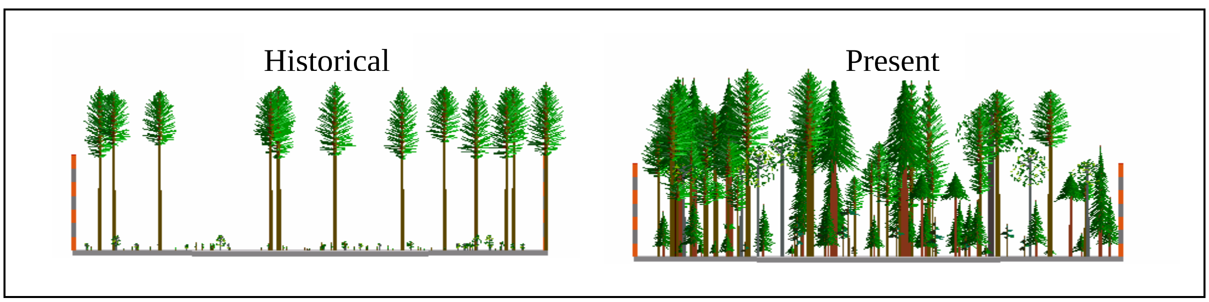


**Figure 7. Changes in vertical arrangement and horizontal continuity in forest fuels. Source: Morris Johnson, PNW Research Station.**

The intensity and severity of a fire, how hot a fire burns and the impacts it has, is determined by many factors besides fuel loading, although fuel accumulation is the only component that can be controlled by landowners. Uncontrollable factors include season, topography, wind speed and direction, air temperature, and humidity. Fires that ignite under extreme weather conditions such as high winds and very low humidity are much more likely to become high-intensity crown fires than those started under cool, moist and calm conditions. This is especially so when fuel has accumulated for more than one to two fire return intervals.

The intensity at which a fire burns can be categorized by its flame length. The longer the flame length, the more vegetation will be consumed, and the greater the impacts of the fire. However, since wildfires often involve large areas in which flame length differs based on site conditions, most large wildfire events actually include a combination of fire intensities over their geographic extent.

**Figure 8. Low intensity surface fire burning along forest floor**

*Surface fires* are low intensity fires with short flame lengths (under about 3 feet), fed by ground and surface fuel with relatively low ignition temperatures that burn quickly (Figure 8). They can usually be controlled fairly easily by fire fighters constructing fire line with hand tools around the fire. Prescribed fires, also called controlled burns, are usually surface fires. Surface fires consume surface fuel and so temporarily reduce the likelihood of future surface fires turning into crown fires. Individual trees may occasionally be killed if their needles are scorched.

*Under story fires* have longer flame lengths, up to about 10 feet. These fires are fed by larger surface fuel. They consume surface fuel as well as small trees and shrubs in the under story. Fire fighting equipment is generally needed to successfully suppress these fires. In areas with plentiful ladder fuel, these may transition into destructive crown fires.

**Figure 9. High intensity crown fire approaching a forest community. Source: Jerry Hurley.**

*Crown fires* are the most intense, reaching into the crowns of trees. When the fire moves into the crowns of the trees it is often said to be crowning. Flame lengths can be greater than 10 feet (Figure 9). The behavior of crown fires can be unpredictable and very difficult to control. Fire can spread from tree crown to crown without touching the ground by means of floating embers. These fires can jump fire lines and quickly increase in size. Crown fires begin with a transition from a surface or under story fire to the ignition of the canopy. They are therefore dependent on the sequence of available fuel, also known as the fuel profile.

High intensity crown fires alter a forest for many decades. Probably most important to forest residents is the visual impact. In fires where most trees have been killed, it may take 40 years or more for new trees to grow to a size that will provide shade and a “forested feeling”. Soil is sometimes so severely burned that it has less water holding capacity, causing more precipitation to runoff. This can cause soil erosion which carries away productive topsoil and clogs streams with large volumes of sediment, degrading habitat for fish and aquatic species.

### *The Fuel Profile*

The primary objective of fuel management projects should be to reduce the potential for destructive crown fires. To do this, projects must reduce the volume of surface, ladder and crown fuel and create horizontal and vertical separation between them. Fuel beds can be classified into strata depending on their location: 1) surface fuel 2) ladder fuel 3) crown and/ or aerial fuel.

*Surface fuel* includes all dead and down woody material, grasses and short shrubs which are often the most hazardous fuel in many forests. Deep layers of continuous surface fuel are often found in forests that have not experienced fire for several decades, with large accumulations near the bases of large trees. Moss, lichens, and litter have high surface area and when very dry can facilitate the spread of surface fire. Woody fuel (sound and rotten logs, stumps and wood piles) can easily ignite under dry windy conditions leading to under story and crown fires. Surface fuel is most often removed by burning or by mastication.

*Ladder fuel* includes small trees or tall shrubs that provide a path for a surface fire to climb up into the crowns of shrubs or trees. These include live trees with branches reaching to the ground, saplings growing under taller trees, and standing dead trees. Removing ladder fuel should be the first priority of fuel treatment projects. Thinning and pruning are good ways to remove ladder fuel.

*Crown fuel* includes fuel that is not in contact with the ground such as limbs, foliage, and branches of the living tree canopy and any dead needles caught up in the branches of other plants. Aerial fuel can be reduced by thinning the tree canopy so that the live branches of individual trees do not touch or overlap each other.

### *Creating Fire Resistant Forests*

Fire resistant forests combine fire resistant tree species suitable to a site in a spatial arrangement that discourages surface fires from climbing into the tree canopy. Overcrowded forests can be made more resistant to fire by reducing surface and ladder fuel, increasing the height of the base of the canopy, decreasing the crown density, and removing smaller trees while retaining larger more fire resistant trees (See Table 2).

**Table 2. Principles of Fire Resistant Forests adapted from Agee 2002 by Graham et al 2004**

| Recommendation | Physical Effects | Fire Advantage | Concerns |
|---|---|---|---|
| Reduce surface and ladder fuel | Reduces potential flame length | Fire control easier, less torching | Surface disturbance less with fire than other techniques |
| Increase canopy base height | Requires longer flame length to ignite tree crowns | Less torching | Opens under story, may allow surface wind to increase |
| Decrease crown density | Makes independent crown fire less probable | Reduces crown fire propagation | Surface wind may increase, surface fuel may be drier |
| Retain larger trees | Thicker bark and taller crowns | Increases survivability of trees | Removing only smaller trees is economically less feasible |
| Retain fire resistant tree species | Promotes trees most likely to survive fires | Reduces mortality from future fires | Repeated treatments may be necessary to promote desired trees |

With any fuel treatment, it is important to identify short- and long-term management goals before proceeding. An assessment should be done to determine the level of fire hazard from surface, ladder and aerial fuel, and determine the level of risk the fuel poses. The treatment should be designed to mitigate that particular risk by treating the appropriate component of the fuel profile. Any treatments should make sure not to increase surface fuel load by leaving behind slash (tree branches and needles from trees that have been removed). In forests that have not experienced fire for many decades, multiple fuel treatments including mastication and prescribed fire may be required to significantly affect crown fire hazard under extreme weather.

In a fire break, all vegetation is removed down to bare soil leaving nothing left to burn. Fire breaks are generally a minimum of three feet wide used to control low-intensity fires (hand lines) to much wider lines created by bulldozers and used to contain large fires. Often these are strategically placed along ridges. Roads may function as effective fire breaks.

*Shaded fuel breaks* or *defensible fuel profile zones* (DFPZs) are strips of land in which vegetation has been modified, but not entirely removed (Figure 10). The purpose is to reduce the amount of combustible material so that when a fire reaches the shaded fuel break, it will decrease in intensity, burn less hot, and drop from the canopy to the ground. Typically trees are spaced so their crowns no longer touch. Lower branches are pruned. Shrubs and dead and down material are removed to reduce surface fuel. Not all small trees need to be removed but care should be taken to create horizontal space between small trees and nearby larger trees. Shaded fuel breaks are most often placed strategically along ridges, roads and around communities. Fuel breaks give fire fighters a location from which to control a fire, but they may not be effective at stopping a wildfire when extreme fire weather with high heat and wind and low humidity may cause fires to jump fire lines. Treating all elements of the fuel profile throughout the entire forest parcel by thinning increases the chances of tree survival during extreme fire conditions.

**Figure 10. A shaded fuelbreak created along a road to improve the chances of controlling wildfire. Source: Jerry Hurley.**


**Figure 11. The Greater the distance between surface fuel (A) and the base of tree crowns (B), the more difficult it is for surface fires to become crown fires. Source: Graham et al 2004.**

*Thinning* involves removing individually selected live trees to reduce density and continuity of fuel. *Thinning from below* means removing only excess smaller trees while leaving larger and more fire resistant trees. The trees that are left will occupy a healthier, more open and vigorous stand with less competition for sunlight, water, and nutrients. This decreases their susceptibility to mortality from insects and disease and increases their growth and likelihood of surviving low intensity fires.

Used alone, especially emphasizing the smaller trees and shrubs, thinning can be effective in reducing the vertical fuel continuity and ladder fuel that fosters crown fires (Figure 11). However, by itself, thinning does little to affect surface fuel unless it is accompanied by burning, crushing or masticating. Thinning may also add to surface fuel unless whole trees are removed and residual slash is removed from the stand or otherwise treated.

*Mastication* treats surface and ladder fuel by chopping and grinding them with a mechanical grinder using a wheeled or tracked machine with a specialized cutting head (Figure 12). The fuel is not removed, but its size is reduced, and it is rearranged to be in contact with the ground where decomposition can occur more quickly (Figure 13). A masticated area may result in flame lengths of less than 4 feet when weather conditions are not extreme. Prescribed fires usually burn well after mastication because it leaves a continuous layer of surface fuel and reduces ladder fuel. It is limited to gentle terrain with a slope under 30%. Mastication is very effective for control of non-sprouting brush and is an alternative to using herbicides. Another benefit of mastication is that it discourages regrowth of plants and trees because accumulated chips form a physical barrier to establishment of new plants. In addition, the accumulated fuel is flammable until they adequately decompose.

*Grubbing* involves removal of stumps and root wads from the ground by hand or by using heavy equipment.

**Figure 12. Rotary masticator on a skid-steer**

**Figure 13. Ground disturbance after mastication. Source: Jerry Hurley.**

*Pruning* involves removing the lower (live and dead) limbs of a tree to reduce ladder fuel. It may be done alone or in combination with a thinning (Figure 14). It is very labor intensive and so is most frequently done in small areas alongside roads to increase the effectiveness of the road as a fuel break. It is most commonly done using loppers or power limbing saws. Hand shears, saws or clippers may be used when more care is required. Lower limbs should be pruned to a height of 15 to 20 feet. Care should be taken to not remove more than 50 percent of the live crown length.

Conifer limbs should be cut flush against the bole so healing will occur quickly. Hardwood pruning should not remove the branch collar. Pruning also causes trees to grow wood that is free of knots, improving the wood quality and commercial value. Pruning for wood quality should be done along the first 16 feet of the bole.

**Figure 14. Pruned off branches from this ponderosa pine stand will be stacked and burned.**

*Fire Resistant Tree Species*

Trees (and other vegetation) differ in their ability to withstand fire (See Table 3). Bark thickness is very important because it protects the living cambium, just below the bark, from destruction due to excessive heat from fires. Bark thickness increases with tree age and size and it varies with tree species. For example a mature ponderosa pine will have thicker bark than a white fir tree. However, a small, young ponderosa pine will have bark that is thinner than one that is mature and large.

A deep rooting habit is also protective. A tree with many shallow roots is vulnerable to its roots being charred in hot fires when ground temperatures rise significantly. Trees that create dense canopies tend to trap heat, causing vegetation to become drier and easier to ignite. Trees with flammable foliage and branches growing close to the ground increase the chances that a passing surface fire will become a crown fire.

Both white fir and incense cedar are shade tolerant. By being more tolerant of shade than associated pines, their lower limbs will continue to live rather than dying and breaking off or "self-pruning". Because the lower limbs live longer, the height to the base of the live crown is lower. The longer crowns, which can often be near the ground, can create a fuel ladder.

**Table 3. Fire resistance of Sierra Nevada Tree Species, adapted from Agee 1993.**

| Species | Bark thickness | Rooting habit | Branching habit | Canopy cover | Foliage flammability | Most vulnerable to |
|---|---|---|---|---|---|---|
| Douglas-fir | Very thick | Deep | High and dense | Dense | High | Crown fires |
| Lodgepole pine | Very thin | Deep | Moderately low and open | Open | Medium-low | Scorching cambium, crowning |
| Ponderosa pine | Thick | Deep | Moderately high and open | Open | Low | Crown fires |
| White fir | Medium | Shallow | Low and dense | Dense | Medium | Root char, |

| Species | Bark thickness | Rooting habit | Branching habit | Canopy cover | Foliage flammability | Most vulnerable to |
|---|---|---|---|---|---|---|
| | | | | | | crown fires |
| Sugar pine | Thick | Moderately deep | Moderately high and open | Open | Low | Crown fires |
| Black oak | Thick | | Moderately high and open | Open | Low | Crown fires |
| Jeffrey pine | Thick | Deep | Moderately high and open | Open | Low | Crown fires |
| Incense cedar | Thick | Moderately deep | Low and dense | Dense | High | Root char, crown fires |

Fuel treatment prescriptions should take into account the natural resistance of tree species to fire. Thinning should prioritize the removal of more susceptible species and retention of more resistant species that are adapted to the site. In the Sierra, this frequently means removing a high concentration of less resistant white fir, and promoting the more resistant pines, including ponderosa, Jeffrey, and sugar pines.

*Fuel Management Methods*

Accomplishing your fuel management objective on the ground is fairly straight forward, although it can be time consuming, labor intense and expensive. A variety of treatment methods are available using hand labor, equipment (light or heavy), chemicals, or animals.

**Figure 15. Manual fuels treatment using a chainsaw.**

**Figure 16. This feller buncher, mounted on a skid-steer, grasps a tree and cuts it using a circular saw blade.**

*Manual fuel treatments* clear or prune herbaceous and woody plants without the use of heavy equipment. Instead, hand tools such as hand saws, axes, shovels, rakes, and loppers and power tools such as chainsaws and brush saws are used (Figure 15). Root systems of sprouting species may be dug out to prevent subsequent sprouting and regrowth. Manual treatments cause less impacts to soil, water quality and sensitive vegetation than mechanical or biological treatments and can be used on steep slopes where mechanical treatments are limited. However, manual treatments are usually more costly.

*Mechanical fuel treatments* remove live and dead fuel using wheeled or tracked equipment and specially designed vehicles with attached implements, such as the feller-buncher (Figure 16). Mechanically treated material may be left on site or removed. Both manual and mechanical treatments may be used alone or be followed by the burning of debris piles or

**Figure 17. This small tree processor delimbs and cuts trees to the desired length.**

prescribed burning of the treatment site.

Mechanical methods are typically more cost-effective and less labor intensive than manual methods and so are more practical for large scale treatments. They can also produce forest commodities such as saw logs or chips that can be used to offset treatment costs (Figure 17). However, mechanical treatments may disturb more soil and so can cause erosion, stream sedimentation, and an increase in root pathogens if not managed properly. Small Skid-Steer equipment has been used very effectively to treat small parcels causing very little disturbance.

*Chemical fuel treatments* involve the application of chemical agents to kill or restrict the growth of existing vegetation. They are predominantly used to reduce the distribution of non-native, invasive, and/or exotic species, and to maintain fuel treatments once completed. Chemical treatments are almost always followed by another treatment such as prescribed burning or planting of desired vegetation. Chemical treatments can be implemented quickly but they have the potential to impair water quality.

*Biological fuel treatments* involve the use of grazing animals such as cattle, horses and goats to selectively suppress, inhibit, or remove herbaceous and woody vegetation (Figure 18). Using animals requires proper management to prevent overgrazing, soil erosion, and reduction in sensitive plants. Animals must be contained by fences and have access to water sources. If fences already exist on the property, treatment can be very inexpensive. Use of animals can be a viable alternative to chemical use for maintaining fuel treatments.

**Figure 18. Goats grazing on underbrush and reducing hazardous fuels. Source: Walter Herzog, BLM.**

Goats will graze in areas and eat non-palatable species that cattle and horses will not. They typically prune the under story to 4 feet above the ground, but they do not remove or kill woody vegetation. They can be used after other techniques to retard brush regrowth and are not restricted by slope steepness. However, they may require food supplements and protection from predators.

*Prescribed fires* are fires started to accomplish a specific purpose, usually to reduce ground and surface fuel. Fires are started only under prescribed weather conditions to minimize the risk of escape. Prescribed fire is a useful tool that can effectively reduce loading of fine fuel, duff, large woody fuel, rotten material, shrubs and other live surface fuel. However, prescribed fires may not be safe to use where dense ladder fuel exists, as the risks of crown fires would be too great. In this case, removal of ladder fuel should be done first. Trained fire management personnel should be involved when conducting a prescribed fire because of the dangers inherent in this fuel treatment.

*A Mechanical Thinning Project Example*

The photos below show two stands in the Lassen National Forest in 2002 before (Figures 19 and 21) and after thinning (Figures 20 and 22). Treatment consisted of mechanical thinning of smaller trees leaving the largest and healthiest behind. Note that most of the larger trees remain after the treatment. 82 percent of trees removed were less than 10 inches in diameter and 98 percent were less than 20 inches (Figure 23). Canopy cover was reduced by an average of only 24 percent.

**Figure 19. East side mixed conifer stand, Lassen National Forest May 2002.**

**Figure 20. Same stand in August 2002 after mechanical treatment. In addition to small trees, an average of 3 trees over 20” in diameter per acre were removed.**

Figure 21. East side pine stand, Lassen National Forest, May 2002.

Figure 22. Same stand in August 2002 after mechanical thinning. An average of 135 trees under 10” in diameter per acre were removed.

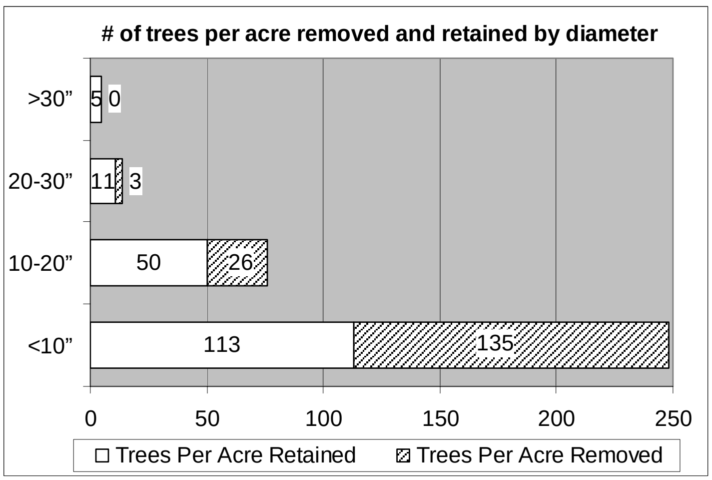


**Figure 23. Tree removal and retention on the Lassen National Forest's Bridge Project, 2002.**

*Fuel Treatment Effectiveness*

A recent study at the UC Blodgett experimental forest in the Sierra Nevada (Stephens and Moghaddas 2005) showed that any fuel treatment technique reduced the risk of trees dying in future wildfires when compared to taking no action. Researchers conducted different combinations of fuel treatments (thinning, thinning and prescribed fire, and prescribed fire alone), characterized the remaining fuel load, and then used fire simulation computer software to predict how many remaining trees would be killed under moderate, high and extreme weather conditions.

Without treatment, the majority of large and very large trees were projected to survive fires when the weather was of moderate to high severity (Figure 24). However, when weather was extreme (with very low humidity and high temperatures and winds), nearly all trees were killed, with less than one of three very large trees (diameter over 30 inches) surviving.

Mechanical thinning alone greatly reduced the projected mortality of larger trees. Mortality of very large trees decreased to 6 percent under extreme fire weather with 16 percent of large trees projected to die (Figure 25).

In moderate weather, thinning alone actually increased the risk of mortality for small trees (from 72 to 85 percent) and medium trees (from 25 to 40 percent). This is because thinning leaves behind increased surface fuel.

Thinning combined with prescribed fire was the most effective at reducing tree mortality during the extreme weather conditions. Mortality of very large and large trees was projected at 3 and 6 percent respectively. Only 21 percent of medium and 50 percent of small trees were likely to die.

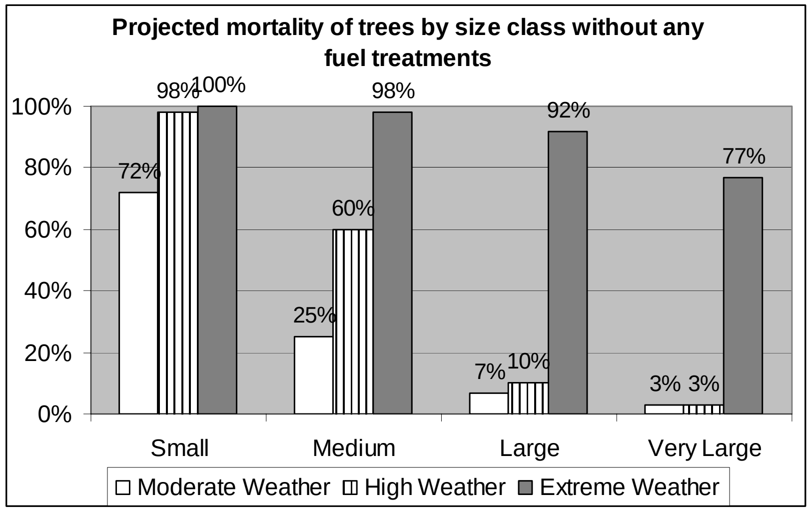


**Figure 24. Predicted fire mortality for conifers at Blodgett Forest, California. Small trees = 10 inches in diameter and under, Medium = 10-20", Large = 20-30", Very Large = >30". Source: adapted from Stephens and Moghaddas 2005**

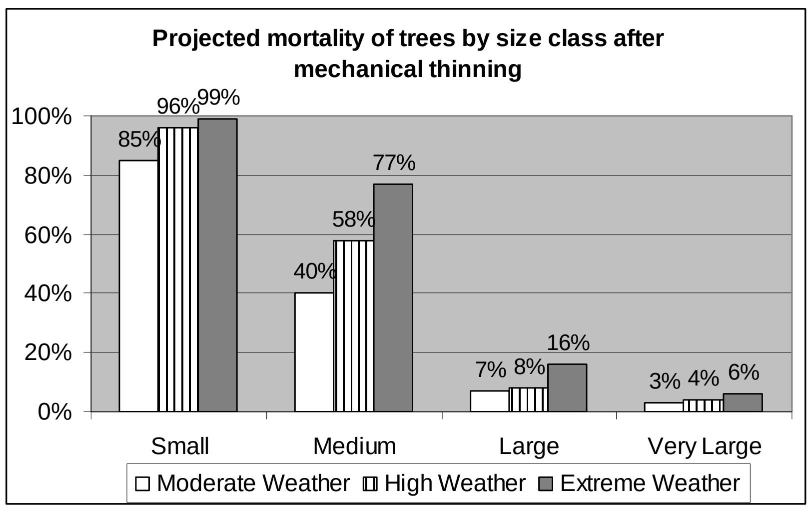


**Figure 25. Predicted fire mortality at Blodgett forest after mechanical thinning**

*How Long Will Treatments Last?*

**Figure 26. Dense pine seedling re-growth among homes.**

As any casual gardener can tell you, plants have an amazing ability to keep growing. Shrubs that are trimmed will eventually grow back and areas that are cleared will eventually fill in again. New tree seedlings will sprout in cleared areas (Figure 26). Surface fuel such as pine needles will continue to accumulate. For these reasons, fuel treatment must be considered an on-going effort.

How long a treatment remains effective at reducing the risk of crown fires varies with climate, soils, and other factors. Slash that results from thinning, especially finer woody material, takes longer to decompose on drier sites, particularly compared to fine fuel in wetter forests. Thinning and clearing treatments remain effective longer in areas where vegetation grows more slowly.

The natural fire regime in your area may be used as a rough predictor of when treatments will need to be repeated. If your parcel has a mixed conifer pine stand with a natural fire return interval of 15 years on average, you can estimate that enough fuel will accumulate to carry a fire after about 15 years of regrowth. Treatments then, should be planned every 15 years or so.

*Treating Slash*

The majority of fuel treatment methods including pruning, fuel breaks, thinning, and commercial harvests generate waste materials called slash which become surface fuel if left on the ground. Slash may be treated by changing its size and arrangement, burning it, or removing it from the site altogether.

*Lopping and scattering* is a commonly used slash treatment method for some types of thinning projects. It involves cutting unusable branches with a chain saw and scattering them on the ground. This technique is relatively inexpensive, but adds substantially to the surface fuel layer. Most slash will decompose eventually if left untreated, but this can take up to 30 years in some dry forest environments. During that time, slash actually increases your chances of tree mortality during low intensity fires. Therefore, lopping and scattering should only be used as pre-treatment for a later prescribed fire in most forests.

An alternative to scattering slash is *piling and burning* (Figure 27). This is probably the least risky method of slash treatment since the location of the burn can be controlled and the potential for the fire to escape is low. Piles can be assembled by hand or by heavy equipment during the thinning process.

*Broadcast burning* involves burning slash where it is deposited in the treatment area. This is more risky than pile burning because there is greater chance of fire escape. It can be used on steep slopes that heavy equipment cannot reach, but requires construction of fire lines scraped to mineral soil around the burn perimeter to reduce the chance of spread.

In areas where there is an active market for wood chips, slash may be chipped and hauled away to power electrical generation plants or used as part of a engineered wood product such as particle board. The income generated by selling chips can be used to partially subsidize the cost of the rest of the fuel treatment.

**Figure 27. Fuel treatment slash piled for later burning.**

*How to Pile and Burn*

If you choose to pile and burn, follow these tips on how to burn safely. Call your local fire department first to find out if there are any special restrictions or requirements in your area. Since escaped debris burns are one of the leading starts of human caused wildfires, use extreme caution when burning (Figure 28).

1. Locate piles in areas that will not cause damage to the residual stand when burned. If possible, locate piles away from the drip line (edge of crowns) of remaining trees.
2. Construct piles in a teepee fashion with large ends of the branches or boles to the inside.
3. Keep your burn pile under 4 feet in diameter; larger piles are subject to special rules. To keep piles this small, use multiple piles and/or feed material into piles by hand.
4. Don’t burn material over 12 inches in diameter. Set these pieces aside when piling to use as firewood instead.
5. Keep dirt out of the burn pile as much as possible. This will help it burn cleanly, with less smoke.
6. Cover your pile using black plastic. All covering should be weighted down with more slash to a depth of at least 6 inches so that it won’t shift or blow away in high winds and/or heavy rain, and removed before burning.
7. Burn only dry material that has cured at least six weeks to reduce the smoke produced.
8. Obtain a burn permit from fire agency when required and burn in accordance with permit terms.
9. Construct a fire line around your pile when burning in dry conditions.
10. Burn on a “burn day” (call your Air Quality Management District to find out). Don’t burn during periods of high winds.
11. Make sure your smoke does not become a nuisance to neighbors.
12. Make sure your burn is extinguished before leaving it. Piles can have hot embers for days afterwards.

**Figure 28. Pile burning by a forest landowner.**

## *Wildlife Impacts of Fuel Treatment*

A downed log can be both a landowner's hazardous fuel and a woodrat's preferred nest material. A standing dead tree, although flammable, is also home for cavity nesting birds. Landowners should carefully weigh these competing interests when carrying out fuel reduction projects. Removal of all downed wood from a forest reduces its habitat value for many species, especially those that need high density stands for feeding or nesting such as hawks and owls.

One way to mitigate the effects of fuel treatments on wildlife species that are dependent on woody debris is to leave patches or clumps of unburned snags and downed wood throughout the site. Forest scientists believe that without fire suppression, Sierran forests would have had not only less woody fuel on the ground, but that the fuel would have been less continuous across the landscape. Frequent low-intensity fires would have left behind patches of standing and downed wood. These patches of unburned debris created small refuges for wildlife to survive and later recolonize the whole burned area.

Woody debris patches should be left only in areas not adjacent to large trees so that if they do catch on fire, they do not act as a fuel ladder to convey the fire into the canopy. Landowners who burn their landscape may want to consider conducting burns in spring instead of fall. One recent study in Sequoia National Park (Knapp et al 2004) found that prescribed burns conducted in the spring burn less woody debris (67 percent) than fall burns (88 percent). Fires conducted during the spring covered less of the treatment unit (73 percent) than in the fall (88 percent) and were patchier. However, spring burns may carry more risk of fire escapement and should be undertaken with caution.

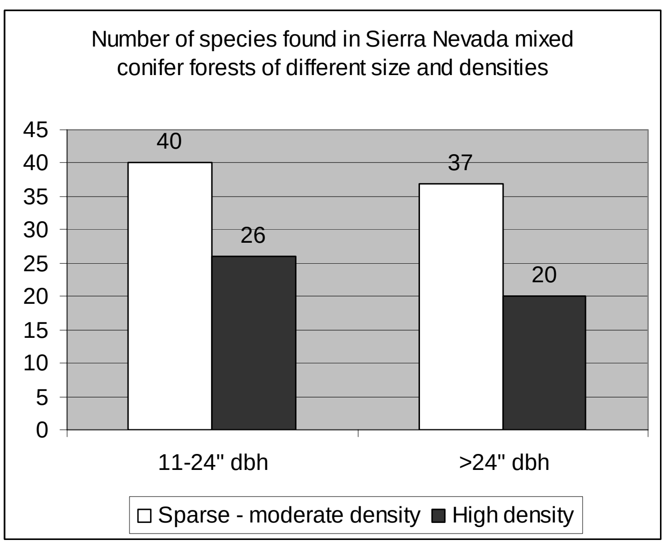


**Figure 29. More wildlife species are found in sparse to moderate density forests than in high density forests. Adapted from Holl, 2005.**

Much evidence suggests that thinning out the forest canopy can have a net positive effect on wildlife. Research has found that the highest number of wildlife species are found where the forest canopy cover is sparse to moderate (Figure 29). Sparse to moderate canopy cover supports many species that require ground-based forage resources such as invertebrates, terrestrial insects, or shrubs. Researchers from the Point Reyes Bird Observatory suggest that densely stocked forests of trees that are between 6 and 11 inches are the lowest quality for birds (Burnett 2006). These forests have low species abundance and diversity.

A recent project assessment of the effects of understory thinning of trees less than 12 inches in diameter projected a decrease in habitat value for 20 species, an increase in habitat value for 72 species, and no change for another 277 species (Fizthugh, 2002).

*Watershed Impacts of Fuel Treatment*

Impacts on watersheds depend on the type of treatment undertaken. Removal of ground and surface fuels may expose the soil making it more vulnerable to erosion. Mechanical treatments that use heavy equipment will disturb more soil than burning or manual, or chemical treatments. Disturbed soils on steep slopes can more easily erode into stream channels. To avoid impacts, steep slopes should be treated using manual methods. When heavy equipment is used it should be of the variety that minimizes soil compaction. Water bars should be constructed on slopes to slow and divert runoff and its ability to carry away soil. Some fine fuels such as leaf litter should be left behind so that bare mineral soil is not exposed to precipitation.

Chemical and animal treatments both carry some risk for water quality impacts. For chemical applications, choosing chemicals that are biodegradable and limiting the amount used can help reduce impacts. Animal treatments should involve fencing of riparian areas to reduce animal congregation in stream side areas.

*Fuel Treatment Equipment*

The least expensive fuel treatment options usually include mechanical thinning and chipping of slash in areas where a market for chips exists. Where no market exists, chips can be accumulated on site and then used for landscaping purposes. The equipment best suited for a project will vary according to the specific characteristics of the site including its size, slope, species composition, density, vegetation maturity, and soil conditions. A common suite of equipment is pictured below.

**Figure 30. Feller buncher reaching for a tree.**

**Figure 31. Feller buncher transporting the cut tree to a doodle pile.**

The feller-buncher in this photo sequence approaches a small tree to be removed (Figure 30) and grabs it with its mechanical arm. The rotary blade at the bottom of the arm severs the tree at its base (Figure 31) then places it in a pile (Figure 32) with other cut trees called a "doodle" (Figure 33).

**Figure 32. Pile of small cut trees for a doodle.**

**Figure 33. Doodles ready for transport.**

The doodles are then skidded to a landing by a rubber tired or tracked skidder (Figure 34). This skidder has boom mounted grapples that allow it to maneuver around residual trees to haul the doodles without striking and damaging the live trees left behind. The small trees are then fed into a stroke de-limber which removes the tree's branches with one stroke (Figure 35).

When limbed, the small logs are piled in decks to be loaded onto log trucks. The decked logs are visible to the right in Figure 36. In the foreground are the removed limbs waiting to be chipped. Here, a chipper uses its boom grapple to pull a bundle of small logs, tops and branches into the grinding blades and blows the ground chips into a chip van for delivery to a mill (Figure 37).

**Figure 34. Doodles being transported to a landing by a tracked skid-steer with a log grapple attachment.**

**Figure 35. Log being processed by a stroke-delimber.**

**Figure 36. Logs being stacked in a deck by a log loader.**

**Figure 37. Chipper self feeding small logs and blowing chips into a chip truck.**

*Getting the Work Done*

Projects that involve selling logs or chips are subject to California's Forest Practices Rules. The rules require landowners conducting forestry activities to receive a permit from the California Department of Forestry and Fire Protection (CDF) which specifies how treatments may take place in order to reduce the potential for environmental impacts. The Forest Practice Rules include a special fuel hazard reduction emergency regulation that allows a landowner to remove and sell trees when the goal is fuel hazard reduction. The emergency permit requires environmental review and documentation of project impacts but does not require the landowner to file a detailed Timber Harvest Plan. This greatly shortens the time needed to receive a permit.

The Forest Practice Rules are extremely detailed and complex, so landowners conducting mechanical fuels treatment projects are required to retain the services of a Registered Professional Forester (RPF) to help them stay within the law. RPFs typically examine the site, recommend treatment methods and measures to minimize environmental impacts, complete necessary documentation for permits, recommend contractors and help landowners remit any timber taxes due. Licensed Timber Operators (LTOs) are contractors who do mechanical treatments. Other types of contractors such as fire suppression and vegetation management contractors may also be qualified to conduct prescribed burns and do manual thinning and piling.

Both RPFs and LTOs are licensed by the state and are required to know timber harvest laws, have harvesting experience, and present certificates of insurance. When choosing an RPF or LTO, ask for references, locations of recent jobs, and ask to visit a recent job site. RPFs typically offer a free onsite consultation. It is important to find an RPF that you are comfortable with since they look out for your financial and environmental interests. The California State Board of Forestry maintains a list of RPFs on their website. Word of mouth, a search of the phone book, or internet might also provide you with a list of available professionals. Always check qualifications.

*Developing Project Contracts*

Most professional contractors have developed their own contract language to define their responsibilities for fuels treatment contracts. At a minimum, project contracts should specify what actions will be taken on the treatment site and standards for the fuels and vegetation remaining. Actions and possible standards are listed below:

- How trees to be removed or retained will be identified (typically retained trees are marked with paint)
- Where logs removed will be stacked (usually at landings near roads on site)
- Who will be responsible for hauling logs and chips off site (typically the contractor)
- How slash created by the operation will be treated (chipped and removed or piled and burned)
- How slash remaining from previous operations will be treated (crushed)
- How burn piles will be covered for the winter period (with plastic over 80% of its surface area)
- Who verifies burn permits and days with appropriate agencies (typically the contractor)
- What type of safety equipment should be on site during burns
- How roads used during treatment will be treated (watered and maintained by the contractor)
- How snags are treated (cut and removed unless designated for retention by the RPF).
- How any sensitive plants will be avoided (protected by buffer zones)
- How any archaeological or historical sites discovered during operations will be handled (notification of landowner and RPF)
- How any streams will be avoided (protected by buffer zones)
- How any disturbed soil will be treated (with erosion control methods in highly erodible areas)

## *How Much Does It All Cost?*

Fuel treatment costs depend on the size of parcel to be treated, the methods used, and the commercial value of any materials created by the project. Total project costs include professional forestry services needed to complete environmental reviews and documentation and treatment contractors who do the ground work. The cost of recent manual thinning projects carried out by the Plumas County Fire Safe Council ranged from $767 to $2,351 per acre depending on treatment type (See Table 4). Manual thinning, chipping and burning on small parcels was the most expensive, costing $1,246 to $2,351 per acre for parcels 11 acres and under. Manual thinning for a larger parcel cost $767 per acre.

**Table 4. Manual thinning costs for Plumas County Fire Safe Council's Demonstration Project. Source: Plumas County Fire Safe Council.**

| Site | Acres | Treatment | Forestry Services Cost | Treatment Contract Cost | Total cost | Cost per acre |
|---|---|---|---|---|---|---|
| Gansner Park | 3 | Hand thinning and burning | $1,052 | $6,000 | $7,052 | $2,351 |
| Indian Falls | 11 | Hand thinning and chipping | $3,859 | $13,700 | $17,559 | $1,596 |
| Grizzly Creek | 4.3 | Hand thinning, burning, chipping | $1,508 | $3,850 | $5,358 | $1,246 |
| Oakland Camp | 30 | Hand thinning, burning, chipping | $10,523 | $12,500 | $23,023 | $767 |

Treating slash is a critical though costly component of fuel projects. One means of reducing costs for landowners is to sell the wood fiber removed by the treatment to a nearby mill. The revenue generated by the removal of saw logs and biomass with commercial value can offset some of the over all costs of fuel treatments (See Table 5). Treatment costs for recent Plumas County Fire Safe Council mechanical thinning projects partially subsidized by sales of chips and saw logs ranged from $854 per acre to no net cost. Unfortunately, sales of wood fiber are only feasible when the treatment area is located within a short distance of a mill for saw logs or an electrical cogeneration facility for chips. At a certain distance, the cost of hauling heavy materials to the mill exceeds the revenues generated and sales are no longer feasible.

A recent review of fuels treatment projects by the State Board of Forestry (BOF 2005) found that 71% only broke even or were unprofitable to the landowner. In over half the projects reviewed, slash treatments were the most significant cost components. Mastication and chipping were identified as the single most costly treatment component.

*Cost Share Programs*

A number of state and federal programs exist to assist landowners with land management activities, including fuels reduction projects. Funding for these programs varies considerably from year to year. Two excellent guides are available electronically through the Forest Stewardship Helpline, at 1-800-738-8733, or e-mail at ncsaf@mcn.org. One is the *Cost Share and Assistance Program Directory for Individual California Landowners and Indian Tribes* which is updated annually (http://ceres.ca.gov/foreststeward/html/financial.html). The other is *The California Fire Alliance Community Resources Guide* (http://www.firesafecouncil.org/about/attachments/2002resourceguide.doc) which provides a brief summary of assistance available from various state and federal agencies to help tribes, communities and other agencies plan and implement community fire protection.

The California Department of Forestry and Fire Protection's has a cost-sharing program that focuses on the use of prescribed fire to reduce wildland fire fuel hazards on State Responsibility Area (SRA) lands. The Vegetation Management Program (VMP) allows private landowners to enter into a contract with CDF to use prescribed fire in priority areas identified through their Fire Plan. The Vegetation Management Program has treated approximately 35,000 acres per year since 1982.

**Table 5. Treatment costs for Plumas County Fire Safe Council's Demonstration and Delleker North projects. Source: Plumas County Fire Safe Council.**

| Site | Acres | Treatment | Forestry Services Cost | Treatment Contract Cost | Total Cost | Net Volume Removed | | Revenue | | Total Revenue | Net cost | Cost per acre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Saw logs (Thousand Board Feet) | Biomass (Bone Dry Tons) | Saw logs | Biomass | | | |
| Chandler Road | 8.5 | Manual thinning and chipping | $2,982 | $8,000 | $10,982 | 12.9<br><br>1.5 trees / acre<br>97% pine | 0 | $3,721<br><br>$280 - $460<br>Per thousand | 0 | $3,721 | $7,261 | $854 |
| Almanor West | 16.5 | Mechanical thinning and chipping, burning | $5,788 | $18,798 | $24,586 | 33.1<br><br>2 trees / acre<br>66% fir | 116<br>6.8 / acre | $10,968<br><br>$280 - $400<br>per thousand | $4,399<br>$38/<br>BDT | $15,367 | $9,219 | $559 |
| Delleker North | 111 | Mechanical thinning and chipping | $9,426 | $93,800 | $103,226 | 267.8<br><br>2.4 trees / acre<br>pine | 1,106<br>10 / acre | $68,992 | $38,701 | $107,694 | 0<br>($4,468<br>income) | 0 |

*Working Collaboratively*

Collaborative fuel treatment projects include multiple landowners who conduct simultaneous fuels reduction treatments. Collaborative projects, although they can be more time consuming to coordinate and plan have many potential benefits for land owners. The primary benefit is that treatment of larger forest areas, or landscapes, is more effective at reducing fire hazards than projects carried out on isolated parcels. A truly "firesafe" landscape must treat hundreds to thousands of acres because crown fires burning during extreme weather can produce firebrands causing new ignitions up to one-half mile from the active burn. Treating fuels on contiguous parcels increases the chances of reducing fire severity on each parcel.

Another reason to collaborate with neighbors is that projects on multiple parcels may be less expensive. There is an economy of scale for land owners that can share the expenses of a project contractor and a Registered Professional Forester, if needed (See Table 5). Collaborative projects may also be eligible for cost share funding or technical assistance from agencies or Fire Safe Councils.

**Figure 38. Landowners planning a fuels treatment project with their local Fire Safe Council.**

*Fire Safe Councils*

Fire Safe Councils are groups of people who come together to protect homes, neighborhoods, and communities, to discuss fire safety issues, and to determine appropriate actions to improve fire safety (Figure 38). They may also have nonprofit tax status and be involved in acquiring, funding, and administering fuel reduction grants. Public safety issues may extend beyond fire safety, to earthquake preparedness, emergency medical response, etc. Membership may include representatives from public agencies, private organizations, companies, landowners, or interested citizens. There are two levels of Fire Safe Councils: state and local.

The statewide Fire Safe Council is a partnership of dozens of public and private agencies and organizations. They have a website and several publications (see Resource section). Local Fire Safe Councils are grassroots organizations that can be started by anyone. Participants might include interested citizens (landowners, neighbors), civic service organizations (Red Cross, Rotary Club), local business interests (Chamber of Commerce, forestry companies, etc.), insurance companies, environmental organizations (The Nature Conservancy, The Audubon Society), and/or county, state or federal government (local fire districts, CDF, BLM, USFS, etc.).

Examples of Fire Safe projects include:

- Planning cleanup days.
- Sponsoring a neighborhood chipper program.
- Producing educational material.
- Sponsoring a seminar on designing and maintaining fire safe landscapes.
- Setting up demonstration projects.
- Forming a speakers' bureau to give fire safe presentations.
- Organizing safety fairs or mock fire exercises.
- Sharing information and solving problems.

## *Resources*

The following agencies, documents, and publications can provide more information about fire safe actions to interested communities.

*California Department of Fish and Game*. A state agency that manages California's wetlands, wildlife habitats, and ecosystems. Look under State Government in the phone book.

*California Department of Forestry and Fire Protection*. A state agency that provides fire protection and a multitude of fire-related and natural resource management services to state lands. Look under State Government in the telephone book.

*City or County Public Works or Planning Departments*. These city and county agencies can provide information about building codes and other fire safe requirements.

*Fire Safe Council (*2410 K Street, Suite C, Sacramento, CA 95816, (916) 447-7415 http://www.firesafecouncil.org). Useful publications include: Fire Safe brochure, Community Action Guide. Fire Safe - Inside and Out—a kit to help you make your home and property fire safe, Fire Safe Landscaping—10-minute instructional video outlining four keys to fire safe landscape, Community Fire Safe Binder—demonstrates how neighbors can work together to protect homes from wildfire. Trees Under Power Lines -A Homeowners Guide – precautions to take when working around power lines, and California's Urban-Wildland Interface Inspection Guide—the state's guidebook for city planners, developers, and professionals concerned about fire safety.

*Forest Stewardship Helpline*. This service of the Forest Stewardship Program provides information and referral to landowners, resource professionals, and others. The Helpline is an excellent information clearinghouse, answering your questions about forest management—what to do, whom to call, where to go for more information, etc. Call 1-800-738-8733 or e-mail ncsaf@mcn.org.

*Local Fire Stations*. Local fire departments have professionals to help communities identify fire hazards and implement loss reduction programs.

*Natural Resource Conservation Service.* A federal agency with experts in agronomy, natural resources, and civil engineering can help communities identify problems before construction begins and can help burned areas begin the recovery process. Look under US Government.

*University of California Cooperative Extension*. The University of California has an extensive network of agricultural and natural resources services. It offers a wide variety of information including research, landscaping, and farming. Look in the government listings in the telephone directory, or contact the nearest University of California campus.

*U.S. Fish and Wildlife Service*. This federal agency can help with information about wildlife, endangered species, and other habitat questions. Look under US Government.

## *References*


Agee, J.K. 1993. *Fire Ecology of Pacific Northwest Forests*. Island Press, Washington, D.C.

BOF. January 2005. *Fuel Hazard Reduction Emergency Regulation: Field Monitoring Results.* California State Board of Forestry and Fire Protection. Sacramento, California.

Fitzhugh, E. Lee 2002. *Small-Parcel Fuel Treatment and Utilization Demonstration Thinning Project: Wildlife Evaluation.* http://ucce.ucdavis.edu/fuelreduction/_private/reports/wildlife_analysis.pdf

Graham, R.T., McAffrey, S. and T.B. Jain. 2004. *Science Basis for Changing Forest Structure to Modify Wildfire Behavior and Severity*. General Technical Report RMRS-GTR-120. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 43 p.

Gruell, G. E. 2001. *Fire in Sierra Nevada Forests: A Photographic Interpretation of Ecological Change Since 1849*. Missoula, Mont.: Mountain Press Pub. Co.

Holl, S. 2006. *Effects of Fuel Reduction and Forest Restoration on Wildlife in Lake Tahoe's Wildland Urban Interface*. A report to Tahoe Regional Planning Agency. 24 p.

Knapp, E.E., Keeley, J.E., Ballenger, E.A. and T.J. Brennan. 2004. *Fuel Reduction and Course Woody Debris Dynamics with Early Season and Late Season Prescribed Fire in a Sierra Nevada Mixed Conifer Forest.* Forest Ecology and Management 208 (2005) 383-397.

Peterson, D.L., Johnson, M.C., Agee, J.K., Jain, T.B., McKenzie, D., and E.D. Reinhardt. 2005. *Forest Structure and Fire Hazard in Dry Forests of the Western United States*. U.S.D.A Forest Service, Pacific Northwest Research Station, PNW-GTR-628. Portland, OR. 30 pages.

SNEP, 1996. *An Overview of Fire in the Sierra Nevada.* Sierra Nevada Ecosystem Project, Volume II, Chapter 37. Page 1033-1043. Davis, California.

Stephens, S.L. and J.J. Moghaddas. 2005. *Experimental Fuel Treatment Impacts on Forest Structure, Potential Fire Behavior, and Predicted Tree Mortality in a California Mixed Conifer Forest.* Forest Ecology and Management 215 (2005) 21-36.

Walker, P.A., Marvin, S.J. and L.P. Fortmann. 2003. *Landscape Changes in Nevada County Reflect Social and Ecological Transitions.* California Agriculture, Volume 57, Number 4. Page 115-121.


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