



Guide to Fuel Treatments in Dry Forests of the Western United States: Assessing Forest Structure and Fire Hazard

Morris C. Johnson, David L. Peterson, and Crystal L. Raymond



Wildland Fire Behavior & Forest Structure

Environmental Consequences

Economics

Social Concerns



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Authors

Morris C. Johnson is an ecologist and **David L. Peterson** is a research biologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Pacific Wildland Fire Sciences Laboratory, 400 N 34th Street, Suite 201, Seattle, WA 98103; **Crystal L. Raymond** is a research scientist, College of Forest Resources, University of Washington, Box 352100, Seattle, WA 98195.

Abstract

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Guide to Fuel Treatments analyzes a range of fuel treatments for representative dry forest stands in the Western United States with overstories dominated by ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), and pinyon pine (*Pinus edulis*). Six silvicultural options (no thinning; thinning from below to 50 trees per acre [tpa], 100 tpa, 200 tpa, and 300 tpa; and prescribed fire) are considered in combination with three surface fuel treatments (no treatment, pile and burn, and prescribed fire), resulting in a range of alternative treatments for each representative stand. The Fire and Fuels Extension of the Forest Vegetation Simulator (FFE-FVS) was used to calculate the immediate effects of treatments on surface fuels, fire hazard, potential fire behavior, and forest structure. The FFE-FVS was also used to calculate a 50-year time series of treatment effects at 10-year increments. Usually, thinning to 50 to 100 tpa and an associated surface fuel treatment were shown to be necessary to alter potential fire behavior from crown fire to surface fire under severe fire weather conditions. This level of fuel treatment generally was predicted to maintain potential fire behavior as surface fire for 30 to 40 years, depending on how fast regeneration occurs in the understory, after which additional fuel treatment would be necessary to maintain surface fire behavior. Fuel treatment scenarios presented here can be used by resource managers to examine alternatives for National Environmental Policy Act documents and other applications that require scientifically based information to quantify the effects of modifying forest structure and surface fuels.

Keywords: Dry forest, FFE-FVS, fire, fire behavior, fire hazard, fuel treatments, silviculture.

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What Is *Guide to Fuel Treatments in Dry Forests of the Western United States*?

Guide to Fuel Treatments analyzes potential fuel treatments, and the potential effects of those treatments, for dry forest lands in the Western United States. The *Guide* examines lower to mid-elevation dry forest stands with high stem densities and heavy ladder fuels, which are currently common owing to fire exclusion and various land management practices such as timber harvest. These stands are the focus of potential management activities intended to modify forest structure and fuels to reduce crown-fire hazard on public lands. The *Guide* is intended for use by fire managers, silviculturists, and other resource specialists who are interested in evaluating the effects of fuel treatment on dry forest ecosystems.

The scientific basis for fuel treatments is documented in recent syntheses (Graham et al. 2004, Peterson et al. 2005) and numerous publications (Agee 1996, 2002; Brown et al. 2004; Carey and Schuman 2003; Fitzgerald 2002; Kalabokidis and Omi 1998; Keyes and O'Hara 2002; Pollet and Omi 2002; Sandberg et al. 2001; Scott and Reinhardt 2001; Weatherspoon 1996). The *Guide* provides quantitative guidelines for treatments based on the scientific principles in these documents and is intended to cover a broad range of possible treatments and stand conditions. However, the representative cases in this publication are not comprehensive, and interpretation and application of quantitative output will typically need to be adjusted based on local conditions and objectives.

The effects of fuel treatments are quantified for forest structure, surface fuels, and potential fire behavior. The Fire and Fuels Extension—Forest Vegetation Simulator (FFE-FVS) (Reinhardt and Crookston 2003) was used to calculate a variety of fuel treatment combinations (5 levels of thinning, 3 types of surface fuel modification; and prescribed fire only) for each of 25 representative forest stands. Output from FFE-FVS runs is summarized for each stand with visualizations and extensive tabular data. In addition, forest structure and fuels are calculated for 50 years posttreatment at 10-year increments, so that long-term stand conditions can be assessed and users can determine when additional fuel treatments might be needed. Users familiar with FFE-FVS have the option of running their own simulations to calculate site-specific effects of treatments.

Why Is *Guide to Fuel Treatments Needed*?

Federal agencies in the United States have a strong policy and management focus on reduction of fuels that have accumulated in dry forest ecosystems from which fire has been excluded for up to a century. For example, the Healthy Forests Restoration Act (2003) provides affirmative direction for increased fuel treatments to reduce accumulated fuels and reduce the risk of large and severe fires, especially in the wildland-urban interface and municipal watersheds. As federal agencies and other institutions begin to increase the amount of land area subjected to fuel treatments, they will need quantitative guidelines to develop alternatives for achieving desired future conditions. These alternatives need to consider options for silvicultural manipulation (thinning)

of stands, as well as surface fuel treatments. The temporal effectiveness of fuel treatments also needs to be quantified, so that additional treatments can be considered in long-term planning.

Science-based rationale and quantitative guidelines are especially needed for regulatory documentation associated with fuel management and planning. The National Environmental Policy Act (NEPA) requires that alternatives be considered in the development of environmental impact statements, environmental assessments, and associated documentation. These alternatives typically contain qualitative and quantitative descriptions of proposed management actions for a particular forest stand or landscape. The *Guide* displays potential outcomes of applying alternative combinations of fuel treatments—namely, removal of tree stems (thinning) and reduction in surface fuels (surface fuel treatment)—and facilitates quantitative analysis and review of the alternatives in terms of forest stand attributes, fuels, and potential fire behavior. The availability of visualizations and tabular data in a standard format allows resource managers to examine and select preferred fuel treatment alternatives. Visualizations are particularly useful for displaying the outcome of fuel treatment options to stakeholders and the general public who do not have formal training in natural resources.

How Was *Guide to Fuel Treatments* Developed?

The *Guide* was developed by scientists at the Pacific Wildland Fire Sciences Laboratory, Pacific Northwest Research Station, in cooperation with other scientists and resource managers throughout the Western United States. The central concept is

to link information and data from silviculture and fire science to (1) assist decisionmaking about fuel treatments in dry forest stands and (2) provide quantitative guidelines for fuel treatment that allow consideration of desired future conditions for multiple resources (e.g., wildlife, water, timber production). Final structure of the *Guide* was determined after reviews by scientists and resource managers, and two tests with national forests.

The FFE-FVS (Reinhardt and Crookston 2003) was used to prepare the *Guide*. This tool links forest growth modeling (FVS) with fire behavior modeling (FFE) to produce information relevant to management of forest stands, fuels, and fire. FVS has been widely used by resource managers and scientists for over two decades, has been programmed to cover many of the major forest types in the United States, and is regarded as a credible tool for applications in forest management. Integration of fire concepts is a recent and valuable extension of the FVS approach to forest stand simulation, and has not been available long enough to be thoroughly tested. However, it is the only analytical tool currently available that quantitatively links stand dynamics and fire science. At a minimum, FFE-FVS requires input of forest stand attribute data (species, diameter at breast height [d.b.h.], and height), although fuels data are extremely helpful.

Scenarios displayed in the *Guide* are intended to represent a range of dry forest types in the Western United States, specifically those forests dominated by ponderosa pine (*Pinus ponderosa* Dougl. ex Laws), mixed conifer (often including Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] as a codominant), and pinyon-juniper (*Pinus* spp., *Juniperus* spp.). Specific stand data were obtained

from resource managers on national forest units throughout the Western United States. Stands selected for analysis had high stem densities, and had not experienced recent fire or thinning. In the *Guide*, only stands at relatively low elevations and slopes <40 percent were considered as potential candidates for fuel treatment. Fuel treatment scenarios are organized according to Forest Service regions in the Western United States.

Which Data Are Used for Forest Stands, Fuels, and Fire Weather?

Field Sampled Vegetation (FSVeg) is an Oracle¹ database used to store data on overstory trees from grid-based strategic inventories, permanent remeasured inventory plots, and stand examinations. Data were obtained for ponderosa pine, mixed conifer, and pinyon-juniper forests in the FSVeg database from national forests in the Northern Region (Region 1), Southwestern Region (Region 3), Intermountain Region (Region 4), Pacific Southwest Region (Region 5), and Pacific Northwest Region (Region 6); we were unable to obtain usable data from the Rocky Mountain Region (Region 2). Two scenarios for pinyon-juniper were derived from Forest Inventory and Analysis (FIA) data. The FSVeg data were converted to files that could be loaded directly into FVS. Data from 37,734 stands were obtained and screened for selection of stands to be used in fuel treatment scenarios.

Default values are provided in FFE-FVS for initial surface fuel loadings. Although actual fuels data can be entered, those data are converted to stylized

fuel models (Anderson 1982), which are then used for fire behavior calculations; the original fuel values are not used. There are only 14 fuel models, only a few of which are generally used for forest fuels, although an option within FFE-FVS can be selected to use mixtures of fuel models to approximate conditions that are not well represented by an individual fuel model. Decision rules in FFE-FVS assign fuel loadings based on dominant cover type and percentage of cover. The rules and values used to estimate default initial fuel loads by size class differ between FVS variants.

The FFE-FVS model allows users to specify moisture percentage for woody surface fuels (1-, 10-, 100-, 1,000- and >1,000-hr, or 0-¼, ¼-1, 1-3, 3-6, and >6 in diameter, respectively; see glossary), duff, and live vegetation. Default values for live and duff fuel moisture for each variant were used. Twenty-foot windspeed and temperature can also be adjusted. The 20-foot windspeed is a 10-minute average windspeed 20 feet above the ground.

The 75th and 98th percentile historical fire weather data from each geographic area were obtained from the USDA Forest Service Predictive Service Division and the Western Regional Climate Center (Reno, Nevada). Remote automated weather stations (RAWS) located near each national forest were identified by using geographic information system coverages of federal land ownership and latitude/longitude coordinates for all hourly RAWS data archived at the Western Regional Climate Center. We used historical data from the fire season only (typically April to September, although this can vary) for fire behavior predictions. The 75th and 98th percentiles represent conditions at

¹The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

the extreme of the range of values for temperature (high), relative humidity (low), windspeed (high), and fuel moisture (low) that facilitate fuel flammability and fire spread. These percentiles are commonly used in NEPA assessments involving fire, and slight variations of these percentiles are used for various applications in fire management and planning. For convenience, they are referred to in the *Guide* as **moderate** (75th) and **severe** (98th) fire weather.

A coarse quality control evaluation of the RAWs data was conducted similar to that described in Brown et al. (2002). The program removed erroneous data and physically unreasonable values (e.g., negative windspeed). Data used in the percentile calculations of fire weather were for the period between 1985 and 2004. The 100-hr fuel moistures were derived through scaling by adding 3 percent to the 10-hr fuel moistures from the RAWs data; this closely matches what is observed in the field.² Windspeeds were adjusted by using a wind gusting estimation table (Crosby and Chandler 2004).

How Is the Fire and Fuels Extension—Forest Vegetation Simulator (FFE-FVS) Used?

The Forest Vegetation Simulator (FVS) is an individual-tree growth and yield model for major forest tree species, forest types, and stand conditions (Dixon 2002). Variants of FVS are available for specific areas of the United States (fig. 1). Variants are versions of simulated growth and yield customized for species and productivities in forest

ecosystems. The FVS variants for the Intermountain and Northern Rocky Mountain regions are generally considered more accurate than other variants, and have more detailed options, because FVS has been developed and used at these locations much longer than at other locations.

The FVS is a deterministic model, and for a given set of inputs will always calculate the same outputs. This contrasts with stochastic models that can introduce variability into calculations and thereby derive multiple outputs for the same set of inputs. Resource managers also need to consider ecological disturbances such as fire, insects, windthrow, and fungal pathogens as potential sources of variability within the fixed time series of FVS outputs.

First, forest stand structure and composition data (also called an FVS portfolio) were developed for each national forest by using the FVS-ready files, historical fire weather data, and default surface fuel loadings. A complete list of FVS “keywords” used initially to build the portfolios is listed in appendix 1; these keywords are used to select specific assumptions and options for growth and yield simulation. The portfolio was projected 50 years to observe potential fire behavior under moderate and severe weather scenarios. Each stand was visualized in Stand Visualization Software (SVS) and converted to EnVision images to observe the horizontal and vertical distribution of stand structure, canopy fuels, and subcanopy fuels. For each candidate stand, 14 FFE-FVS key files were developed according to the treatment options summarized in figure 2.

²Agee, James. 2003. Personal communication. Fire ecologist, University of Washington.

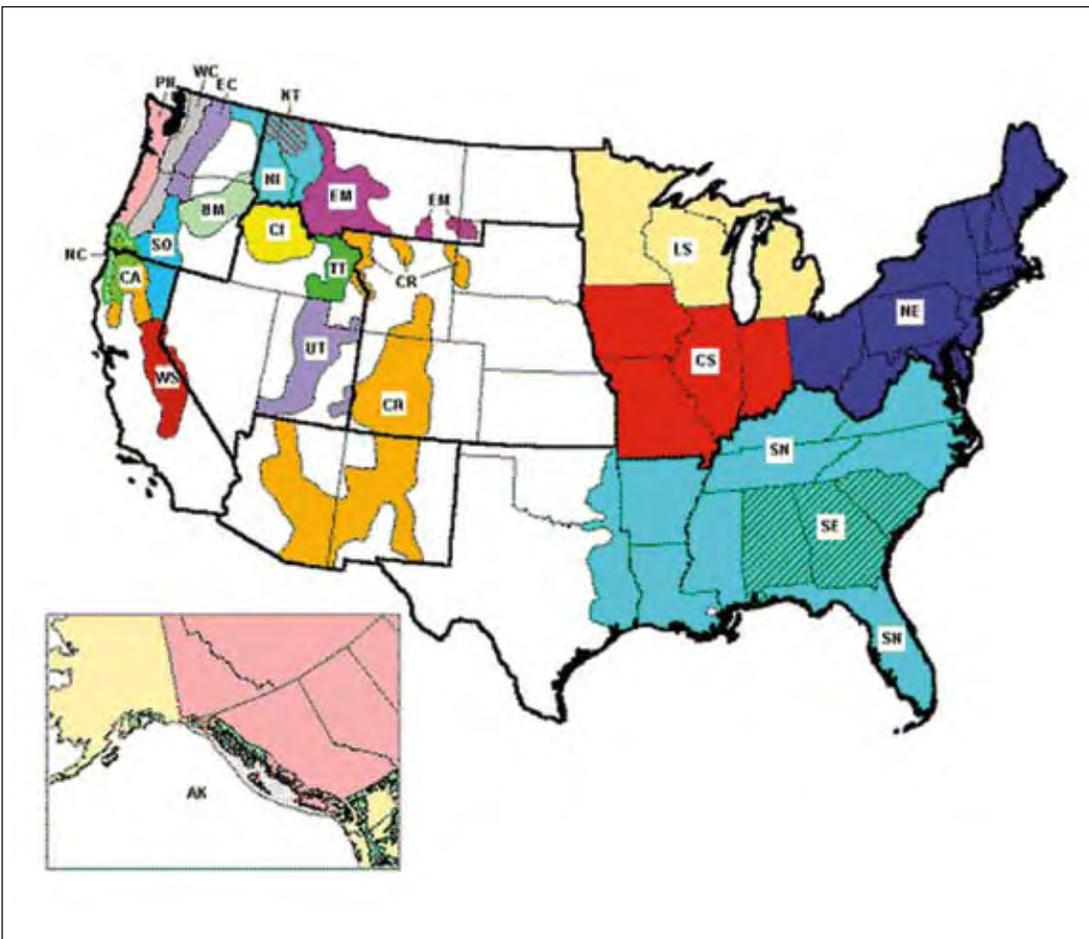


Figure 1—Geographic variants of the Forest Vegetation Simulator. These variants account for tree growth rates and structures associated with specific geographic locations, and are described in detail in Dixon (2002).

The *Guide* displays treatment effects on stand structure, surface fuel loading, and potential fire behavior. The potential fire behavior report is generated for moderate and severe fire weather scenarios, and provides information about expected fire type, flame length, crown fire potential, and tree mortality, given the weather and stand structure conditions. Different treatments can then be compared with respect to desired future conditions for specific management objectives.

Fuel Model Selection for Fire Behavior Calculations

Fire behavior calculations in FFE-FVS depend on stylized fuel models (Anderson 1982) rather than actual fuels. When silvicultural treatments are implemented in FFE-FVS, the actual activity fuel or slash created is not used to estimate potential fire behavior. The FFE-FVS model has the capacity to simulate and track fuel loadings by size class over time, although it does not use the loadings directly as inputs for calculating fire behavior. Instead, FFE uses the loadings and other stand

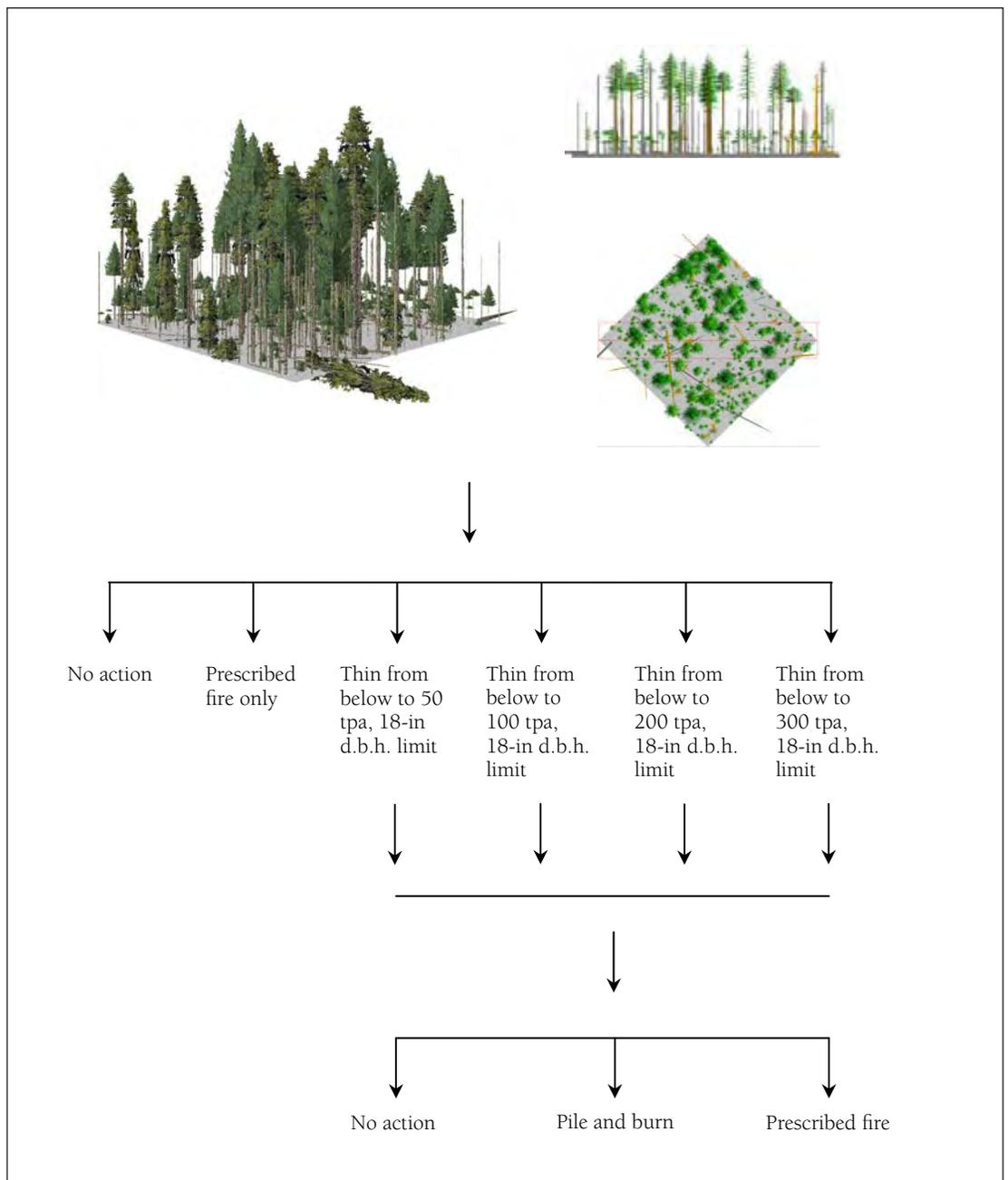


Figure 2—Conceptual diagram of the process used to simulate the effects of fuel treatments for a forest stand in FFE-FVS. Note: tpa = trees per acre; d.b.h.= diameter at breast height.

characteristics to select one or more models from 14 fuel models. The rules used to select fuel models differ among geographic variants.

Each fuel model represents homogeneous surface fuel conditions in which fire behavior is considered to respond similarly to changes in fuel moisture, wind, and slope. The models define values for several parameters difficult to measure in the stand and that are not tracked in FFE, including fuel surface-to-volume ratio, loading, depth, moisture of extinction, heat of combustion, dry density, total mineral content, and silica-free mineral content.

The “dynamic option” in FFE that we used in simulations to produce the *Guide* selects one or more fuel models based on fuel loadings and other stand characteristics, calculates fire intensity from each one, then computes a weighted average flame length by interpolating factors such as fuel loading or canopy cover. This approach can use several fuel models, weighted by percentage of each fuel model, and calculates flame lengths that change more gradually as stand conditions change than those computed from a “static” approach with a single fuel model. It partially addresses the concern about using single fuel models to represent large, complex fuelbeds. Based on feedback we obtained from resource managers, we feel that the dynamic option provides more accurate output for Intermountain and Northern Rocky Mountain forests than for locations where other FVS variants were used.

Once a fuel model is selected, its parameters are used to estimate potential fire behavior (Reinhardt and Crookston 2003). Using fuel models rather

than actual fuel quantities reduces the accuracy with which fuels are represented in the simulation process. Because of the limited number of fuel models, the same fuel model may be used for very different fuelbeds, resulting in no difference in predicted fire behavior.

There are common situations for which FFE-FVS may produce unrealistic predictions of potential fire behavior. For example, fuels can be removed through thinning or surface fuel treatment without a commensurate change in fuel models and potential fire behavior. Another unrealistic situation occurs as fuels accumulate through time such that a threshold is exceeded and another fuel model is selected, leading to a sudden, large change in fire behavior with only a small change in fuel conditions. A more reasonable result is a gradual change in predicted fire behavior corresponding to gradual changes in fuels. Finally, fuel model 2, a grass-dominated fuel model, is sometimes selected after heavy thinning (to 50 to 100 trees per acre [tpa]); this model results in higher flame lengths and increased crown fire potential, which is typically unlikely, especially if surface fuels have also been treated.

For all variants, different selection logic is used for natural fuels than for activity fuels (fuels resulting from harvest within the last 5 years), and for high and low loadings of woody fuel. All variants use the same logic for activity fuels and when woody debris is abundant. In these cases, the fuel model depends only on the amount of small (<3 in) and large (>3 in) fuel in the stand, and whether the fuel is natural or activity.

Limitations of FFE-FVS Simulations

The FVS model simulates growth and mortality typically using cycles of 10 years, whereas FFE operates on a 1-year cycle. This can lead to model behavior that is an artifact of combining the two time steps, and is not intended to represent a real phenomenon (Reinhardt and Crookston 2003). For example, snag numbers tend to exhibit a saw-toothed pattern, with sharp increases at cycle boundaries when all the cycle's natural mortality is added, and gradual declines between cycle boundaries as snag fall-down occurs. Choosing short cycle lengths or reporting indicators only at cycle boundaries can somewhat compensate for this problem.

Discontinuous behavior is particularly evident in indicators that depend in part on canopy base height: canopy base height itself, torching index, potential tree mortality, and fire type. For example, regeneration often occurs in pulses, and a stand passes a critical point after which vulnerability to torching sharply increases or decreases. These discontinuities are probably exaggerated by the fact that regeneration and mortality occur on cycle boundaries in the model. Self-pruning of large trees and mortality of understory trees may cause canopy base height to increase sharply at a cycle boundary, or understory regeneration may cause the canopy base height to decrease abruptly (Reinhardt and Crookston 2003).

Live fuels (herbaceous plants and shrubs) are poorly represented in FFE-FVS. Their biomass and contribution to fuel consumption and smoke are only nominally represented as a fixed amount that depends on percentage of cover and dominant tree

species. Live fuels can contribute significantly to fire behavior in many forest systems, but they are represented only by how fuel models are selected rather than by what is really present in a stand. For example, some shrubs regenerate quickly after thinning and prescribed fire, but shrub regeneration, growth, and fuels are not explicitly simulated in FFE-FVS. Therefore, users need to adjust simulation output to account for shrub fuels and their role in fire behavior.

Canopy cover, overstory composition, habitat type, and stand history influence selection of fuel models. Live fuels are not dynamically tracked and simulated in FFE-FVS. The default decomposition rate is often inaccurate, generally resulting in higher rates of decomposition and loss of organic matter than is realistic for most forest systems, and unrealistic transfer rates between litter and duff. The default decomposition rate is not sensitive to aspect, elevation, or potential vegetation type in FFE-FVS. Experienced FFE-FVS users can adjust these rates to more accurately reflect processes within specific forest stands.

Which Fuel Treatment Scenarios Are Analyzed?

Fuel treatment scenarios analyzed in *Guide to Fuel Treatments* were determined with extensive feedback from federal resource managers. These scenarios cover a range of potential thinning and surface fuel treatments that would be reasonable and appropriate alternatives for NEPA analysis and similar documentation. The scenarios are intended to illustrate representative situations that might be encountered in operational management and planning, and do not illustrate all possible treatments.

Thinning

The following thinning options are considered:

- No thinning
- Thinning from below to 50 tpa
- Thinning from below to 100 tpa
- Thinning from below to 200 tpa
- Thinning from below to 300 tpa
- Prescribed fire only

Thinning from below (or low thinning) refers to removal of stems starting from smallest to increasingly larger stems until the target density is reached. In practice, thinning from below often has a d.b.h. limit below which no stems are harvested, with that lower limit set to reduce costs and maximize value of harvested material. In *Guide* scenarios, all stems are harvested starting with trees smaller than 1 in d.b.h., then proceeding to larger stems. For all thinnings, no trees larger than 18 in d.b.h. are allowed to be harvested. This limit is intended to retain larger, more fire-resistant individuals. In practice, this upper d.b.h. limit could be higher or lower depending on local harvest specifications and resource objectives.

Thinning from below is the most commonly used approach to modify stand structure, density, and fuels, although many other silvicultural approaches are available (Graham et al. 1999). Thinning as used within FVS is applied equally across a given stand. In practice, variable-density thinning—a spatial pattern of tree clumps and openings—can be used to achieve the same final tree density but attain greater heterogeneity in stand structure. Variable-density thinning cannot be represented in FVS, and is therefore not considered here.

For target densities different than those in the *Guide*, users can interpolate or extrapolate the results found in tables and visualizations. Exploratory runs of FFE-FVS indicate that **thinning to densities greater than 300 tpa rarely changes fuel conditions enough to modify fire hazard** significantly from initial stand conditions.

Some managers prefer to use basal area as a target for thinning. This measurement may be more appropriate for even-aged stands with relatively low variability in tree size. Basal area is calculated for each thinning treatment, so both basal area and stem density are available for all scenarios.

Surface Fuel Treatments

The following fuel treatment options are considered for all types of stands (table 1):

- No surface fuel treatment
- Pile and burn
- Prescribed fire

In practice, techniques used for modification of activity fuels and residual surface fuels vary considerably, as does the effectiveness of those techniques. Options included in the *Guide* are intended to capture the more common approaches currently used in the field, and to represent moderately high effectiveness. Assumptions regarding slash disposal, material left on site, area affected, and effectiveness of treatments are summarized in table 1. Prescribed fire is considered to be a broadcast burn that covers the entire treatment area.

The assumptions in table 1 can be quite important with respect to fuel characteristics and potential fire behavior after treatments. For example, the effectiveness of prescribed fire varies greatly in

Table 1—Summary of values and assumptions used in FFE-FVS for surface fuel treatments

Surface fuel treatment	FFE-FVS values and assumptions	FVS keywords
No action	All boles greater than 6 in diameter at breast height (d.b.h.) are removed from stand. The entire tree (branch and bole) and branch material from trees greater than 6 in d.b.h. are left in stand.	Yardloss
Pile and burn	All boles greater than 6 in d.b.h. are removed from stand. The entire tree (branch and bole) and branch material from trees greater than 6 in d.b.h. are left in stand. 80% of the remaining fuel from the entire stand is concentrated into piles that cover 10% of the stand area. No tree mortality will result.	Yardloss PileBurn
Prescribed fire	All boles greater than 6 in d.b.h. are removed from stand. The entire tree (branch and bole) and branch material from trees greater than 6 in d.b.h. are left in stand. Windspeed at 20 ft above vegetation = 10 mph. FVS predefined moisture group (3) selected to represent fuel moisture percentages for prescribed fires. Temperature equals 70 °F. Note: predefined moisture values are specific to FVS variants.	Yardloss SimFire

terms of quantity and sizes of fuels removed. Users need to consider how variation in surface fuel treatment might affect the output tables for scenarios presented here. Experienced FVS users can modify fuel treatment options in terms of both technique and effectiveness to more accurately represent specific treatments.

Successful use of prescribed fire as the only fuel treatment can be challenging in stands with dense ladder fuels and high loadings of surface fuel. However, prescribed fire is sometimes used as the only method of fuel treatment in mixed-conifer forest of the Sierra Nevada, typically with successive burns 5 to 10 years apart. We examined the case of two successive burns for the three Sierra Nevada mixed-conifer stand examples in the *Guide* and found that an additional prescribed burn conducted 10 years later reduced surface loadings and surface flame height. The effects from the second prescribed burn also increased torching index, tree mortality, and canopy base height. However, we have not included the two-burn case

in the scenarios because it is not widely used in Western dry forests and is considered too risky by some resource managers.

Tree Regeneration

Regeneration in FFE-FVS can affect stand structure and potential fire behavior through its influence on canopy base height and canopy bulk density, so careful attention is necessary when simulating regeneration. The FVS model includes two regeneration models: (1) a full establishment model that automatically simulates input and growth of regeneration after tree removal, and (2) a partial establishment model that requires user input for stocking (portion of area that contains at least one seedling), density, and size of regeneration.

The full establishment model was used for the national forests for which it was available: Payette, Bitterroot, Lewis and Clark, and Gallatin National Forests. The model automatically predicts natural regeneration when thinning removes >30 percent

of trees in the stand, and then adds this regeneration to the tree list for growth simulation. FVS predicts stocking level, density, and species composition of regeneration by using several variables including geographic location, topography, habitat type, and basal area and species composition of residual overstory (Ferguson and Crookston 1991). Regeneration can be added incrementally for up to 20 years after thinning, or in one pulse immediately after thinning. We used the latter option, and regeneration was restricted to one pulse 5 years after thinning. Site preparation (scarification and prescribed burning) increases mineral soil exposure enabling more regeneration (Sackett 1984), so we increased stocking area for the pile and burn (1.5 times) and prescribed fire (2 times) surface fuel treatments to simulate this effect.

A combination of scientific literature, unpublished data, and expert knowledge of local managers was used to determine region-specific values for regeneration where the full establishment model was not available, and these values were adjusted

based on expected trends associated with residual overstory density and surface fuel treatments (table 2). Regeneration after thinning is variable and depends on the residual overstory and site quality of the stand, as well as seed availability and soil moisture in the years after treatment (Bailey and Covington 2002, Sackett 1984). Therefore, values used in the *Guide* are estimates and should be adjusted based on local conditions when information is available. The more a stand is opened by thinning, the more growing space is available for regeneration (Bailey and Covington 2002, McDonald 1976). We used this general relationship to estimate regeneration in the 100 tpa thinning as half that of the 50 tpa thinning, and regeneration in the 200 tpa and 300 tpa thinning as half that of the 100 tpa thinning (table 2). These values were then adjusted for the surface fuel treatment options; regeneration in the pile and burn is 1.5 times that of the no surface fuel treatment option, and regeneration in the prescribed fire is 3 times that of the no surface fuel treatment option.

Table 2—Number of trees used for regeneration in the partial establishment model of FVS

Forest Service Region	FVS-simulated thinning treatment	Surface fuel treatment		
		None	Pile and burn	Prescribed fire
		<i>Trees per acre</i>		
Region 3	50	15	23	45
	100	8	12	25
	200	4	6	12
	300	4	6	12
Region 5	50	50	75	150
	100	25	38	75
	200	13	20	40
	300	13	20	40
Region 6	50	100	150	300
	100	50	75	150
	200	25	38	75
	300	25	38	75

How Do I Use *Guide to Fuel Treatments*?

Output for each scenario in the *Guide* is organized as follows:

- **Page A**—Initial stand conditions, including a stand visualization for 1 acre.
- **Page B**—Visualizations for four thinning treatments without surface fuel treatments for 1 acre. Surface fuel treatments cannot be shown in images produced by FVS.
- **Page C**—Narrative describing highlights of FFE-FVS output for different fuel-treatment alternatives.
- **Page D**—Fuel, fire behavior, and fire effects (percentage basal area mortality) for all possible combinations of thinning and surface fuel treatments, immediately after treatments.
- **Pages E, F, G, and H**—Fuel, fire behavior, and snags for all treatments for 1, 10, 20, 30, 40, and 50 years after treatment.
- **Pages H, I, and J**—Forest stand attributes for all treatments 1, 10, 20, 30, 40, and 50 years after treatment.
- **Pages K and L**—Summary of fire behavior fuel models assigned by FFE-FVS for all possible combinations of thinning and surface fuel treatments for 1, 10, 20, 30, 40, and 50 years after treatments.
- **Page L**—Summary of fire weather values used in simulations for moderate and severe conditions; limits used for prescribed fire.

The following describes a step-by-step approach to analyzing a scenario:

Step 1—

After you read and understand the material above, identify the region where your stand is located. For example, if you are working on the Okanogan-Wenatchee National Forests, you should look in the section for the Pacific Northwest Region (Region 6). Figure 1 shows the geographic distribution of FVS variants used for each scenario. You may occasionally find that other Regions contain scenarios that you consider to be more appropriate for a particular situation.

Step 2—

Review the fuel treatment scenarios under the appropriate appendix and find the initial stand conditions (page A) and initial fuel conditions (page D) that best match the stand (or broader landscape) in which you are interested. You will rarely find a perfect match, and may need to mentally extrapolate *Guide* stand conditions to your situation. For example, grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.) may be the understory dominant in a *Guide* scenario, but white fir (*A. concolor* (Gord. & Glend.) Lindl.) is the understory dominant in your stand. The difference in the effects of a given fuel treatment owing to understory species will probably not be large, because the basic principles of how fuels and forest structure affect fire behavior drive FFE-FVS calculations. Local knowledge should always guide interpretation of this type of situation.

Step 3—

Decide which silvicultural option(s) you want to consider: no thinning, thinning to 50 tpa, thinning to 100 tpa, thinning to 200 tpa, or thinning to 300 tpa. Find the appropriate visualization (page B) and compare it to initial stand conditions.

Step 4—

Decide which surface fuel treatments you want to consider: no surface fuel treatment, pile and burn, or prescribed fire.

Step 5—

The extensive tabular data for each scenario may be difficult for inexperienced users to navigate, and even experienced users can miss important points. Therefore, narrative page C summaries are provided that highlight critical outputs of the FFE-FVS simulations that may be particularly helpful in evaluating alternative fuel treatments in the pages that follow.

Step 6—

Determine immediate effects of fuel treatments on fuels, fire, and fire effects (percentage basal area mortality) (page D). Thinning treatments are listed across the top of the table, and surface fuel treatments are listed down the left side.

Step 7—

Determine long-term effects of fuel treatments on fuels, fire, and fire effects (pages E through H). Silvicultural options (including both with and without prescribed fire) are listed across the top of the table, and surface fuel treatments are listed down the left side for 1, 10, 20, 30, 40, and 50 years after treatment. By moving across the table from left to right, you can observe how fuel load-

ings change through time, as well as how type of fire changes. This information can help determine when subsequent fuel treatment might be needed.

Step 8—

Determine long-term effects of fuel treatments and silvicultural options on forest stand attributes (pages H through J). Interpretations are similar to those in Step 6 but with projections for 1, 10, 20, 30, 40, and 50 years after treatment. Information on snags may be helpful for evaluation of wildlife habitat. A guideline often applied in the field is that canopy base height should be considerably higher than potential flame length to reduce crown fire hazard—**compare canopy base height (pages H through J) to flame length (pages E through H) to evaluate crown fire potential.**

Step 9—

Determine the long-term effects of thinning options and surface fuel treatments on forest stand attributes 1, 10, 20, 30, 40, and 50 years after thinning (pages H through J). By moving across the table from left to right, you can observe how stand density and structure change over time. This may affect decisions about subsequent thinning, commercial harvest, and wildlife habitat. Note that canopy base height is a particularly important feature of canopy fuels that affects the potential for fire to propagate from surface fuels into the canopy.

Step 10—

Determine how fuel model assignment within FFE-FVS varies through time for fuel treatment alternatives; fuel model and relative weight are given (pages K and L). This information allows users to determine if appropriate fuel models have been assigned. In addition, fire weather data

used in the FFE-FVS simulation are summarized in two small, separate tables (page L). These data provide a quantitative context for “moderate” and “severe” weather conditions. If you prefer to use other weather conditions, you can extrapolate or interpolate as needed.

Do Your Own FVS Runs

Fuel treatment scenarios in the *Guide* illustrate how silviculture and fire can be integrated. An increasing number of resource managers are using FVS as an analytical tool for assessing alternative management options. Current and potential FFE-FVS users who want to run their own simulations are encouraged to use the *Guide* as a basis for screening potential management options. Users may wish to run simulations on their own FVS-ready files. The benefits of doing your own FFE-FVS runs include generating output more specific to a particular location, and the ability to run FVS options other than the ones used here.

How Is Output From the *Guide* Interpreted and Applied?

An Example Scenario

The step-by-step approach described above is used here to illustrate how to interpret output for a specific scenario in the *Guide*: **Region 6—Deschutes National Forest 1**. In this example, we assume the management objective is to make the stand as resilient to fire as possible by reducing crown fire hazard while maintaining good forage for deer and elk. For this example, assume that pile and burn is the preferred surface fuel treatment.

Step 1—

The Deschutes National Forest is in Region 6, so that section (Deschutes National Forest 1) of the *Guide* (pages 239–250) should be consulted.

Step 2—

The stand has high stem density of 1,345 tpa owing to fire exclusion, with a dense understory of white fir creating ladder fuels into the ponderosa pine overstory. The basal area of 246 ft²/ac is relatively high, indicating potential for wood production, and for large trees and snags for wildlife habitat (page 239). Surface fuel loadings are very high, with 11 tons/ac for fuels <6 in diameter, and very high duff loading of 20 tons/ac (page 242); this is typical of forests with a long period of fire exclusion. These conditions are conducive to high-intensity surface fire with the potential for crown fire.

Step 3—

Thinning to 50 tpa or 100 tpa (page 240) appears visually to be the only treatments that would reduce ladder fuels sufficiently to reduce crown fire hazard. Canopy base height (4 ft) (page 246) needs to be raised considerably above the predicted flame length of the initial stand condition (5 ft for severe weather) (page 242). Retention of large ponderosa pine helps meet this objective, because the high crowns avoid surface fire and moderate crown fire, and the thick bark resists surface fire.

Step 4—

The narrative summary (page 241) can help to interpret important aspects of the simulation output. All thinning treatments effectively reduce canopy bulk density and increase canopy base

height enough to reduce crown fire potential; the greater the thinning, the greater the reduction in fire hazard. Thinning without surface fuel treatments increases surface fuel; the greater the thinning, the greater are activity fuels and potential flame lengths.

Step 5—

Pile and burn (starting on page 242) will be used to treat surface fuels, as noted above.

Step 6—

First, note that if fire were to occur in the stand without any treatment, it would start a crown fire (flame length of 4 or 5 ft on page 242 and canopy base height of 4 ft on page 246). Thinning to 50 or 100 tpa with pile and burn confers considerable fire resilience on the stand. Surface fuel treatment (pile and burn) for the 50 tpa thinning greatly reduces surface fuels <6 in diameter to 5 tons/ac (page 242), or about half of the initial total (page 242), even though the thinning created activity fuels from slash. Predicted flame length of 5 ft (page 242) is well below the new canopy base height of 44 ft (page 247); therefore fire behavior changes from crown fire to surface fire, with negligible basal area mortality following all treatments.

Step 7—

We now examine the long-term effects of pile and burn fuel treatments (pages 243 through 248). The potential for crown fire remains low for 30 to 40 years. However, as surface fuels increase over time, canopy base height decreases owing to growth of small regenerating trees, canopy bulk density increases, and the potential for crown fire returns. Note that crown fire potential increases as flame length (page 244) and canopy base height (page

247) become more similar. For this example stand, thinning to 50 tpa and to 100 tpa appear to have similar long-term effects on fuels and fire.

Step 8—

We may want to consider how an initial prescribed burn would compare to our preferred fuel treatment options (page 242, 247). In this case, a “successful” prescribed burn would have reduced surface fuels, and removed most of the small white fir and some ponderosa pine while retaining only the largest overstory ponderosa pine. Canopy base height remains well above flame length for 30 years of the simulation, thereby reducing long-term crown fire hazard.

Conclusions—

The above information indicates that thinning to either 50 tpa or 100 tpa with surface fuel treatment would meet the objective of reducing crown fire hazard (page 247). However, this reduction will last for 40 years in the 50 tpa thinning versus 50 years in the 100 tpa thinning. The 100 tpa thinning has the benefit of more snags and cover, which could benefit certain types of wildlife. It is important to remember the recruitment of herbaceous vegetation and shrubs is not simulated in FVS. Therefore, additional thinning and/or surface fuel treatment would be needed after 30 to 50 years to maintain a fire-resilient condition. The option of using prescribed fire as the only fuel treatment appears attractive. However, considerable risk and planning are involved in implementing a prescribed burn, particularly in a dense stand where protection of large trees is a priority, and an effective burn is subject to weather and fuel conditions. As with any fuel treatment, all relevant resources, including

posttreatment hydrology, social concerns, and smoke production, should be included in the decisionmaking process.

FFE-FVS Output and Expert Judgment

The *Guide* is intended to inform decisions—not make decisions. It is generally inappropriate for users to directly apply information from the *Guide* to management and planning issues. In fact, doing so could sometimes cause significant errors, owing to shortcomings of the modeling approach described above, and differences between example scenarios and local stand conditions. Most of the numbers in the tables should be considered “fuzzy” or to be an estimated mean with a range of possible values.

Simulation models like FFE-FVS attempt to mathematically represent complex interactions for which thorough understanding and adequate data do not exist. This is a challenging objective, and it is often more realistic to **compare the relative magnitude of output among fuel treatment options or between time periods, than to compare the actual magnitude of output.** Using multiple parameters, rather than a single one, is generally more appropriate for making decisions about the effectiveness of a particular fuel treatment. Identifying patterns and trends of outputs can be more valuable than focusing on individual numbers in the tables.

The value of different components of the *Guide* will differ depending on the application. For example, a fuels specialist developing a long-term plan may be particularly interested in the change in fuel loadings over time. A wildlife specialist may

be interested in snags and large surface fuels. A public information specialist may find the images to be a useful component for presentation at local stakeholder meetings. All applications of *Guide* information should include some communication about the positive and negative aspects of the simulation approach. Finally, **the knowledge of local resource specialists in fire and fuels management is always required to interpret and apply the output of simulation models.**

Glossary

active crown fire—A fire that moves as one continuous flame front involving both canopy fuels and surface fuels. If both torching index and crowning index are less than the windspeed measured 20 ft above the ground, fire type is active crown fire.

activity fuel—Combustible material resulting from or altered by forestry practices such as thinning.

basal area—Cross-sectional area of all stems in the stand measured at breast height expressed per unit of land area (reported in English units as ft^2/ac).

canopy cover—FVS defines canopy cover as the percentage of the ground area that is directly covered by tree crowns.

canopy base height—Lowest height (ft) above the ground at which sufficient canopy fuels are available to propagate fire vertically through the canopy. FFE defines “sufficient fuels” as at least $30 \text{ lb ac}^{-1} \text{ ft}^{-1}$ of available canopy fuels expressed as a running 3-ft mean of available canopy fuels.

canopy bulk density—The available canopy fuel load (foliage and 50 percent of branches <0.25 in), calculated as the maximum 15-ft-deep running mean for canopy layers 1 ft thick; reported by convention in metric units (kg/m³) (see Scott and Reinhardt [2001] for a more detailed description).

conditional crown fire—The type of fire observed in the stand depends on the origin of the fire; a surface fire will remain a surface fire when moving into the subject stand, and a crown fire will remain a crown fire. If the crowning index is less than the 20-ft windspeed but the torching index is not, then the fire type is conditional crown fire. Conditional crown fire is possible, but is a rare event. (see Scott and Reinhardt [2001] for a more detailed description).

crown competition factor—Relative measurement of stand density based on tree diameter. The percentage of an acre that would be covered by an individual tree's crown if it were open grown is calculated for each tree, and then the crown competition factors for all trees are summed to get the crown competition factor for the entire stand.

crown fire—A fire that burns in the elevated canopy fuels. Crown fire can be of two main forms, passive and active crown fire.

crowning index—The 20-ft windspeed (in mph) at which active crown fire is likely to be sustained. It is a function of canopy bulk density and crown fire rate of spread.

duff—Partially decomposed organic material of the forest floor beneath the litter layer.

fuel moisture—Moisture content of a specific size class of fuel expressed as a percentage of oven dry weight.

fuel model—A set of values that represents a range of fuel conditions in which fire behavior may be expected to respond similarly to changes in fuel moisture, wind, and slope. FFE uses the 13 stylized fuel models described in Anderson (1982). An additional fuel model (14, light-moderate logging slash) is used within FFE to express fuel conditions intermediate to those in fuel models 11 and 12.

hard snags—Dead trees that are not heavily decayed yet; soft snags have 80 percent of the wood density of hard snags.

litter—The surface layer of the forest floor that is not in an advanced stage of decomposition, usually consisting of freshly fallen leaves and twigs.

merchantable cubic feet—The volume, in cubic feet, of the bole material in a stand suitable for sale.

passive crown fire—A fire in which individual tree crowns or groups of tree crowns burn, but a solid flame is not consistently maintained in the canopy layer, also called torching or candling. If the torching index is less than the 20-ft windspeed, but the crowning index is not, then the fire type is passive crown fire.

potential fire report—An output of FFE-FVS that provides information about the potential fire behavior, fire hazard, and fire effects in a stand under two fire weather scenarios.

prescribed fire—Deliberate burning of wildland fuels under specified environmental conditions.

quadratic mean diameter—The d.b.h. of a tree with average basal area.

stand density index—A density measurement based on the number of trees per acre and the d.b.h. of the average tree.

surface fire—A fire that burns in the surface fuel layer that lies just above the ground, but not in the canopy fuels.

thin from below—A silvicultural treatment in which trees are removed from suppressed and intermediate crown classes, leaving the larger trees on site.

top height—The average height (in feet) of the 40 tpa of the largest diameter.

torching index—The 20-ft windspeed (in mph) at which crown fire initiation is expected to occur. It is a function of surface fireline intensity, foliar moisture content, and canopy base height.

total cubic feet—The total volume in cubic feet of the bole material in a stand.

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Metric Equivalents

When you know	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Feet (ft)	.305	Meters
Acres (ac)	.405	Hectares
Square feet (ft ²)	.093	Square meters
Tons per acre (ton/ac)	2.24	Megagrams per hectare
Pounds per cubic foot (lb/ft ³)	16.02	Kilograms per cubic meter
Miles per hour (mph)	.447	Meters per second

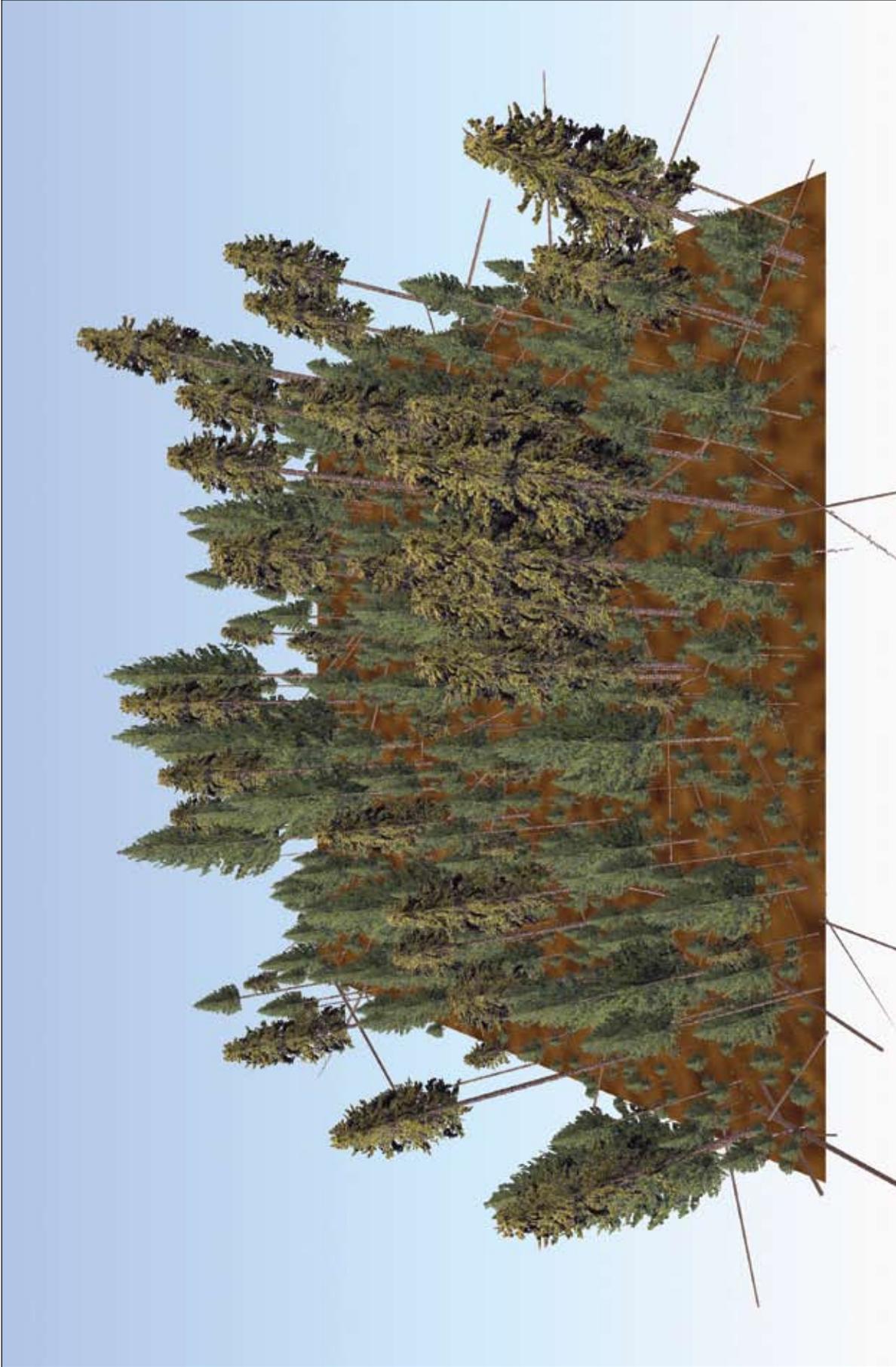
Literature Cited

- Agee, J.K. 1996.** The influence of forest structure on fire behavior. In: Sherlock, J.; Landram, M.; Gray, S., eds. Proceedings, 17th annual forest vegetation management conference: 52–68. On file with: James Agee, University of Washington, College of Forest Resources, Seattle, WA.
- Agee, J.K. 2002.** Fire behavior and fire-resilient forests. In: Fitzgerald, S., ed. Fire in Oregon's forests: risks, effects, and treatment options. Portland, OR: Oregon Forest Resources Institute: 119–126.
- Anderson, H.E. 1982.** Aids to determining fuel models for estimating fire behavior. Res. Pap. INT-RP-122. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experimental Station. 22 p.
- Bailey, J.D.; Covington, W.W. 2002.** Evaluating ponderosa pine regeneration rates following ecological restoration treatments in northern Arizona, USA. *Forest Ecology and Management*. 155: 271–278.
- Brown, R.T.; Agee, J.K.; Franklin, J.F. 2004.** Forest restoration and fire: principles in the context of place. *Conservation Biology*. 18: 903–912.
- Brown, T.J.; Hall, B.L.; McCurdy, G.D. 2002.** Quality control of California historical RAWS data. CEFA Report 02-01. Reno, NV: Desert Research Institute, Program for Climate, Ecosystem, and Fire Applications. 29 p. <http://www.cefa.dri.edu/Publications/qcreport.pdf>. (February 14, 2005).
- Carey, H.; Schuman, M. 2003.** Modifying wildfire behavior—the effectiveness of fuel treatments: the status of our knowledge. National Community Forestry Center, Southwest Region Working Paper 2. Santa Fe, NM: Forest Trust, National Community Forestry Center. 26 p.
- Crosby, J.S.; Chandler, C.C. 2004.** Get the most from your windspeed observation. *Fire Management Today*. 64: 53-55. Reprinted from *Fire Control Notes* 27 (Fall 1966): 12–13.
- Dixon, G.E., compiler. 2002.** Essential FVS: a user's guide to the Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Management Service Center. 196 p.
- Ferguson, D.E.; Crookston, N.L. 1991.** User's guide to version 2 of the Regeneration Establishment Model: part of the Prognosis Model. Gen. Tech. Rep. GTR-INT-279. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 26 p.
- Fitzgerald, S.A. 2002.** Fuel-reduction and restoration treatments for Oregon's forests. In: Fitzgerald, S., ed. Fire in Oregon's forests: risks, effects, and treatment options. Portland, OR: Oregon Forest Resources Institute: 127–138.
- Graham, R.T.; Harvey, A.E.; Jain, T.B.; Tonn, J.R. 1999.** The effects of thinning and similar stand treatments on fire behavior in Western forests. Gen. Tech. Rep. PNW-GTR-463. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 27 p.
- Graham, R.T.; McCaffrey, S.; Jain, T.B. 2004.** Scientific basis for changing forest structure to modify wildfire behavior and severity. Gen. Tech. Rep. GTR-RMRS-120. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 43 p.
- Healthy Forests Restoration Act of 2003;** P.L. 108-148.
- Kalabokidis, K.D.; Omi, P.N. 1998.** Reduction of fire hazard through thinning/residue disposal in the urban interface. *International Journal of Wildland Fire*. 8: 29–35.

- Keyes, C.R.; O'Hara, K.L. 2002.** Quantifying stand targets for silvicultural prevention of crown fires. *Western Journal of Applied Forestry*. 17: 101–109.
- McDonald, P.M. 1976.** Shelterwood cutting in a young-growth, mixed-conifer stand in north central California. Res. Pap. 117. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest Range and Experiment Station. 16 p.
- National Environmental Policy Act of 1969 [NEPA]; 42 U.S.C. 4321 et seq.**
- Peterson, D.L.; Johnson, M.C.; McKenzie, D.; Agee, J.K.; Jain, T.B.; Reinhardt, E.D. 2005.** Forest structure and fire hazard in dry forests of the Western United States. Gen. Tech. Rep. GTR-PNW-628. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 30 p.
- Pollet, J.; Omi, P.N. 2002.** Effect of thinning and prescribed burning on crown fire severity in ponderosa pine forests. *International Journal of Wildland Fire*. 11: 1–10.
- Reinhardt, E.D.; Crookston, N.L., tech. eds. 2003.** The Fire and Fuels Extension to the Forest Vegetation Simulator. Gen. Tech. Rep. GTR-RMRS-116. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 209 p. http://www.fs.fed.us/rm/pubs/rmrs_gtr116.pdf. (10 May 2006).
- Sackett, S.S. 1984.** Observations on natural regeneration in ponderosa pine following a prescribed fire in Arizona. Res. Note RM-435. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 8 p.
- Sandberg, D.V.; Ottmar, R.D.; Cushon, G.H. 2001.** Characterizing fuels in the 21st century. *International Journal of Wildland Fire*. 10: 381–387.
- Scott, J.H.; Reinhardt, E.D. 2001.** Assessing crown fire potential by linking models of surface and crown fire behavior. Res. Pap. RMRS-RP-29. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 59 p. http://www.fs.fed.us/rm/pubs/rmrs_rp29.pdf (31 May 2006).
- Weatherspoon, C.P. 1996.** Fire-silviculture relationships in Sierra forests. In: Sierra Nevada Ecosystem Project: final report to Congress, volume II, assessments and scientific basis for management options. Davis, CA: University of California, Centers for Water and Wildland Resources: 1167-1176. http://ceres.ca.gov/snep/pubs/web/PDF/VII_C44.PDF (10 May 2006).

Appendix 1—Keywords used in FFE-FVS for Simulations Represented in the *Guide*

Partial establishment model		Full establishment model	
Base FVS system	TreeList	Base FVS system	TreeList
	Cutlist		Cutlist
	SVS		SVS
	StrClass		StrClass
	NumCycle		NumCycle
Fire and Fuels Extension	FuelOut	Fire and Fuels Extension	FuelOut
	FuelRept		FuelRept
	PotFire		PotFire
	PotFTemp		PotFTemp
	PotFWind		PotFWind
	PotFMois		PotFMois
	SnagSum		SnagSum
	SimFire		SimFire
PileBurn	PileBurn		
		Full Establishment Model	NoInGrow StockAdj



Initial stand conditions

Site: Elevation = 4,400 ft, slope = 24 percent, aspect = 90 percent.

Species (based on trees per acre): Douglas-fir (*Pseudotsuga menziesii*) = 60 percent, grand fir (*Abies grandis*) = 31 percent, ponderosa pine (*Pinus ponderosa*) = 4 percent.

Stand attributes: Stem density = 2,345 tpa, basal area = 114 ft²/ac, top height = 78 ft, stand density index = 338, quadratic mean diameter = 3.0 in, crown competition factor = 116, canopy cover = 65 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has a high tree density of 2,345 trees per acre (tpa) primarily composed of grand fir and Douglas-fir with a ponderosa pine overstory. Woody fuel loading is 9 tons/ac, and litter and duff loading is 7 tons/ac. Canopy bulk density is 0.14 kg/m³ (0.0087 lb/ft³), and canopy base height is 3 ft, so ladder fuels are sufficient to enable passive crown fire, but canopy fuels are not sufficient to enable active crown fire spread. Crowning index is 19, and severe-weather windspeed is 17 mph, so although this stand is not classified as active crown fire, crown fire hazard is high. Potential basal area mortality is 97 percent for severe fire weather. With no action, flame lengths, surface fuels, and canopy base height increase slightly over time with crown fire potential decreasing in 20 years and then increasing again in 40 years. Crown fire potential and flame lengths remain low for moderate fire weather for the entire 50-year projection.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment decreases canopy bulk density and slightly increases canopy base height, but not enough to prevent passive crown fire for severe fire weather. This treatment reduces surface fuels in all size classes, but flame lengths increase after treatment owing to grass fuels associated with the use of fuel model 2; grass fuels are not tracked in FFE and may or may not be the primary fuel following prescribed fire. All thinning treatments reduce canopy bulk density and increase canopy base height; the greater the thinning, the greater is the change in forest structure. The predicted fire type after treatment is surface fire for all thinning options, but the more open stands are characterized predominantly by fuel model 2, so flame lengths increase and potential basal area mortality remains above 20 percent regardless of surface fuel treatment. The 200 and 300 tpa treatments have a more closed canopy, and fire behavior is influenced less by grass fuels, so flame lengths and potential basal area mortality are lower than the more open stands. Activity fuels are reduced by the pile and burn treatment and to a greater extent by the prescribed fire treatment, which also reduces litter and duff, but flame lengths and basal area mortality remain high owing to grass fuels.

Silvicultural and surface fuel treatments—long-term effects

Although the prescribed fire only treatment does not reduce crown fire potential in the short term, after 10 years the predicted fire type is surface fire, and crown fire potential continues to decline as canopy base height increases and flame lengths decrease. In all thinning treatments, flame lengths decrease over time as canopy cover increases and fuel model assignment shifts from predominantly 2 to predominantly 9. The 200 tpa treatment has the greatest long-term effect on crown fire potential with a predicted fire type of surface fire for 50 years with pile and burn or no surface fuel treatment, and 40 years with prescribed fire treatment. The 50 tpa treatment had the most short-lived effect on crown fire potential with regeneration causing a drop in canopy base height in 30 years regardless of surface fuel treatment.

Table 3a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit	
None	Surface fuel loadings (tons/ac)	0–3 in	1	5	5	4	4	
		3–6 in	0	3	3	2	2	
		6–12 in	1	1	2	2	2	
		>12 in	0	0	0	0	0	
		Litter	2	1	2	2	2	
		Duff	5	4	3	4	4	
	Flame length (ft)	Moderate	2	3	4	2	2	
		Severe	3	5	7	4	3	
		Severe	15	8	32	35	27	
		Severe	19	51	49	38	38	
Pile and burn	Torching index	Surface	Surface	Surface	Surface	Surface	Surface	
	Crowning index	Passive	Passive	Surface	Surface	Surface	Surface	
	Type of fire	25	15	9	15	19	21	
	Potential basal area mortality (%)	97	72	68	53	29	24	
	Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	1	1	1	1	1
			3–6 in	1	1	1	1	1
			6–12 in	0	0	0	0	0
			>12 in	0	0	0	0	0
			Litter	2	2	2	2	2
			Duff	2	2	3	3	4
Flame length (ft)		Moderate	4	4	3	2	2	
		Severe	7	7	6	4	3	
		Severe	32	32	47	45	34	
		Severe	49	49	45	38	38	
Prescribed fire	Torching index	Surface	Surface	Surface	Surface	Surface	Surface	
	Crowning index	Severe	Severe	Surface	Surface	Surface	Surface	
	Type of fire	9	9	15	15	19	21	
	Potential basal area mortality (%)	80	80	56	28	23	23	
	Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	0	0	0	0
			3–6 in	1	1	1	1	1
			6–12 in	1	1	1	1	1
			>12 in	0	0	0	0	0
			Litter	0	0	0	1	1
			Duff	2	2	3	3	3
Flame length (ft)		Moderate	4	4	4	3	3	
		Severe	7	7	6	6	6	
		Severe	30	30	31	32	26	
		Severe	53	53	52	51	51	
Potential basal area mortality (%)	Torching index	Surface	Surface	Surface	Surface	Surface	Surface	
	Crowning index	Passive	Passive	Surface	Surface	Surface	Surface	
	Type of fire	9	9	11	14	14	14	
	Potential basal area mortality (%)	88	88	81	61	54	54	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 3b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	3	3	3	4	4	4	1	3	2	2	2	2	3
	3–6 in	3	2	3	3	3	4	0	2	2	3	3	3	3
	6–12 in	3	2	2	2	2	3	1	2	2	2	2	2	2
	>12 in	0	0	0	1	2	2	0	1	1	2	2	2	2
	Litter	2	2	2	3	3	3	1	1	1	2	2	2	2
	Duff	5	5	5	6	6	6	4	4	4	4	4	4	4
	Moderate	2	2	2	2	2	2	3	3	2	2	2	2	2
	Severe	3	3	3	3	3	3	5	5	4	4	4	3	3
	Torching index	15	17	24	20	9	7	8	19	30	42	53	54	54
	Crowning index	19	19	19	19	19	20	51	46	43	41	41	40	40
None	Type of fire	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Passive
	Hard snags (stems/ac)	195	316	374	330	286	241	608	17	22	19	18	16	
	0–17.9 in	0	1	2	2	3	4	1	1	1	2	2	3	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
	None	Type of fire	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Passive				
		Thin from below to 50 tpa, 18-in d.b.h. limit	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
		Surface fuel loadings (tons/ac)	5	2	2	2	2	2	5	2	2	2	2	2
		3–6 in	3	3	3	3	3	3	3	3	3	3	3	3
		6–12 in	1	1	1	1	1	1	2	1	1	1	2	2
>12 in		0	0	0	0	1	1	0	0	0	1	1	1	
Litter		2	1	1	1	1	2	2	1	1	1	2	2	
Duff		3	3	3	3	3	3	3	3	3	4	4	4	
Moderate		4	3	3	3	3	2	3	3	3	3	2	2	
Severe		7	7	6	5	5	4	6	5	5	4	4	4	
None	Torching index	32	39	48	1	0	16	38	59	68	84	97	111	
	Crowning index	49	48	47	47	46	46	45	42	39	38	38	38	
	Type of fire	Surface Surface	Surface Surface	Surface Surface	Passive Passive	Passive Passive	Surface Passive	Surface Surface						
	Hard snags (stems/ac)	1	3	4	21	20	17	2	5	7	26	27	24	
	0–17.9 in	0	0	1	1	2	2	0	0	1	1	2	3	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 3b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	1	1	1	2	2	2	1	1	2	2	2	2
	0–3 in	1	1	1	1	1	2	1	1	1	1	1	2
	3–6 in	0	0	0	0	1	1	0	0	1	1	1	1
	6–12 in	2	1	1	1	1	2	2	1	1	2	2	2
	>12 in	2	2	3	3	3	3	3	3	3	3	3	3
	Litter	4	3	3	3	3	2	3	3	3	2	2	2
	Duff	7	7	6	5	5	4	6	5	5	4	4	4
	Moderate	32	39	48	2	0	13	47	59	69	85	14	114
	Flame length (ft)	49	48	47	47	46	46	45	42	39	37	37	37
	Torching index	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Prescribed fire	Crowning index	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Passive	Surface
	Type of fire	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Passive	Surface
	Severe	1	3	4	22	21	18	2	5	7	28	29	25
	0–17.9 in	0	0	1	1	2	2	0	0	1	1	2	3
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	0	1	1	1	2	2	0	1	1	2	2	2
	Surface fuel loadings (tons/ac)	1	1	1	1	1	1	1	2	2	2	2	2
	0–3 in	1	1	1	1	1	1	1	2	2	2	2	2
	3–6 in	1	1	1	1	1	1	1	2	2	2	2	2
	6–12 in	0	1	1	1	2	2	0	1	1	1	2	2
>12 in	0	1	1	1	1	2	2	1	1	1	1	2	
Litter	2	2	2	2	2	2	3	2	2	3	3	3	
Duff	4	4	3	3	3	2	3	3	3	3	3	2	
Moderate	7	7	7	6	5	4	6	6	6	5	4	4	
Flame length (ft)	32	32	42	0	0	6	38	41	52	0	0	7	
Torching index	49	51	51	50	50	50	45	49	46	44	43	43	
Crowning index	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Passive	Passive	Surface	
Type of fire	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Passive	Passive	Surface	
Severe	9	9	7	22	21	18	17	9	8	25	24	21	
0–17.9 in	1	1	1	1	1	2	1	1	1	1	2	2	
18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 3b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	0–3 in	4	2	2	3	3	4	2	3	3	3	3
		3–6 in	2	2	2	2	3	2	2	2	3	3	3
	Flame length (ft)	6–12 in	2	2	2	2	2	2	2	2	2	2	3
		>12 in	0	0	0	1	1	0	0	0	1	2	2
	Torching index	Litter	2	1	2	2	2	2	2	2	2	2	2
		Duff	4	4	4	4	4	4	4	4	5	5	5
	Crowning index	Moderate	2	2	2	2	2	2	2	2	2	2	2
		Severe	4	3	3	3	3	3	3	3	3	3	3
	Type of fire	Severe	35	73	83	99	102	27	47	60	62	10	8
		Moderate	38	37	35	33	32	38	32	30	29	29	28
Hard snags (stems/ac)	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	7	11	15	36	36	9	19	27	61	60	52	
	18–29.9 in	0	1	1	2	3	0	1	2	2	3	4	
Pile and burn	Surface fuel loadings (tons/ac)	30–36 in	0	0	0	0	0	0	0	0	0	0	0
		0–3 in	1	1	2	2	3	1	2	2	3	3	3
	Flame length (ft)	3–6 in	1	1	1	2	2	1	1	1	2	2	3
		6–12 in	1	1	1	1	1	1	1	1	1	1	2
	Torching index	>12 in	0	0	0	1	1	0	0	0	1	1	2
		Litter	2	1	2	2	2	2	2	2	2	2	2
	Crowning index	Duff	3	4	4	4	4	4	4	4	4	4	5
		Moderate	2	2	2	2	2	2	2	2	2	2	2
	Type of fire	Severe	4	3	3	3	3	3	3	3	3	3	3
		Severe	45	73	83	95	103	34	46	48	60	13	10
Hard snags (stems/ac)	Severe	38	37	35	33	32	38	34	33	32	31	31	
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
0–17.9 in	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	18–29.9 in	7	11	15	38	38	12	21	26	63	62	53	
	30–36 in	0	1	1	2	3	0	1	1	2	3	4	
18–29.9 in	Severe	0	0	0	0	0	0	0	0	0	0	0	
	0–17.9 in	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	

Table 3b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
Prescribed fire	Surface fuel loadings (tons/ac)	0	2	2	2	2	2	0	2	2	2	2	2	2
	0–3 in													
	3–6 in	1	3	3	3	3	3	1	3	3	3	3	3	3
	6–12 in	1	2	2	2	2	2	1	2	2	2	2	2	2
	>12 in	0	1	1	1	1	2	0	1	1	1	1	2	2
	Litter	1	1	1	2	2	2	1	1	1	1	2	2	2
	Duff	3	3	3	3	3	3	3	3	3	3	3	4	4
	Moderate	3	3	3	2	2	2	3	3	3	2	2	2	2
	Severe	6	5	5	4	3	3	6	5	4	4	4	3	3
	Torching index	32	44	57	75	10	22	26	41	54	42	72	11	49
Crowning index	Severe	51	45	42	40	39	51	45	42	40	39	39	39	
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Type of fire	Severe	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Passive	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	34	10	9	28	28	55	11	12	30	29	26		
Hard snags (stems/ac)	0–17.9 in	1	1	1	2	2	1	1	1	2	2	2	3	
	18–29.9 in													
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 3c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,345	1,989	1,669	1,391	1,155	960	216	206	191	177	164	154
	Quadratic mean diameter (in)	3	3.5	4.1	4.7	5.3	6	3	9.4	10.4	11.3	12.3	13.2
	Total volume (ft ³)	2,956	3,561	4,108	4,622	5,105	5,577	2,673	2,924	3,422	3,926	4,439	4,936
	Merchantable volume (ft ³)	2,411	2,778	3,214	3,760	4,209	4,674	2,287	2,491	2,945	3,439	3,909	4,357
	Basal area (ft ²)	114	135	151	166	178	189	92	99	112	124	135	146
	Stand density index	338	373	395	410	418	424	178	186	202	216	228	239
	Canopy closure (percent)	65	70	73	74	75	75	41	43	46	48	49	51
	Crown competition factor	116	137	154	168	179	189	79	85	95	105	113	122
	Canopy base height (ft)	3	3	4	4	3	3	4	6	8	10	12	13
	Canopy bulk density (kg/m ³)	0.14	0.14	0.14	0.14	0.13	0.13	0.04	0.04	0.05	0.05	0.05	0.05

Table 3c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,345	49	181	178	157	143	131	99	230	225	199	180	164
	Quadratic mean diameter (in)	3	17.6	9.6	10.2	11.4	12.5	13.5	13.2	9.2	9.8	10.9	11.9	13
	Total volume (ft ³)	2,956	2,671	2,898	3,355	3,804	4,260	4,729	2,998	3,265	3,789	4,321	4,836	5,337
	Merchantable volume (ft ³)	2,411	2,411	2,637	3,059	3,478	3,876	4,281	2,616	2,860	3,411	3,906	4,389	4,853
	Basal area (ft ²)	114	82	92	101	111	121	131	94	106	118	129	140	150
	Stand density index	338	120	170	184	193	203	214	155	202	218	229	239	248
	Canopy cover (percent)	65	31	33	35	38	41	44	36	39	41	43	46	47
	Crown competition factor	116	65	71	77	84	91	98	77	85	94	101	108	115
	Canopy base height (ft)	3	25	25	26	3	2	5	23	25	26	28	29	30
	Canopy bulk density (kg/m ³)	0.14	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.06	0.06	0.06
Pile and burn	Trees per acre	2,345	49	194	191	169	154	141	99	243	238	211	190	173
	Quadratic mean diameter (in)	3	17.6	9.3	9.9	11	12.1	13.1	13.2	9	9.5	10.6	11.6	12.6
	Total volume (ft ³)	2,956	2,671	2,899	3,363	3,816	4,275	4,743	2,998	3,265	3,803	4,322	4,828	5,323
	Merchantable volume (ft ³)	2,411	2,411	2,637	3,067	3,478	3,890	4,279	2,616	2,860	3,423	3,909	4,378	4,826
	Basal area (ft ²)	114	82	92	101	111	122	133	94	106	118	129	140	150
	Stand density index	338	120	173	187	196	207	218	155	204	221	231	242	251
	Canopy cover (percent)	65	31	33	35	39	42	45	36	39	41	44	46	48
	Crown competition factor	116	65	71	77	84	91	99	77	85	94	102	109	116
	Canopy base height (ft)	3	25	25	26	3	2	4	23	25	26	28	4	30
	Canopy bulk density (kg/m ³)	0.14	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.06	0.06	0.06
Prescribed fire	Trees per acre	2,345	49	202	199	177	162	150	99	224	220	195	178	163
	Quadratic mean diameter (in)	3	17.6	8.7	9.3	10.4	11.4	12.5	13.2	8.6	9.2	10.3	11.3	12.3
	Total volume (ft ³)	2,956	2,455	2,671	3,110	3,561	4,026	4,509	2,596	2,835	3,320	3,817	4,324	4,814
	Merchantable volume (ft ³)	2,411	2,217	2,431	2,838	3,241	3,630	4,031	2,303	2,528	3,006	3,461	3,917	4,329
	Basal area (ft ²)	114	82	84	93	103	115	127	94	91	101	112	124	136
	Stand density index	338	120	162	176	187	200	213	155	177	192	204	217	229
	Canopy cover (percent)	65	31	31	33	37	41	45	36	34	36	40	43	46
	Crown competition factor	116	65	64	70	78	86	95	77	71	78	86	95	103
	Canopy base height (ft)	3	26	25	27	2	2	4	24	25	27	2	2	4
	Canopy bulk density (kg/m ³)	0.14	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05

Table 3c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,345	194	317	306	273	247	224	289	472	450	392	347	310
	Quadratic mean diameter (in)	3	9.9	8.3	8.9	9.9	10.9	11.8	8.3	7	7.7	8.6	9.6	10.5
	Total volume (ft ³)	2,956	3,177	3,467	4,059	4,640	5,188	5,704	3,250	3,577	4,220	4,820	5,399	5,968
	Merchantable volume (ft ³)	2,411	2,605	2,824	3,419	4,063	4,619	5,131	2,624	2,847	3,585	4,112	4,651	5,220
	Basal area (ft ²)	114	104	119	133	147	159	169	107	127	145	160	174	187
	Stand density index	338	192	235	256	270	282	291	213	268	294	310	324	336
	Canopy cover (percent)	65	46	49	51	54	55	57	50	55	58	61	63	64
	Crown competition factor	116	92	104	115	125	134	141	99	116	131	144	156	168
	Canopy base height (ft)	3	12	17	18	21	22	23	7	9	11	12	3	4
Canopy bulk density (kg/m ³)	0.14	0.06	0.06	0.06	0.07	0.07	0.07	0.06	0.07	0.08	0.08	0.08	0.08	
Pile and burn	Trees per acre	2,345	194	331	319	283	255	231	289	489	467	407	360	322
	Quadratic mean diameter (in)	3	9.9	8.1	8.8	9.7	10.7	11.6	8.3	6.8	7.4	8.3	9.1	10
	Total volume (ft ³)	2,956	3,177	3,468	4,070	4,646	5,194	5,705	3,210	3,503	4,086	4,643	5,173	5,669
	Merchantable volume (ft ³)	2,411	2,605	2,825	3,403	4,075	4,593	5,135	2,597	2,810	3,335	3,942	4,477	4,998
	Basal area (ft ²)	114	104	119	134	147	159	170	107	123	138	152	164	175
	Stand density index	338	192	237	258	272	284	293	213	264	286	300	312	322
	Canopy cover (percent)	65	46	49	51	54	55	57	50	54	56	59	61	62
	Crown competition factor	116	92	104	115	125	134	142	99	112	125	137	147	156
	Canopy base height (ft)	3	12	17	18	20	21	23	7	9	9	11	3	3
Canopy bulk density (kg/m ³)	0.14	0.06	0.06	0.06	0.07	0.07	0.07	0.06	0.06	0.07	0.07	0.07	0.07	
Prescribed fire	Trees per acre	2,345	194	256	251	224	203	186	289	272	265	237	215	198
	Quadratic mean diameter (in)	3	9.9	8.3	8.9	10	11	12	8.3	8.1	8.7	9.7	10.7	11.6
	Total volume (ft ³)	2,956	2,665	2,918	3,451	3,981	4,516	5,028	2,670	2,924	3,442	3,962	4,475	4,985
	Merchantable volume (ft ³)	2,411	2,297	2,517	3,068	3,583	4,067	4,524	2,293	2,510	3,023	3,519	4,005	4,459
	Basal area (ft ²)	114	104	96	109	121	133	145	107	97	110	122	134	146
	Stand density index	338	192	190	208	222	236	248	213	194	213	226	240	252
	Canopy cover (percent)	65	46	39	42	45	48	51	50	40	43	47	50	53
	Crown competition factor	116	92	79	88	97	107	116	99	81	91	101	110	120
	Canopy base height (ft)	3	17	18	20	22	3	5	12	15	17	19	3	11
Canopy bulk density (kg/m ³)	0.14	0.04	0.04	0.05	0.05	0.05	0.05	0.04	0.04	0.05	0.05	0.05	0.05	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 3d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only							
	Fuel models			Fuel models			Fuel models			Fuel models				
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Percent
None	1	9	100				2	55	9	45				
	10	9	100				9	64	2	36				
	20	9	94	10	6		9	78	2	22				
	30	9	84	10	16		9	89	2	11				
	40	9	74	10	26		9	96	2	3		10	1	
50	9	62	10	38		9	94	10	6					

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit							
	Fuel models			Fuel models			Fuel models			Fuel models				
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Percent
None	1	2	61	10	37	9	2	46	10	31	9	22		
	10	2	84	9	16		2	55	9	45				
	20	2	74	9	26		9	55	2	45				
	30	2	59	9	41		9	67	2	33				
	40	9	57	2	43		9	78	2	22				
50	9	70	2	30		9	86	2	14					
Pile and burn	1	2	96	9	4		2	68	9	32				
	10	2	84	9	16		2	55	9	45				
	20	2	73	9	27		9	56	2	44				
	30	2	56	9	44		9	68	2	32				
	40	9	60	2	40		9	79	2	21				
50	9	75	2	25		9	89	2	11					
Prescribed fire	1	2	100	0	0		2	96	9	4				
	10	2	97	9	3		2	82	9	18				
	20	2	85	9	15		2	69	9	31				
	30	2	64	9	36		2	51	9	49				
	40	9	57	2	43		9	67	2	33				
50	9	74	2	26		9	81	2	19					

Table 3d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit											
	Fuel models					Fuel models					Fuel models					Fuel models						
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	
None	1	9	67	2	18	10	15	Percent	9	90	10	10	Percent	9	90	10	10	Percent	9	90	10	10
	10	9	94	2	6				9	100				9	100				9	100		
	20	9	100						9	100				9	100				9	100		
	30	9	100						9	96	10	4		9	96	10	4		9	96	10	4
	40	9	98	10	2				9	87	10	13		9	87	10	13		9	87	10	13
50	9	91	10	9				9	76	10	24		9	76	10	24		9	76	10	24	
Pile and burn	1	9	79	2	21				9	100				9	100				9	100		
	10	9	94	2	6				9	100				9	100				9	100		
	20	9	100						9	100				9	100				9	100		
	30	9	100						9	100				9	100				9	100		
	40	9	100						9	99	10	1		9	99	10	1		9	99	10	1
50	9	96	10	4				9	90	10	10		9	90	10	10		9	90	10	10	
Prescribed fire	1	2	74	9	26				2	68	9	32		2	68	9	32		2	68	9	32
	10	2	56	9	44				9	52	2	48		9	52	2	48		9	52	2	48
	20	9	59	2	41				9	67	2	33		9	67	2	33		9	67	2	33
	30	9	76	2	24				9	85	2	15		9	85	2	15		9	85	2	15
	40	9	92	2	8				9	100	2	4		9	100	2	4		9	100	2	4
50	9	98	10	2				9	96	10	4		9	96	10	4		9	96	10	4	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 3e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff	Live
Severe—98 th percentile	17	96	2	4	10	15	50	100
Moderate—75 th percentile	9	74	5	7	15	22	125	150

Table 3f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

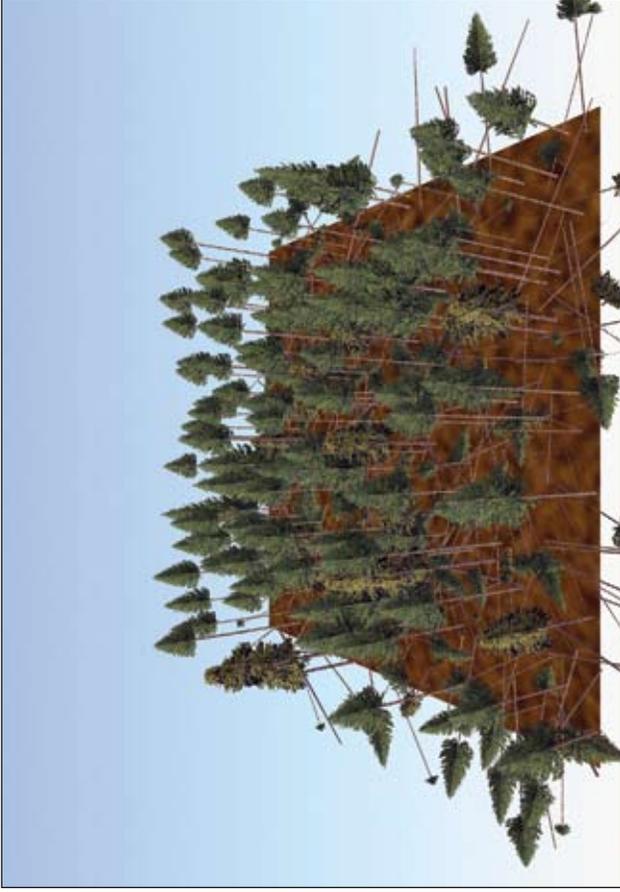
Site: Elevation = 5,200 ft, slope = 33 percent, aspect = 360°.

Species (based on trees per acre): Douglas-fir (*Pseudotsuga menziesii*) = 91 percent, ponderosa pine (*Pinus ponderosa*) = 6 percent.

Stand attributes: Stem density = 452 tpa, basal area = 123 ft²/ac, top height = 63 ft, stand density index = 258, quadratic mean diameter = 7.1 in, crown competition factor = 134, canopy cover = 57 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has 452 trees per acre (tpa) composed primarily of Douglas-fir with a ponderosa pine overstory. Woody fuel loading is 9 tons/ac and litter and duff loading is 12 tons/ac. Canopy base height is 13 ft and canopy bulk density is 0.17 kg/m³ (0.0106 lb/ft³), so ladder fuels are not sufficient to enable passive crown fire, but canopy fuels are sufficient to enable crown fire spread, so the predicted fire type is conditional crown fire under severe fire weather. Potential basal area mortality is relatively low (30 percent) even for severe fire weather, likely because the stand is dominated by fire-resistant tree species. With no action, there is little accumulation of surface fuels, and flame lengths remain below 4 ft for the 50-year projection. Canopy base height remains high enough that passive crown fire is unlikely. Canopy bulk density decreases over time, and is low enough after 40 years that the predicted fire type changes from conditional crown fire to surface fire for severe fire weather. Surface fire remains the predicted fire type under moderate fire weather for the 50-year projection.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment raises canopy base height and decreases canopy bulk density only slightly, but the effect is sufficient to change the predicted fire type to surface fire for severe fire weather. Surface fuels are reduced initially, but more snags are created, which contributes to surface fuel loading in the future. Thinning to 200 tpa or less is needed to raise canopy base height significantly and reduce canopy bulk density enough to affect crown fire potential under severe fire weather. Although heavy thinnings have increased activity fuels, canopy base height is raised well above expected flame length. These activity fuels are reduced by the pile and burn treatment and to a greater extent by the prescribed fire, but this change in surface fuels does not reduce flame lengths, because the heavily thinned stands with low woody surface fuels are characterized by fuel model 2 with grass fuels driving predicted fire behavior. The 200 and 300 tpa treatments are characterized by fuel model 9 after surface fuel treatments and therefore have lower flame lengths. The influence of grass fuels on fire behavior is site specific, and grass fuels are not tracked in the FFE, so these results should be interpreted cautiously.

Silvicultural and surface fuel treatments—long-term effects

The 100 and 200 tpa treatments with pile and burn or no surface fuel treatment have a long-term effect on reducing crown fire potential. In these treatments the predicted fire type remains surface fire, flame lengths remain low, and canopy base height continues to increase over time. The prescribed fire only treatment also has a similar effect on long-term crown fire potential. In the 50 tpa treatment, regardless of surface fuels treatment, regeneration causes a drop in canopy base height in 30 yrs and the predicted fire type is passive crown fire for severe and moderate fire weather. Also in this treatment, flame lengths decrease over time but remain above 5 ft for severe fire weather for the 50-year projection. The 300 tpa treatment is not sufficient to reduce canopy bulk density, so conditional crown fire is predicted for the entire 50-year projection, although flame lengths remain low and canopy base height increases over time.

Table 4a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit	
None	Surface fuel loadings (tons/ac)	0–3 in	1	9	7	4	3	
		3–6 in	0	5	5	5	3	
	>12 in	6–12 in	1	3	3	3	3	
		>12 in	0	0	0	0	0	
	Flame length (ft)	Litter	2	3	2	2	2	
		Duff	10	10	10	10	10	
	Torching index	Moderate	2	3	3	2	2	
		Severe	3	5	5	3	3	
	Crowning index	Severe	57	51	120	45	26	57
		Severe	15	22	50	29	18	15
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Conditional	Surface	Surface	Surface	Surface	Conditional	
Potential basal area mortality (%)	Moderate	20	22	12	17	23	25	
	Severe	30	41	32	42	28	30	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in		2	2	1	1	
		3–6 in		1	1	1	1	
	>12 in	6–12 in		1	1	1	1	
		>12 in		0	0	0	0	
	Flame length (ft)	Litter		2	2	2	2	
		Duff		9	9	9	9	
	Torching index	Moderate		4	3	2	2	
		Severe		8	6	3	3	
	Crowning index	Severe		29	47	63	67	
		Severe		50	29	18	15	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface		
	Severe	Conditional	Surface	Surface	Surface	Conditional		
Potential basal area mortality (%)	Moderate		13	17	23	25		
	Severe		96	78	26	29		
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in		0	0	0	0	
		3–6 in		1	1	1	1	
	>12 in	6–12 in		2	2	2	2	
		>12 in		0	0	0	0	
	Flame length (ft)	Litter		0	0	1	1	
		Duff		7	7	7	7	
	Torching index	Moderate		4	4	3	3	
		Severe		8	7	5	5	
	Crowning index	Severe		31	31	49	51	
		Severe		57	34	24	22	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface		
	Severe	Conditional	Surface	Surface	Surface	Conditional		
Potential basal area mortality (%)	Moderate		13	17	21	22		
	Severe		96	96	48	41		

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 4b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	3	3	4	4	4	4	1	3	3	3	3	3
	0–3 in	3	3	4	4	4	4	1	3	3	3	3	3
	3–6 in	3	3	4	4	4	4	0	4	4	4	4	4
	6–12 in	3	3	4	4	5	6	1	6	6	6	6	6
	>12 in	0	0	1	1	1	2	0	1	1	1	2	2
	Litter	2	2	2	2	2	2	1	1	1	1	1	1
	Duff	10	10	10	10	10	10	7	7	7	7	7	7
	Moderate	2	2	2	2	2	3	3	3	3	3	3	3
	Severe	3	3	4	4	4	4	5	5	4	4	4	4
	Torching index	57	18	20	66	21	27	51	41	51	57	63	67
None	Crowning index	15	16	16	16	17	18	22	23	23	24	24	24
	Type of fire	Surface Cond.	Surface	Surface	Surface	Surface	Surface	Surface					
	Moderate	Surface Cond.	Surface	Surface	Surface	Surface	Surface	Surface					
	Severe	Cond.	Cond.	Cond.	Cond.	Cond.	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	78	82	68	59	53	48	116	20	20	16	15	
	18–29.9 in	2	2	1	1	2	2	2	2	1	1	1	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	
	Hard snags (stems/ac)												
None	Surface fuel loadings (tons/ac)	9	3	2	2	1	2	7	3	2	2	2	2
	0–3 in	9	3	2	2	1	2	7	3	2	2	2	2
	3–6 in	5	5	4	4	4	3	5	5	5	4	4	4
	6–12 in	3	3	3	3	3	3	3	3	3	3	3	3
	>12 in	0	0	1	1	1	1	0	0	1	1	1	1
	Litter	3	1	1	1	1	1	2	1	1	1	1	2
	Duff	10	10	10	10	10	10	10	10	10	10	10	10
	Moderate	3	4	4	4	4	3	3	3	3	3	3	3
	Severe	5	8	8	7	7	5	5	6	5	5	5	4
	Torching index	120	25	30	0	0	15	45	45	57	70	70	88
None	Crowning index	50	44	42	41	41	40	29	28	27	26	26	26
	Type of fire	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	
	Moderate	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	48	32	7	16	15	14	49	34	10	25	25	
	18–29.9 in	2	2	1	1	1	2	2	2	1	1	1	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	
	Hard snags (stems/ac)												

Table 4b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
Pile and burn	Surface fuel loadings (tons/ac)	2	1	1	1	1	2	2	1	2	2	2	2	
	0–3 in													
	3–6 in	1	2	2	2	2	1	1	2	2	2	2	2	
	6–12 in	1	1	1	1	1	1	1	1	2	2	2	2	
	>12 in	0	0	1	1	1	0	0	0	1	1	1	1	
	Litter	2	1	1	1	1	2	1	1	1	1	2	2	
	Duff	9	9	9	9	9	9	9	9	9	9	9	9	
	Moderate	4	4	4	4	4	3	3	3	3	3	3	2	
	Severe	8	8	8	7	7	6	6	6	5	5	4	4	
	Severe	29	26	30	0	4	47	54	54	64	77	91	103	
Type of fire	Crowning index	50	44	42	41	41	29	28	26	26	26	26	26	
	Moderate	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	48	32	7	17	16	49	34	11	26	27	25	25	
	18–29.9 in	2	2	1	1	1	2	2	1	1	1	1	2	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
	Prescribed fire	Surface fuel loadings (tons/ac)	0	1	1	1	1	0	0	1	1	2	2	2
		0–3 in												
		3–6 in	1	2	2	2	2	1	2	2	2	2	2	2
		6–12 in	2	3	3	3	3	2	4	4	4	4	4	4
>12 in		0	1	1	1	1	0	1	1	1	1	1	2	
Litter		0	1	1	1	1	2	1	1	1	1	1	1	
Duff		7	7	7	7	7	9	7	7	7	7	7	7	
Moderate		4	4	4	4	4	4	4	4	3	3	3	3	
Severe		8	8	8	7	7	7	7	7	6	5	5	4	
Severe		31	24	29	0	4	31	39	39	49	0	8	86	
Type of fire	Crowning index	57	49	46	45	44	34	33	31	30	30	29	29	
	Moderate	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	
	0–17.9 in	32	15	9	15	14	36	16	12	23	23	21	21	
	18–29.9 in	2	2	1	1	1	2	2	1	1	1	1	1	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 4b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	2	2	3	3	3	0	3	3	3	3	3
	0–3 in												
	3–6 in	1	4	4	4	4	3	1	5	4	4	4	4
	6–12 in	2	6	6	6	6	6	2	6	6	6	6	6
	>12 in	0	1	1	1	2	2	0	1	1	1	2	2
	Litter	1	1	2	2	2	2	1	1	2	2	2	2
	Duff	7	7	7	7	7	7	7	7	7	7	7	7
	Moderate	3	3	3	3	2	2	3	3	3	2	2	2
	Severe	5	5	4	4	4	4	5	4	4	4	4	4
	Torching index	49	42	49	58	8	74	51	43	50	58	69	72
	Crowning index	24	23	22	22	22	22	22	21	21	21	22	22
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	48	19	17	33	34	31	68	21	21	37	37	33
	0–17.9 in												
	18–29.9 in	2	2	1	1	1	2	2	2	1	1	1	1
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

tpa = trees per acre; d.b.h. = diameter at breast height; cond. = conditional.

Table 4c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	452	399	353	313	279	250	164	159	150	142	134	127
	Quadratic mean diameter (in)	7.1	7.8	8.5	9.3	10.0	10.8	7.1	10.8	11.6	12.3	12.9	13.6
	Total volume (ft ³)	2,774	3,158	3,507	3,833	4,142	4,417	2,261	2,434	2,761	3,077	3,381	3,667
	Merchantable volume (ft ³)	2,097	2,508	2,879	3,292	3,596	3,866	1,838	2,000	2,338	2,682	2,973	3,233
	Basal area (ft ²)	123	132	140	147	153	158	97	101	109	116	122	128
	Stand density index	258	268	274	278	280	281	175	180	189	196	203	208
	Canopy closure (percent)	57	57	58	58	58	58	46	46	47	47	48	48
	Crown competition factor	134	142	148	151	154	156	102	105	110	114	118	121
	Canopy base height (ft)	13	5	6	19	7	9	15	16	19	21	23	25
	Canopy bulk density (kg/m ³)	0.17	0.17	0.16	0.16	0.15	0.15	0.11	0.10	0.10	0.10	0.10	0.10

Table 4c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit					
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs
None	Trees per acre	452	45	154	152	138	129	122	192	197	171	156	142
	Quadratic mean diameter (in)	7.1	14.8	8.5	10.0	11.0	11.9	12.7	9.0	9.5	10.5	11.4	12.3
	Total volume (ft ³)	2,774	1,348	1,476	2,033	2,345	2,698	1,964	2,117	2,421	2,740	3,035	3,318
	Merchantable volume (ft ³)	2,097	1,182	1,313	1,812	2,049	2,376	1,722	1,867	2,142	2,446	2,709	2,955
	Basal area (ft ²)	123	55	61	76	85	95	80	88	95	103	110	117
	Stand density index	258	86	119	139	150	162	133	167	178	185	192	198
	Canopy cover (percent)	57	25	28	34	38	42	37	40	41	43	44	46
	Crown competition factor	134	49	53	64	71	79	79	86	91	95	100	103
	Canopy base height (ft)	13	28	23	2	5	6	22	22	24	26	28	29
	Canopy bulk density (kg/m ³)	0.17	0.04	0.05	0.05	0.05	0.05	0.08	0.08	0.09	0.09	0.09	0.09
Pile and burn	Trees per acre	452	45	165	162	148	138	131	203	208	181	164	151
	Quadratic mean diameter (in)	7.1	14.8	8.2	9.7	10.6	11.6	12.7	8.8	9.3	10.2	11.1	12.0
	Total volume (ft ³)	2,774	1,348	1,477	2,011	2,321	2,683	1,964	2,118	2,441	2,744	3,050	3,340
	Merchantable volume (ft ³)	2,097	1,182	1,310	1,780	2,011	2,338	1,722	1,868	2,155	2,460	2,715	2,964
	Basal area (ft ²)	123	55	61	76	85	96	80	88	96	103	111	118
	Stand density index	258	86	121	141	153	165	133	169	181	188	195	201
	Canopy cover (percent)	57	25	28	35	39	43	37	40	41	43	45	47
	Crown competition factor	134	49	53	64	72	80	79	86	91	96	100	105
	Canopy base height (ft)	13	28	23	2	4	4	22	22	24	26	28	29
	Canopy bulk density (kg/m ³)	0.17	0.04	0.05	0.05	0.05	0.05	0.08	0.08	0.09	0.09	0.09	0.09
Prescribed fire	Trees per acre	452	45	170	167	154	145	138	198	202	177	163	151
	Quadratic mean diameter (in)	7.1	14.8	7.6	8.2	9.1	10.1	11.1	8.2	8.7	9.6	10.5	11.4
	Total volume (ft ³)	2,774	1,183	1,301	1,562	1,846	2,189	1,646	1,787	2,082	2,382	2,687	3,009
	Merchantable volume (ft ³)	2,097	1,037	1,154	1,393	1,619	1,874	1,443	1,576	1,839	2,123	2,363	2,627
	Basal area (ft ²)	123	55	54	61	70	81	80	74	82	90	98	107
	Stand density index	258	86	110	121	133	147	133	147	158	167	177	186
	Canopy cover (percent)	57	25	25	28	34	39	37	35	37	40	43	46
	Crown competition factor	134	49	47	52	59	68	79	71	76	82	88	94
	Canopy base height (ft)	13	32	23	26	2	4	23	22	24	3	4	20
	Canopy bulk density (kg/m ³)	0.17	0.03	0.04	0.04	0.04	0.04	0.06	0.07	0.07	0.07	0.08	0.08

Table 4c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	452	200	299	288	256	230	209	290	370	347	309	276	246
	Quadratic mean diameter (in)	7.1	10.2	8.7	9.2	10	10.7	11.5	8.8	8.3	8.9	9.7	10.6	11.4
	Total volume (ft ³)	2,774	2,788	2,973	3,326	3,650	3,954	4,218	3,060	3,316	3,805	4,241	4,622	4,960
	Merchantable volume (ft ³)	2,097	2,333	2,520	2,857	3,203	3,502	3,752	2,413	2,637	3,228	3,653	4,017	4,337
	Basal area (ft ²)	123	114	124	132	139	145	150	123	137	150	160	167	173
	Stand density index	258	208	240	251	255	258	260	237	272	287	296	300	302
	Canopy cover (percent)	57	53	54	54	55	55	55	57	58	59	59	60	60
	Crown competition factor	134	123	131	136	140	144	146	135	147	155	162	166	169
	Canopy base height (ft)	13	13	15	17	19	21	23	13	16	18	21	23	24
	Canopy bulk density (kg/m ³)	0.17	0.14	0.14	0.14	0.14	0.14	0.13	0.17	0.17	0.17	0.17	0.17	0.16
Pile and burn	Trees per acre	452	200	310	299	265	238	215	290	379	355	315	280	250
	Quadratic mean diameter (in)	7.1	10.2	8.6	9	9.8	10.6	11.3	8.8	8	8.5	9.3	10	10.7
	Total volume (ft ³)	2,774	2,788	2,974	3,318	3,646	3,952	4,227	2,962	3,147	3,506	3,841	4,140	4,409
	Merchantable volume (ft ³)	2,097	2,333	2,518	2,842	3,211	3,521	3,755	2,327	2,503	2,887	3,299	3,593	3,848
	Basal area (ft ²)	123	114	124	132	139	145	150	123	132	140	147	153	158
	Stand density index	258	208	242	252	257	260	262	236	264	274	278	280	281
	Canopy cover (percent)	57	53	54	54	55	55	55	56	57	58	58	58	58
	Crown competition factor	134	123	131	136	140	144	146	134	142	147	151	153	156
	Canopy base height (ft)	13	13	15	17	19	21	23	13	15	17	20	21	23
	Canopy bulk density (kg/m ³)	0.17	0.14	0.14	0.14	0.14	0.14	0.14	0.17	0.16	0.16	0.16	0.15	0.14
Prescribed fire	Trees per acre	452	200	267	259	231	209	190	290	290	279	248	224	204
	Quadratic mean diameter (in)	7.1	10.2	8.2	8.7	9.5	10.3	11.1	8.8	8	8.5	9.3	10.1	10.9
	Total volume (ft ³)	2,774	2,176	2,351	2,693	3,024	3,329	3,612	2,261	2,438	2,789	3,127	3,452	3,757
	Merchantable volume (ft ³)	2,097	1,841	2,019	2,327	2,677	2,952	3,196	1,837	2,003	2,368	2,731	3,023	3,301
	Basal area (ft ²)	123	114	98	106	114	121	128	123	102	110	118	126	132
	Stand density index	258	208	194	206	213	219	224	236	203	215	222	229	234
	Canopy cover (percent)	57	53	46	47	48	50	51	56	47	48	49	51	52
	Crown competition factor	134	123	101	106	112	117	121	134	106	112	117	122	126
	Canopy base height (ft)	13	16	16	18	20	4	24	15	16	18	20	23	24
	Canopy bulk density (kg/m ³)	0.17	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.11	0.11	0.11

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 4d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only									
	Fuel models			Fuel models			Fuel models			Fuel models						
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent
None	1	9	93	10	7	73	9	27	2	27	73	9	2	27	73	9
	10	9	88	10	12	59	9	29	10	29	59	9	2	13	59	9
	20	9	78	10	22	63	9	26	10	26	63	9	2	11	63	9
	30	9	71	10	29	64	9	27	10	27	64	9	2	10	64	9
	40	9	65	10	35	64	9	27	10	27	64	9	2	9	64	9
50	9	58	10	42	63	9	29	10	29	63	9	2	8	63	9	

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit									
	Fuel models			Fuel models			Fuel models			Fuel models						
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent
None	1	11	65	2	18	17	11	49	2	25	49	11	9	14	49	11
	10	2	83	10	17	44	2	44	9	41	44	2	10	15	44	2
	20	2	99	9	1	51	9	51	2	43	51	9	10	6	51	9
	30	2	79	9	21	61	9	61	2	35	61	9	10	3	61	9
	40	2	59	9	41	69	9	69	2	27	69	9	10	4	69	9
50	9	58	2	42	74	9	74	2	19	74	9	10	6	74	9	
Pile and burn	1	2	100				2	63	9	37	63	2	9	37	63	2
	10	2	100				2	52	9	48	52	2	9	48	52	2
	20	2	98				9	56	2	44	56	9	2	44	56	9
	30	2	77				9	65	2	35	65	9	2	35	65	9
	40	2	55				9	75	2	25	75	9	2	25	75	9
50	9	64	2	36	83	9	83	2	17	83	9	2	17	83	9	
Prescribed fire	1	2	100				2	92	9	8	92	2	9	8	92	2
	10	2	100				2	76	9	24	76	2	9	24	76	2
	20	2	100				2	66	9	34	66	2	9	34	66	2
	30	2	81				2	51	9	49	51	2	9	49	51	2
	40	2	54				9	65	2	35	65	9	2	35	65	9
50	9	69	2	31	78	9	78	2	22	78	9	2	22	78	9	

Table 4d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit									
	Years					Fuel models					Fuel models					Fuel models				
	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent
None	1	9	64	11	36	9	93	10	7	9	93	10	7		9	93	10	7		
	10	9	82	10	18	9	87	10	13	9	87	10	13		9	87	10	13		
	20	9	79	10	21	9	75	10	25	9	75	10	25		9	75	10	25		
	30	9	75	10	25	9	67	10	33	9	67	10	33		9	67	10	33		
	40	9	71	10	29	9	59	10	41	9	59	10	41		9	59	10	41		
50	9	65	10	35						9	50	10	50		9	50	10	50		
Pile and burn	1	9	100			9	100			9	100				9	100				
	10	9	100			9	100			9	100				9	100				
	20	9	100			9	96	10	4	9	96	10	4		9	96	10	4		
	30	9	93	10	7	9	85	10	15	9	85	10	15		9	85	10	15		
	40	9	86	10	14	9	78	10	22	9	78	10	22		9	78	10	22		
50	9	79	10	21	9	69	10	31	9	69	10	31		9	69	10	31			
Prescribed fire	1	9	64	2	36	9	73	2	27	9	73	2	27		9	73	2	27		
	10	9	63	10	20	2	18	10	29	9	61	10	29		9	61	10	29		
	20	9	65	10	21	2	13	10	29	9	64	10	29		9	64	10	29		
	30	9	71	10	22	2	7	10	30	9	68	10	30		9	68	10	30		
	40	9	75	10	23	2	2	10	30	9	70	10	30		9	70	10	30		
50	9	74	10	26	2	2	10	31	9	69	10	31		9	69	10	31			

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 4e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					Live
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff	
Severe—98 th percentile	17	96	2	4	10	15	50	100
Moderate—75 th percentile	9	74	5	7	15	22	125	150

Table 4f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

Site: Elevation = 5,200 ft, slope = 40 percent, aspect = 225°.

Species (based on trees per acre): Douglas-fir (*Pseudotsuga menziesii*) = 74 percent, hardwoods = 23 percent, ponderosa pine (*Pinus ponderosa*) = 2 percent.

Stand attributes: Stem density = 873 tpa, basal area = 197 ft²/ac, top height = 75 ft, stand density index = 430, quadratic mean diameter = 6.4 in, crown competition factor = 280, canopy cover = 71 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has initial tree density of 873 trees per acre (tpa) composed of Douglas-fir and hardwood understory with Douglas-fir and ponderosa pine overstory. Woody fuel loading is 10 tons/ac, and litter and duff loading is 12 tons/ac. Canopy bulk density is 0.21 kg/m³ (0.0131 lb/ft³), and canopy base height is 7 ft, so ladder fuels are not sufficient to enable passive crown fire. Canopy fuels are sufficient to sustain crown fire spread, so the predicted fire type is conditional crown fire for severe fire weather. Predicted basal area mortality is about 25 percent for moderate and severe fire weather. With no action, surface fuels accumulate and potential flame lengths increase, but canopy base height also increases, so passive crown fire remains unlikely. Canopy bulk density remains high, so the predicted fire type for severe fire weather is conditional crown fire for the 50-year projection.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment raises canopy base height and decreases canopy bulk density only slightly, so there is little change in crown fire potential. Surface fuels are consumed, and flame lengths decrease immediately after treatment. All thinning treatments reduce canopy bulk density and increase canopy base height, but thinning to 100 tpa or less is necessary to decrease crown fire potential. However, the lower density thinning treatments greatly increase surface fuel loading and have higher potential flame lengths and basal area mortality. Activity fuels are reduced by the pile and burn treatment and to a greater extent by the prescribed fire treatment, but flame lengths and basal area mortality increase following surface fuel treatments in the low-density treatments, because fire behavior predictions are dominated by fuel model 2. In the high-density treatments, activity fuels are reduced by surface fuel treatments causing a decrease in potential flame lengths and basal area mortality.

Silvicultural and surface fuel treatments—long-term effects

In the prescribed fire only treatment, surface fuels and flame lengths increase in 10 years as snags fall and contribute to surface fuel loading, but after 10 years, surface fuels and flame lengths decrease. Canopy bulk density remains high, so the predicted fire type is conditional crown fire for the 50-year projection. In the lower density treatments (50 and 100 tpa), predicted fire type is surface fire for the 50-year projection, and potential flame lengths decrease over time as the influence of grass fuels declines. Crown fire potential continues to decrease over time as trees grow and the stand self-thins, causing canopy base height to increase. In the higher density treatments (200 and 300 tpa), canopy bulk density remains high and the predicted fire type for severe fire weather is conditional crown fire for the 50-year projection except in the 200 tpa treatment with a prescribed fire. In this treatment, additional fire-caused tree mortality reduces canopy bulk density, and the predicted fire type changes from conditional crown fire to surface fire in 20 years.

Table 5a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit	
None	Surface fuel loadings (tons/ac)	0–3 in	1	12	10	7	5	
		3–6 in	0	6	6	6	5	
	>12 in	6–12 in	2	3	3	3	3	
		>12 in	0	0	0	0	0	
	Flame length (ft)	Litter	1	4	3	3	3	
		Duff	10	10	10	10	10	
	Torching index	Moderate	2	1	4	3	2	
		Severe	2	1	6	3	3	
	Crowning index	Severe	163	234	116	163	262	105
		Type of fire	13	17	45	24	13	13
Potential basal area mortality (%)	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Conditional	Conditional	Surface	Surface	Conditional	Conditional	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	3	3	2	2	2	
		3–6 in	2	2	2	2	1	
	>12 in	6–12 in	1	1	1	1	1	
		>12 in	0	0	0	0	0	
	Flame length (ft)	Litter	3	3	3	3	2	
		Duff	9	9	9	9	9	
	Torching index	Moderate	5	5	3	1	1	
		Severe	8	8	5	1	1	
	Crowning index	Severe	36	36	147	147	782	315
		Type of fire	24	45	24	24	13	13
Potential basal area mortality (%)	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Conditional	Conditional	Surface	Surface	Conditional	Conditional	
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	0	0	0	0	
		3–6 in	2	2	2	2	1	
	>12 in	6–12 in	2	2	2	2	2	
		>12 in	0	0	0	0	0	
	Flame length (ft)	Litter	1	1	1	1	1	
		Duff	7	7	7	7	7	
	Torching index	Moderate	5	5	4	2	1	
		Severe	9	9	6	3	1	
	Crowning index	Severe	36	36	80	362	255	
		Type of fire	48	48	28	17	17	
Potential basal area mortality (%)	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Conditional	Conditional	Surface	Surface	Conditional	Conditional	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 5b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	0–3 in	3	5	6	6	6	7	1	5	4	4	4	4
		3–6 in	4	4	4	4	4	5	0	4	4	4	4	4
	Torching index	6–12 in	3	3	3	4	4	4	2	5	5	5	5	5
		>12 in	0	0	0	1	2	2	0	1	1	2	2	2
	Crowning index	Litter	2	3	3	3	3	3	1	2	2	2	2	2
		Duff	10	10	10	11	11	11	7	7	7	8	8	8
	Flame length (ft)	Moderate	2	2	3	3	3	3	1	3	2	2	3	3
		Severe	2	3	4	4	4	4	1	4	3	4	4	4
	Type of fire	Severe	163	128	91	77	56	48	234	70	95	111	82	85
		Severe	13	13	13	13	14	14	17	20	20	20	19	19
Hard snags (stems/ac)	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	
	0–17.9 in	146	98	38	40	34	34	187	16	14	12	11	9	
None	Surface fuel loadings (tons/ac)	0–3 in	12	5	3	2	2	2	10	5	3	3	3	3
		3–6 in	6	5	5	4	4	4	6	5	5	5	4	4
		6–12 in	3	3	3	3	2	2	3	3	3	3	3	3
Flame length (ft)	>12 in	0	0	0	1	1	2	0	0	0	1	1	2	
	Litter	4	1	1	1	2	2	3	2	2	2	2	2	
Type of fire	Duff	10	10	10	10	10	10	10	10	10	10	10	11	
	Moderate	4	5	5	4	4	4	4	3	3	2	2	2	
Torching index	Severe	6	7	7	7	7	6	5	5	4	3	3	3	
	Severe	116	33	46	62	82	95	163	116	250	427	517	488	
Crowning index	Severe	45	43	42	44	44	45	24	26	26	27	27	27	
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Hard snags (stems/ac)	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	132	74	5	6	6	6	133	75	7	8	9	9	
	18–29.9 in	0	1	1	2	2	2	0	1	1	1	2	2	
None	Surface fuel loadings (tons/ac)	0–3 in	0	0	0	0	0	0	0	0	0	0	0	0
		3–6 in	0	0	0	0	0	0	0	0	0	0	0	0
		6–12 in	0	0	0	0	0	0	0	0	0	0	0	0

Table 5b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	0–3 in	7	4	4	4	4	5	4	4	5	6	5
		3–6 in	6	5	5	5	5	5	5	5	5	5	5
	>12 in	6–12 in	3	3	3	3	3	3	3	3	3	4	4
		>12 in	0	0	0	1	1	2	0	0	0	1	2
	Litter	Litter	3	2	2	2	2	3	3	3	3	3	3
		Duff	10	10	10	11	11	11	10	10	10	11	11
	Flame length (ft)	Moderate	3	2	2	2	2	2	2	2	2	3	3
		Severe	3	3	3	3	3	4	3	3	3	4	4
	Torching index	Severe	262	225	428	435	412	389	105	185	263	238	224
		Crowning index	13	17	18	18	18	18	13	15	16	16	16
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	
	0–17.9 in	134	77	10	11	12	12	135	79	14	23	23	
Hard snags (stems/ac)	18–29.9 in	0	1	1	1	2	2	0	1	1	2	4	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	
	0–3 in	2	3	3	4	4	4	2	3	4	5	5	
Pile and burn	Surface fuel loadings (tons/ac)	3–6 in	2	2	2	2	3	3	1	2	2	3	3
		6–12 in	1	1	1	1	2	2	1	1	1	2	3
	>12 in	>12 in	0	0	0	1	1	2	0	0	0	1	2
		Litter	3	2	2	2	2	3	2	3	3	3	3
	Duff	Duff	9	9	9	9	10	10	9	9	9	10	10
		Moderate	1	1	1	1	2	2	1	1	1	2	3
	Flame length (ft)	Severe	1	1	1	2	3	3	1	1	2	3	4
		Severe	782	702	1038	775	612	554	315	562	498	361	294
	Torching index	Severe	13	17	18	17	17	17	13	15	16	16	16
		Crowning index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Type of fire	Moderate	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	
	Severe	134	77	10	11	12	12	135	79	15	23	24	
	0–17.9 in	0	1	1	1	2	2	0	1	1	2	4	
Hard snags (stems/ac)	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	
	0–3 in	2	3	3	4	4	4	2	3	4	5	5	

Table 5b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	3	3	3	3	4	0	4	3	3	4	4
	0–3 in												
	3–6 in	2	3	3	3	3	4	1	4	4	4	4	4
	6–12 in	2	5	5	5	5	5	2	5	5	5	5	5
	>12 in	0	1	1	2	2	2	0	1	1	2	2	2
Flame length (ft)	Litter	1	2	2	2	2	2	1	2	2	2	2	2
	Duff	7	7	7	7	8	8	7	7	7	8	8	8
	Moderate	2	2	2	2	2	2	1	2	2	2	2	3
	Severe	3	3	3	3	3	3	1	3	3	3	4	4
	Torching index	362	367	456	469	436	404	255	153	231	274	269	266
Type of fire	Crowning index	17	20	21	22	22	22	17	20	21	21	21	21
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Cond.	Cond.	Surface	Surface	Surface	Surface	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.
	0–17.9 in	75	16	13	10	10	11	90	17	14	12	12	12
	18–29.9 in	1	1	1	2	2	2	1	1	1	2	2	2
Hard snags (stems/ac)	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

tpa = trees per acre; d.b.h. = diameter at breast height; cond. = conditional.

Table 5c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	873	843	847	817	834	809	307	304	298	292	286	282
	Quadratic mean diameter (in)	6.4	6.9	7.1	7.5	7.7	8.0	6.4	6.9	10.4	11.0	11.5	12.0
Total volume (ft ³)	Total volume (ft ³)	4,211	4,984	5,763	6,529	7,347	8,155	3,722	4,077	4,816	5,587	6,389	7,252
	Merchantable volume (ft ³)	3,327	4,005	4,787	5,397	6,156	6,811	3,136	3,504	4,201	4,891	5,612	6,472
Stand density index	Basal area (ft ²)	197	216	234	250	267	282	153	162	177	193	208	223
	Stand density index	430	460	491	514	543	565	286	298	320	340	360	380
Canopy closure (percent)	Canopy closure (percent)	71	71	72	72	72	72	56	58	60	60	61	62
	Crown competition factor	280	300	318	334	351	365	184	192	207	222	236	251
Canopy base height (ft)	Canopy base height (ft)	7	10	10	10	9	9	8	10	10	12	10	11
	Canopy bulk density (kg/m ³)	0.21	0.21	0.20	0.20	0.19	0.20	0.16	0.13	0.13	0.13	0.13	0.14

Table 5c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	873	50	127	123	121	118	115	99	175	171	167	163	160
	Quadratic mean diameter (in)	6.4	18.0	11.8	12.4	13.1	13.7	14.3	14.8	11.7	12.4	13.0	13.6	14.2
	Total volume (ft ³)	4,211	2,736	2,982	3,501	4,053	4,643	5,249	3,376	3,689	4,348	5,047	5,769	6,521
	Merchantable volume (ft ³)	3,327	2,452	2,728	3,184	3,708	4,250	4,834	2,989	3,327	3,924	4,585	5,284	5,986
	Basal area (ft ²)	197	87	96	104	112	121	129	119	131	143	154	166	177
	Stand density index	430	127	165	175	185	195	205	187	226	241	255	269	282
	Canopy cover (percent)	71	29	31	32	34	35	37	42	44	46	48	50	50
	Crown competition factor	280	76	82	88	95	102	109	119	129	139	149	159	169
Pile and burn	Canopy base height (ft)	7	30	24	28	30	34	36	26	24	29	33	36	39
	Canopy bulk density (kg/m ³)	0.21	0.05	0.05	0.05	0.05	0.05	0	0.10	0.09	0.09	0.09	0.09	0.09
Pile and burn	Trees per acre	873	50	134	131	128	125	122	99	183	179	175	171	167
	Quadratic mean diameter (in)	6.4	18.0	11.4	12.1	12.7	13.3	13.9	14.8	11.5	12.1	12.7	13.3	13.9
	Total volume (ft ³)	4,211	2,736	2,982	3,501	4,053	4,642	5,248	3,376	3,689	4,348	5,046	5,769	6,517
	Merchantable volume (ft ³)	3,327	2,452	2,728	3,184	3,708	4,250	4,834	2,989	3,327	3,924	4,583	5,284	5,986
	Basal area (ft ²)	197	87	96	104	112	121	129	119	131	143	154	166	177
	Stand density index	430	127	166	177	187	197	207	187	228	243	257	271	284
	Canopy cover (percent)	71	29	31	33	34	36	37	42	43	45	47	48	49
	Crown competition factor	280	76	82	88	96	102	109	119	129	139	150	159	169
Prescribed fire	Canopy base height (ft)	7	30	24	28	31	34	37	26	24	29	33	36	39
	Canopy bulk density (kg/m ³)	0.21	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.09	0.09	0.09	0.09	0.09
	Trees per acre	873	50	137	134	130	127	124	99	175	171	167	163	160
	Quadratic mean diameter (in)	6.4	18.0	10.9	11.5	12.1	12.7	13.3	14.8	11.0	11.7	12.3	12.9	13.5
	Total volume (ft ³)	4,211	2,533	2,765	3,253	3,772	4,327	4,898	3,030	3,317	3,924	4,569	5,239	5,938
	Merchantable volume (ft ³)	3,327	2,271	2,528	2,982	3,466	3,961	4,527	2,690	3,004	3,558	4,190	4,797	5,432
	Basal area (ft ²)	197	87	88	96	104	112	119	119	116	127	137	148	158
	Stand density index	430	127	157	167	177	186	196	187	204	218	232	245	257
Pile and burn	Canopy cover (percent)	71	29	29	30	32	33	35	42	40	42	44	45	46
	Crown competition factor	280	76	75	81	88	94	101	119	112	121	131	140	148
Prescribed fire	Canopy base height (ft)	7	30	33	34	37	36	39	26	27	29	32	35	39
	Canopy bulk density (kg/m ³)	0.21	0.04	0.04	0.04	0.04	0.04	0.04	0.08	0.08	0.08	0.08	0.08	0.07

Table 5c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	873	198	272	266	260	254	249	300	372	363	348	335	323
	Quadratic mean diameter (in)	6.4	12.1	10.8	11.4	12.0	12.5	13.1	10.4	9.9	10.4	10.9	11.4	11.9
	Total volume (ft ³)	4,211	4,122	4,504	5,302	6,147	7,015	7,895	4,407	4,817	5,655	6,397	7,157	7,934
	Merchantable volume (ft ³)	3,327	3,600	3,982	4,718	5,547	6,300	7,204	3,642	4,101	4,924	5,635	6,326	7,082
	Basal area (ft ²)	197	157	173	188	203	218	231	178	197	215	227	239	251
	Stand density index	430	268	308	328	347	365	382	321	363	387	402	416	429
	Canopy cover (percent)	71	55	58	61	62	63	63	64	67	68	67	67	67
	Crown competition factor	280	178	192	206	220	233	246	216	234	251	262	273	284
	Canopy base height (ft)	7	26	22	31	34	38	41	9	15	20	25	29	32
Canopy bulk density (kg/m ³)	0.21	0.21	0.16	0.15	0.15	0.15	0.15	0.21	0.17	0.17	0.17	0.17	0.17	
Pile and burn	Trees per acre	873	198	280	274	267	261	256	300	380	370	355	341	330
	Quadratic mean diameter (in)	6.4	12.1	10.6	11.2	11.8	12.4	12.9	10.4	9.8	10.3	10.8	11.3	11.8
	Total volume (ft ³)	4,211	4,122	4,504	5,302	6,147	7,015	7,904	4,407	4,817	5,644	6,385	7,145	7,922
	Merchantable volume (ft ³)	3,327	3,600	3,982	4,718	5,547	6,298	7,212	3,642	4,101	4,913	5,624	6,316	7,069
	Basal area (ft ²)	197	157	173	188	203	218	232	178	197	214	227	239	250
	Stand density index	430	268	309	330	349	367	385	321	365	388	403	417	430
	Canopy cover (percent)	71	55	58	61	62	63	63	64	67	67	67	67	67
	Crown competition factor	280	178	192	206	220	233	246	216	234	250	262	273	284
	Canopy base height (ft)	7	26	22	31	34	38	41	9	15	19	25	29	32
Canopy bulk density (kg/m ³)	0.21	0.21	0.16	0.15	0.15	0.15	0.15	0.21	0.17	0.17	0.17	0.17	0.17	
Prescribed fire	Trees per acre	873	198	239	234	229	223	219	300	286	280	274	268	262
	Quadratic mean diameter (in)	6.4	12.1	10.5	11.1	11.7	12.3	12.9	10.4	10.0	10.6	11.2	11.7	12.3
	Total volume (ft ³)	4,211	3,527	3,864	4,577	5,346	6,148	6,952	3,668	4,020	4,769	5,560	6,378	7,202
	Merchantable volume (ft ³)	3,327	3,099	3,444	4,099	4,829	5,599	6,342	3,123	3,544	4,216	4,965	5,777	6,545
	Basal area (ft ²)	197	157	144	157	171	185	197	178	156	172	187	201	215
	Stand density index	430	268	259	277	295	312	328	321	286	307	328	346	363
	Canopy cover (percent)	71	55	51	53	55	57	58	64	56	59	60	61	62
	Crown competition factor	280	178	154	166	179	192	203	216	175	189	204	218	231
	Canopy base height (ft)	7	26	26	30	33	36	40	9	15	20	25	28	31
Canopy bulk density (kg/m ³)	0.21	0.15	0.13	0.12	0.11	0.11	0.11	0.16	0.13	0.12	0.12	0.12	0.12	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 5d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only								
	Fuel models			Fuel models			Fuel models			Fuel models					
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight
None	1	8	87	10	13	Percent	8	100			Percent				
	10	8	66	10	34		8	52	10	48					
	20	8	51	10	49		8	64	10	36					
	30	10	58	8	42		8	61	10	39					
	40	10	68	8	32		8	57	10	43					
50	10	75	8	25		8	52	10	48						

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit								
	Fuel models			Fuel models			Fuel models			Fuel models					
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight
None	1	11	73	14	27	Percent	11	92	14	8	Percent				
	10	2	62	10	36		8	46	10	35		2	18		
	20	2	80	8	11		8	69	10	16		2	15		
	30	2	78	8	20		8	82	10	10		2	8		
	40	2	72	8	27		8	84	10	14		2	2		
50	2	63	8	31		8	78	10	22						
Pile and burn	1	2	86	10	14		8	57	2	40		10	3		
	10	2	96	8	4		8	72	2	28					
	20	2	87	8	13		8	82	2	18					
	30	2	79	8	21		8	91	2	9					
	40	2	72	8	28		8	96	2	4					
50	2	67	8	33		8	92	10	8						
Prescribed fire	1	2	100				2	65	8	35					
	10	2	100				2	51	8	49					
	20	2	98	8	2		8	61	2	39					
	30	2	90	8	10		8	69	2	29		10	1		
	40	2	83	8	17		8	72	2	21		10	7		
50	2	77	8	23		8	71	2	15		10	14			

Table 5d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit												
	Fuel models					Fuel models					Fuel models					Fuel models							
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Percent	
None	1	11	73	8	27	8	27	8	27	8	27	8	27	8	27	8	27	8	27	8	27	8	27
	10	8	65	10	35	10	35	10	35	10	35	10	35	10	35	10	35	10	35	10	35	10	35
	20	8	75	10	25	10	25	10	25	10	25	10	25	10	25	10	25	10	25	10	25	10	25
	30	8	71	10	29	10	29	10	29	10	29	10	29	10	29	10	29	10	29	10	29	10	29
	40	8	63	10	37	10	37	10	37	10	37	10	37	10	37	10	37	10	37	10	37	10	37
	50	8	58	10	42	10	42	10	42	10	42	10	42	10	42	10	42	10	42	10	42	10	42
Pile and burn	1	8	100			8	100			8	100			8	100			8	100			8	100
	10	8	100			8	100			8	100			8	100			8	100			8	100
	20	8	100			8	100			8	100			8	100			8	100			8	100
	30	8	91	10	9	10	9	10	9	10	9	10	9	10	9	10	9	10	9	10	9	10	9
	40	8	79	10	21	10	21	10	21	10	21	10	21	10	21	10	21	10	21	10	21	10	21
	50	8	72	10	28	10	28	10	28	10	28	10	28	10	28	10	28	10	28	10	28	10	28
Prescribed fire	1	8	84	2	16	2	16	2	16	2	16	2	16	2	16	2	16	2	16	2	16	2	16
	10	8	83	10	17	10	17	10	17	10	17	10	17	10	17	10	17	10	17	10	17	10	17
	20	8	83	10	17	10	17	10	17	10	17	10	17	10	17	10	17	10	17	10	17	10	17
	30	8	80	10	20	10	20	10	20	10	20	10	20	10	20	10	20	10	20	10	20	10	20
	40	8	73	10	27	10	27	10	27	10	27	10	27	10	27	10	27	10	27	10	27	10	27
	50	8	64	10	36	10	36	10	36	10	36	10	36	10	36	10	36	10	36	10	36	10	36

tpa = trees per acre; d.b.h. = diameter at breast height.

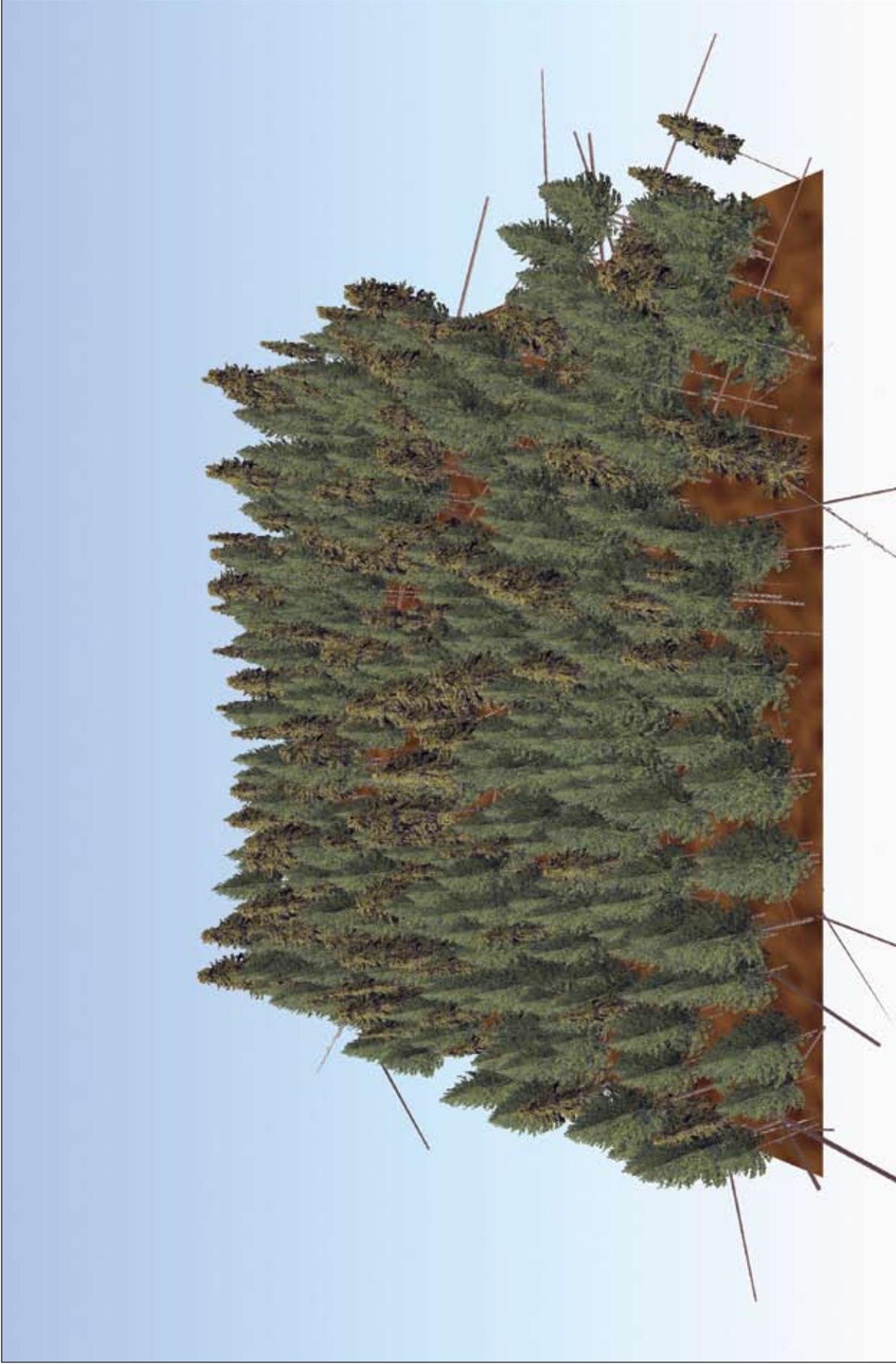
Table 5e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					Live
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff	
Severe—98 th percentile	21	94	3	5	8	16	50	100
Moderate—75 th percentile	13	80	5	7	10	23	125	150

Table 5f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

Site: Elevation = 6,200 ft, slope = 27 percent, aspect = 90°.

Species (based on trees per acre): Douglas-fir (*Pseudotsuga menziesii*) = 76 percent, hardwoods = 13 percent, ponderosa pine (*Pinus ponderosa*) = 11 percent.

Stand attributes: Stem density = 707 tpa, basal area = 195 ft²/ac, top height = 47 ft, stand density index = 408, quadratic mean diameter = 7.1 in, crown competition factor = 281, canopy cover = 81 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has initial tree density of 707 trees per acre (tpa) composed of Douglas-fir and hardwood understory and Douglas-fir and ponderosa pine overstory. Woody fuel loading is 9 tons/ac, and litter and duff loading is 1.3 tons/ac. Canopy bulk density is 0.29 kg/m³ (0.0181 lb/ft³), and canopy base height is 6 ft. Ladder fuels are not sufficient to enable passive crown fire, but canopy fuels are sufficient to sustain crown fire spread should a crown fire enter the stand under severe fire weather conditions. Predicted basal area mortality is 34 percent for moderate fire weather and 57 percent for severe fire weather. With no action, canopy base height declines in 20 years as small trees move into the canopy, and active crown fire becomes likely. In 30 years, canopy base height increases as the stand self-thins, and the predicted fire type becomes conditional crown fire again. Surface fuels accumulate slowly over time, but potential flame lengths remain 4 ft or less for the 50-year projection.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment raises canopy base height and decreases canopy bulk density, but not enough to significantly affect crown fire potential. Surface fuels are consumed in the prescribed fire but increase greatly in 10 years. All thinning treatments reduce canopy bulk density and increase canopy base height, but thinning to 200 tpa or less is necessary to decrease canopy bulk density sufficiently to affect crown fire potential. However, the lower density thinning treatments greatly increase surface fuel loading causing higher potential flame lengths and basal area mortality. Activity fuels are reduced by the pile and burn treatment and, to a greater extent, by the prescribed fire treatment, but flame lengths and basal area mortality decrease only slightly following treatment because fire behavior predictions are dominated by fuel models 1 and 2 rather than 8. Grass fuels are not tracked well in FFE and may or may not be the primary surface fuel following treatment; the influence of grass fuels should be interpreted with caution.

Silvicultural and surface fuel treatments—long-term effects

In the prescribed fire only treatment, surface fuels increase in 10 years as snags fall and contribute to surface fuel loading, but after 10 years surface fuels and flame lengths stabilize. Canopy bulk density remains high enough that the predicted fire type is conditional crown fire for the 50-year projection. The lower density treatments (50, 100, and 200 tpa) have the greatest long-term effect on crown fire potential. In these treatments, the predicted fire type is surface fire for the 50-year projection, and potential flame lengths decrease over time as the influence of grass fuels declines. Crown fire potential continues to decline as tree growth and self-thinning cause canopy base height to increase. In the highest density treatment (300 tpa), canopy bulk density remains high; the predicted fire type for severe fire weather is conditional crown fire for the 50-year projection except for the 300 tpa treatment with a prescribed fire surface fuel treatment. In this treatment, additional fire-caused tree mortality reduces canopy bulk density, and the predicted fire type changes from conditional crown fire to surface fire.

Table 6a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	3	1	14	12	9	7
		3	0	7	7	7	7
		3	2	4	4	4	4
		0	0	0	0	0	0
		3	1	5	4	4	3
		10	7	10	10	10	10
	Flame length (ft)	3	3	5	4	3	2
		4	4	6	5	4	3
	Torching index	18	35	37	52	82	82
	Crowning index	11	16	45	28	19	14
Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	
Potential basal area mortality (%)	Conditional	Conditional	Surface	Surface	Surface	Surface	
	34	32	22	21	25	27	
	57	65	94	60	30	29	
Pile and burn	Surface fuel loadings (tons/ac)	3	3	3	3	2	2
		2	2	2	2	2	2
		1	1	1	1	1	1
		0	0	0	0	0	0
		4	4	4	4	4	3
		9	9	9	9	9	9
	Flame length (ft)	3	3	3	3	3	3
		5	5	5	5	5	4
	Torching index	22	22	26	26	30	40
	Crowning index	45	45	45	28	19	14
Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	
Potential basal area mortality (%)	Surface	Surface	Surface	Surface	Surface	Surface	
	18	18	21	21	25	28	
	48	48	45	45	67	57	
Prescribed fire	Surface fuel loadings (tons/ac)	0	0	0	0	0	0
		2	2	2	2	2	2
		2	2	2	2	2	2
		0	0	0	0	0	0
		0	0	0	1	1	1
		7	7	7	7	7	7
	Flame length (ft)	4	4	3	3	3	3
		5	5	4	4	5	5
	Torching index	29	29	34	34	27	31
	Crowning index	51	51	34	34	23	19
Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	
Potential basal area mortality (%)	Surface	Surface	Surface	Surface	Surface	Surface	
	18	18	21	21	24	27	
	42	42	32	32	68	73	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 6b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	3	6	7	7	7	6	1	6	5	4	4	4
	3–6 in	3	3	3	4	4	4	0	5	5	5	4	4
None	6–12 in	3	3	4	4	5	5	2	7	7	7	6	6
	>12 in	0	0	0	0	0	1	0	0	0	0	0	1
None	Litter	3	3	3	3	3	3	1	2	2	2	2	2
	Duff	10	10	11	11	11	11	7	7	7	8	8	8
None	Flame length (ft)	3	3	3	3	3	3	3	3	3	3	3	3
	Severe	4	4	4	4	4	4	4	4	4	4	4	4
None	Torching index	18	28	14	25	38	54	35	60	73	79	92	101
	Crowning index	11	11	11	11	11	12	16	16	15	15	15	15
None	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Cond.	Cond.	Active	Cond.	Cond.	Cond.	Cond.	Surface	Cond.	Cond.	Cond.	Cond.
None	Hard snags (stems/ac)	2/4	131	31	32	28	28	178	19	14	11	11	11
	0–17.9 in	0	0	0	0	0	0	0	0	0	0	0	0
None	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	14	5	2	1	1	1	12	5	3	2	2	2
	3–6 in	7	6	5	5	4	4	7	6	5	5	4	4
None	6–12 in	4	4	4	3	3	3	4	4	4	3	3	3
	>12 in	0	0	0	0	0	0	0	0	0	0	0	1
None	Litter	5	1	1	1	1	1	4	1	1	1	2	2
	Duff	10	10	10	10	10	10	10	10	10	10	10	10
None	Flame length (ft)	5	3	3	3	3	3	4	2	1	1	1	1
	Severe	6	5	5	4	4	4	5	3	2	1	1	1
None	Torching index	37	24	36	45	47	47	52	121	303	624	694	793
	Crowning index	45	49	51	53	55	57	28	31	33	34	35	36
None	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
None	Hard snags (stems/ac)	201	111	5	6	5	5	202	112	7	7	8	8
	0–17.9 in	0	0	0	0	0	0	0	0	0	0	0	0
None	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

Table 6b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	3	2	1	1	1	3	2	2	2	2	2
		3–6 in	2	2	2	2	2	2	2	2	2	2	2
		6–12 in	1	1	1	1	1	1	1	1	2	2	2
		>12 in	0	0	0	0	0	0	0	0	0	0	1
		Litter	4	1	1	1	1	4	1	1	1	1	2
		Duff	9	9	9	9	9	9	9	9	9	9	9
		Moderate	3	3	3	3	3	3	3	3	3	3	3
		Severe	5	5	5	4	4	5	5	5	5	5	5
		Torching index	22	34	39	45	47	26	38	40	47	47	53
		Crowning index	45	49	51	53	55	28	31	33	34	35	35
Prescribed fire	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Hard snags (stems/ac)	201	111	6	6	6	202	112	7	8	8	9
		0–17.9 in	0	0	0	0	0	0	0	0	0	0	0
		18–29.9 in	0	0	0	0	0	0	0	0	0	0	0
		30–36 in	0	0	0	0	0	0	0	0	0	0	0
		Surface fuel loadings (tons/ac)	0	1	1	1	1	0	2	1	1	1	1
		0–3 in	2	2	2	2	2	2	2	2	2	2	2
		3–6 in	2	3	3	3	3	2	4	4	4	4	4
		6–12 in	0	0	0	0	1	0	0	0	0	1	1
Pile and burn	Litter	0	1	1	1	1	4	1	1	1	1	1	
	Duff	7	7	7	7	7	9	7	7	7	7	7	
	Moderate	4	3	3	3	3	3	3	3	3	3	3	
	Severe	5	5	5	5	5	4	4	4	5	5	5	
	Torching index	29	33	37	42	45	34	39	40	45	47	49	
	Crowning index	51	55	59	61	63	34	36	38	40	41	41	
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Hard snags (stems/ac)	86	12	8	6	5	95	18	10	7	7	7
		0–17.9 in	0	0	0	0	0	0	0	0	0	0	0
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	

Table 6b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	9	5	4	3	3	4	7	5	5	5	5	5
	0–3 in												
	3–6 in	7	6	5	5	5	4	7	6	6	5	5	5
	6–12 in	4	4	4	4	4	4	4	4	4	4	4	5
	>12 in	0	0	0	0	0	1	0	0	0	0	0	1
	Litter	4	2	2	2	2	2	3	2	2	2	3	3
	Duff	10	10	10	11	11	11	10	10	10	11	11	11
	Moderate	3	2	2	2	2	2	2	3	3	3	3	3
	Severe	4	3	3	2	2	2	3	4	4	4	4	4
	Flame length (ft)	82	159	302	450	535	562	82	63	76	89	103	106
Torching index	19	21	21	22	22	22	14	15	15	14	15	15	
Crowning index													
Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Severe	Surface	Surface	Surface	Surface	Surface	Surface	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	
0–17.9 in	203	114	9	10	11	11	204	116	12	14	21	24	
18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
Pile and burn	Surface fuel loadings (tons/ac)	2	3	3	3	3	3	2	4	4	4	5	4
	0–3 in												
	3–6 in	2	2	2	2	2	2	2	2	2	2	2	2
	6–12 in	1	1	2	2	2	2	1	1	2	2	2	3
	>12 in	0	0	0	0	0	1	0	0	0	0	0	1
	Litter	4	2	2	2	2	2	3	2	2	2	3	3
	Duff	9	9	9	9	9	10	9	9	9	10	10	10
	Moderate	3	3	3	3	3	3	3	3	3	3	3	3
	Severe	5	5	5	5	5	4	4	4	4	4	4	4
	Flame length (ft)	30	48	58	69	76	85	40	57	69	83	95	103
Torching index	19	21	21	21	22	22	14	15	15	14	15	15	
Crowning index													
Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Severe	Surface	Surface	Surface	Surface	Surface	Surface	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	
0–17.9 in	203	114	9	10	11	12	204	116	12	15	21	24	
18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 6b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	3	2	2	2	3	0	4	3	3	3	3
		0–3 in											
		3–6 in	2	3	3	3	3	2	4	4	4	4	3
		6–12 in	2	5	6	5	5	2	7	7	6	6	6
	>12 in	0	0	0	0	1	1	0	0	0	0	0	1
	Litter	1	1	2	2	2	2	1	2	2	2	2	2
	Duff	7	7	7	7	7	8	7	7	7	7	8	8
	Moderate	3	3	3	3	3	3	3	3	3	3	3	3
	Severe	5	5	5	5	5	5	5	4	4	4	4	4
	Torching index	27	35	44	49	59	68	31	47	55	64	75	84
	Crowning index	23	26	27	27	27	27	19	20	20	20	20	20
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	103	19	12	9	9	10	114	20	13	10	11	12
	0–17.9 in	0	0	0	0	0	0	0	0	0	0	0	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	

tpa = trees per acre; d.b.h. = diameter at breast height; cond. = conditional.

Table 6c— Treatment effect on forest stand attributes, 50-year trajectory orest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	707	682	691	667	662	643	318	315	309	302	296	290
	Quadratic mean diameter (in)	7.1	7.5	7.7	8.1	8.4	8.7	7.1	9.2	9.7	10.2	10.7	11.2
	Total volume (ft ³)	3,048	3,737	4,456	5,165	5,925	6,675	2,332	2,626	3,246	3,891	4,568	5,277
	Merchantable volume (ft ³)	2,035	2,683	3,302	3,994	4,722	5,391	1,741	1,970	2,537	3,097	3,841	4,521
	Basal area (ft ²)	195	211	226	239	253	266	137	144	159	172	185	198
	Stand density index	408	432	459	477	498	515	263	274	294	313	331	348
	Canopy closure (percent)	81	80	78	76	75	74	65	66	65	64	64	64
	Crown competition factor	281	294	310	323	337	347	187	194	207	219	230	241
	Canopy base height (ft)	6	8	5	7	10	14	12	17	24	28	34	38
	Canopy bulk density (kg/m ³)	0.29	0.30	0.30	0.29	0.29	0.28	0.19	0.19	0.20	0.21	0.22	0.21

Table 6c— Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	707	49	132	128	125	122	119	99	180	176	172	168	164
	Quadratic mean diameter (in)	7.1	12.4	8.1	8.6	9.2	9.7	10.2	11.4	8.9	9.5	10.1	10.7	11.2
	Total volume (ft ³)	3,048	843	956	1,204	1,474	1,764	2,069	1,396	1,585	1,995	2,442	2,912	3,401
	Merchantable volume (ft ³)	2,035	739	800	1,029	1,302	1,576	1,868	1,205	1,335	1,745	2,119	2,596	3,055
	Basal area (ft ²)	195	42	47	52	57	63	68	70	79	87	96	105	113
	Stand density index	408	70	93	101	109	116	124	122	151	163	175	187	198
	Canopy cover (percent)	81	22	25	27	29	31	33	37	40	42	44	46	47
	Crown competition factor	281	47	51	56	62	67	72	83	91	98	107	115	122
	Canopy base height (ft)	6	17	18	20	23	24	24	15	19	20	24	24	27
	Canopy bulk density (kg/m ³)	0.29	0.05	0.04	0.04	0.04	0.04	0.04	0.09	0.08	0.08	0.07	0.07	0.07
Pile and burn	Trees per acre	707	49	140	136	133	130	127	99	189	184	180	176	172
	Quadratic mean diameter (in)	7.1	12.4	7.8	8.4	8.9	9.4	9.9	11.4	8.7	9.3	9.9	10.5	11.0
	Total volume (ft ³)	3,048	843	956	1,204	1,475	1,765	2,070	1,396	1,585	1,994	2,441	2,910	3,399
	Merchantable volume (ft ³)	2,035	739	800	1,029	1,302	1,576	1,866	1,205	1,335	1,745	2,119	2,596	3,055
	Basal area (ft ²)	195	42	47	52	57	63	68	70	79	87	96	105	113
	Stand density index	408	70	94	102	110	118	125	122	152	165	177	189	200
	Canopy cover (percent)	81	22	25	27	29	31	33	37	40	42	44	46	47
	Crown competition factor	281	47	51	56	62	68	73	83	91	98	107	115	123
	Canopy base height (ft)	6	17	18	20	23	24	25	15	19	20	24	24	27
	Canopy bulk density (kg/m ³)	0.29	0.05	0.04	0.04	0.04	0.04	0.04	0.09	0.08	0.08	0.07	0.07	0.07
Prescribed fire	Trees per acre	707	49	139	136	132	129	126	99	176	172	168	164	160
	Quadratic mean diameter (in)	7.1	12.4	7.1	7.7	8.2	8.7	9.2	11.4	8.1	8.7	9.3	9.8	10.4
	Total volume (ft ³)	3,048	693	790	1,004	1,243	1,501	1,773	1,110	1,267	1,613	1,995	2,401	2,829
	Merchantable volume (ft ³)	2,035	608	657	885	1,108	1,337	1,588	958	1,061	1,410	1,748	2,133	2,560
	Basal area (ft ²)	195	42	39	43	48	53	58	70	63	71	78	86	94
	Stand density index	408	70	81	88	96	103	111	122	125	137	148	159	169
	Canopy cover (percent)	81	22	21	24	26	28	29	37	33	36	38	40	42
	Crown competition factor	281	47	43	47	53	58	63	83	72	79	87	94	102
	Canopy base height (ft)	6	17	19	21	23	24	25	16	19	20	23	25	26
	Canopy bulk density (kg/m ³)	0.29	0.04	0.04	0.03	0.03	0.03	0.03	0.07	0.07	0.06	0.06	0.06	0.06

Table 6c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	707	198	277	271	265	260	254	297	374	366	358	344	332
	Quadratic mean diameter (in)	7.1	10.2	9.2	9.8	10.3	10.9	11.4	9.5	8.9	9.4	9.9	10.4	10.8
	Total volume (ft ³)	3,048	2,176	2,467	3,087	3,756	4,462	5,191	2,700	3,039	3,742	4,463	5,133	5,833
	Merchantable volume (ft ³)	2,035	1,831	2,072	2,641	3,282	3,960	4,627	2,241	2,509	3,155	3,866	4,462	5,198
	Basal area (ft ²)	195	113	127	141	155	168	181	145	162	177	192	202	213
	Stand density index	408	205	241	261	280	298	314	272	310	333	353	365	378
	Canopy cover (percent)	81	55	56	56	57	57	58	67	67	67	67	67	67
	Crown competition factor	281	139	151	163	175	186	197	190	205	219	231	240	248
	Canopy base height (ft)	6	13	20	24	29	33	38	13	20	26	32	37	40
Canopy bulk density (kg/m ³)	0.29	0.16	0.14	0.14	0.13	0.13	0.13	0.22	0.21	0.21	0.22	0.21	0.21	
Pile and burn	Trees per acre	707	198	286	279	273	267	262	297	383	374	365	351	339
	Quadratic mean diameter (in)	7.1	10.2	9.0	9.6	10.2	10.7	11.2	9.5	8.8	9.3	9.8	10.3	10.7
	Total volume (ft ³)	3,048	2,176	2,467	3,087	3,756	4,462	5,191	2,700	3,039	3,741	4,452	5,122	5,822
	Merchantable volume (ft ³)	2,035	1,831	2,072	2,641	3,282	3,960	4,627	2,241	2,509	3,155	3,858	4,453	5,187
	Basal area (ft ²)	195	113	127	141	155	168	181	145	162	177	191	202	212
	Stand density index	408	205	243	262	281	299	316	272	312	334	353	366	379
	Canopy cover (percent)	81	55	57	58	59	60	60	67	67	67	67	67	67
	Crown competition factor	281	139	151	163	175	187	197	190	205	219	231	239	248
	Canopy base height (ft)	6	13	20	24	29	33	38	13	20	26	32	37	40
Canopy bulk density (kg/m ³)	0.29	0.16	0.14	0.14	0.13	0.13	0.13	0.22	0.21	0.21	0.22	0.21	0.21	
Prescribed fire	Trees per acre	707	198	243	237	232	227	222	297	304	297	290	284	278
	Quadratic mean diameter (in)	7.1	10.2	8.5	9.2	9.8	10.3	10.9	9.5	8.5	9.0	9.6	10.1	10.6
	Total volume (ft ³)	3,048	1,649	1,884	2,400	2,969	3,572	4,200	1,977	2,245	2,827	3,451	4,111	4,801
	Merchantable volume (ft ³)	2,035	1,392	1,582	2,063	2,594	3,164	3,795	1,649	1,862	2,391	2,986	3,614	4,272
	Basal area (ft ²)	195	113	97	109	121	133	144	145	118	132	145	158	170
	Stand density index	408	205	189	206	224	240	255	272	232	252	271	289	305
	Canopy cover (percent)	81	55	48	50	52	53	54	67	57	58	59	60	61
	Crown competition factor	281	139	114	125	136	146	156	190	148	160	173	184	195
	Canopy base height (ft)	6	13	18	22	24	29	34	13	20	24	28	33	37
Canopy bulk density (kg/m ³)	0.29	0.12	0.10	0.10	0.10	0.10	0.10	0.16	0.15	0.14	0.14	0.14	0.14	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 6d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only								
	Fuel models			Fuel models			Fuel models			Fuel models					
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight
None	1	2	84	10	16	Percent	2	100			Percent				
	10	2	57	10	43		10	77	2	23					
	20	10	55	2	45		10	56	2	44					
	30	10	61	2	39		2	51	10	49					
	40	10	65	2	35		2	56	10	44					
50	10	66	2	34	2	58	10	42							

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit								
	Fuel models			Fuel models			Fuel models			Fuel models					
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight
None	1	14	57	11	43	Percent	11	61	14	39	Percent				
	10	1	52	10	48		8	53	10	47					
	20	1	93	10	7		8	86	10	14					
	30	1	100				8	98	10	2					
	40	1	95	2	5		8	100							
50	1	87	2	13	8	100									
Pile and burn	1	1	68	10	32							2	28		
	10	1	100			1	51	2	49						
	20	1	100			2	61	1	39						
	30	1	100			2	71	1	29						
	40	1	94	2	6	2	79	1	21						
50	1	86	2	14	2	84	1	16							
Prescribed fire	1	1	100			1	97	2	3						
	10	1	100			1	83	2	17						
	20	1	100			1	70	2	30						
	30	1	100			1	59	2	41						
	40	1	100			2	50	1	50						
50	1	100			2	58	1	42							

Table 6d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit						Thin from below to 300 tpa, 18-in. d.b.h. limit									
	Fuel models			Fuel models			Fuel models			Fuel models						
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent
None	1	11	86	14	14	Percent	11	90	2	10	Percent	11	90	2	10	Percent
	10	8	50	10	50		10	53	2	47		10	53	2	47	
	20	8	70	10	30		2	55	10	45		2	55	10	45	
	30	8	77	10	23		2	62	10	38		2	62	10	38	
	40	8	78	10	22		2	59	10	41		2	59	10	41	
50	8	76	10	24		2	58	10	42		2	58	10	42		
Pile and burn	1	2	100				2	100				2	100			
	10	2	100				2	95	10	5		2	95	10	5	
	20	2	100				2	86	10	14		2	86	10	14	
	30	2	100				2	84	10	16		2	84	10	16	
	40	2	96	10	4		2	78	10	22		2	78	10	22	
50	2	92	10	8		2	74	10	26		2	74	10	26		
Prescribed fire	1	2	75	1	25		2	100				2	100			
	10	2	74	10	17	1	2	59	10	41		2	59	10	41	
	20	2	90	10	10		2	71	10	29		2	71	10	29	
	30	2	93	10	7		2	75	10	25		2	75	10	25	
	40	2	92	10	8		2	77	10	23		2	77	10	23	
50	2	90	10	10		2	76	10	24		2	76	10	24		

tpa = trees per acre; d.b.h. = diameter at breast height.

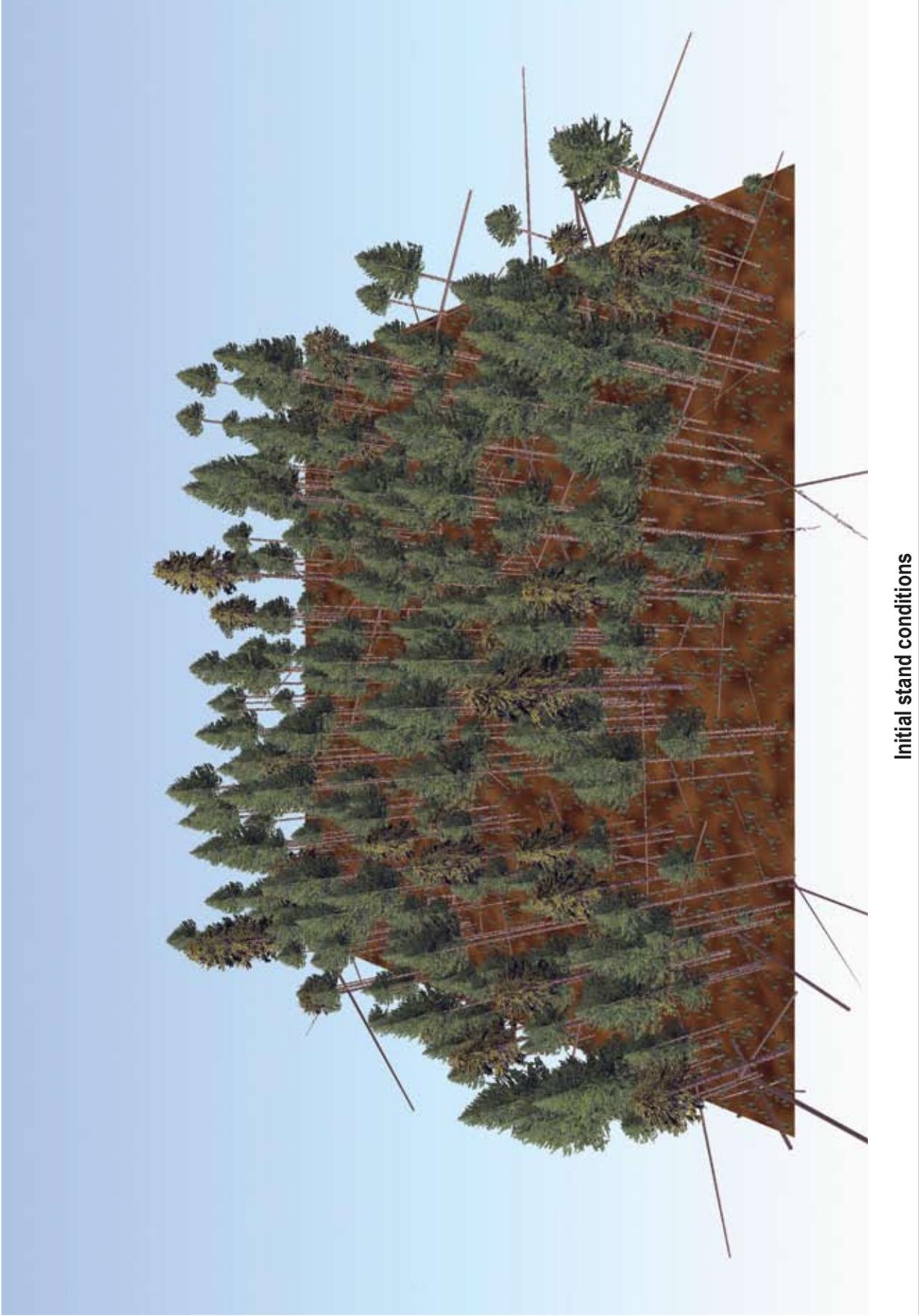
Table 6e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff	Live
Severe—98 th percentile	16	80	4	6	15	16	50	100
Moderate—75 th percentile	11	65	6	9	18	25	125	150

Table 6f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

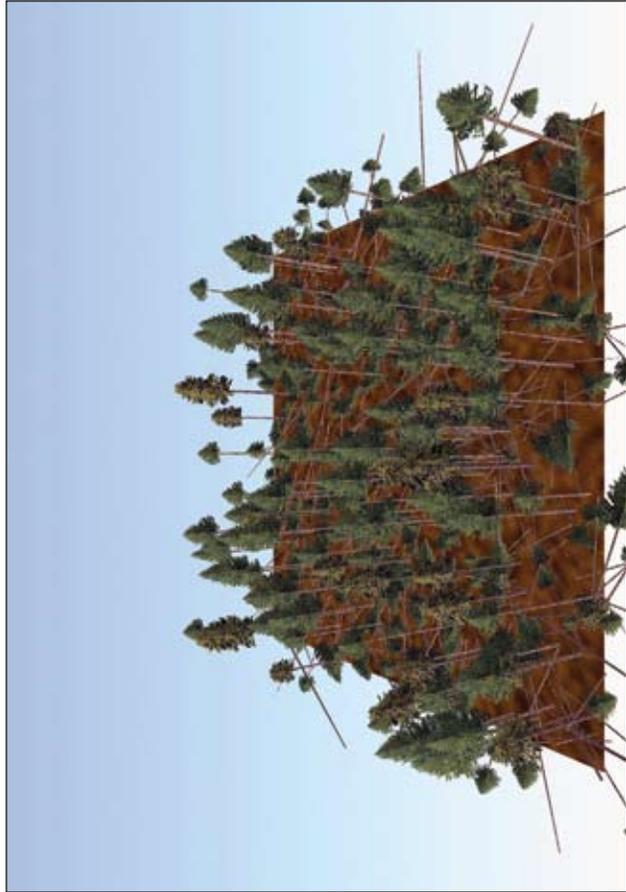
Site: Elevation = 5,600 ft, slope = 25 percent, aspect = 360°.

Species (based on trees per acre): Douglas-fir (*Pseudotsuga menziesii*) = 92 percent, hardwoods = 6 percent, ponderosa pine (*Pinus ponderosa*) = 1 percent, lodgepole pine (*Pinus contorta*) = 1 percent.

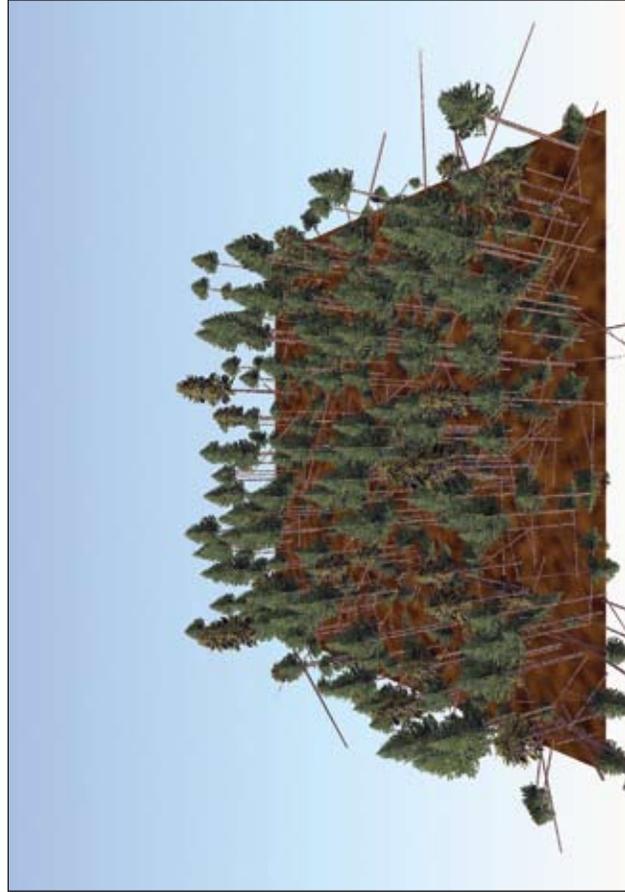
Stand attributes: Stem density = 6,573 tpa, basal area = 172 ft²/ac, top height = 54 ft, stand density index = 575, quadratic mean diameter = 2.2 in, crown competition factor = 243, canopy cover = 69 percent.



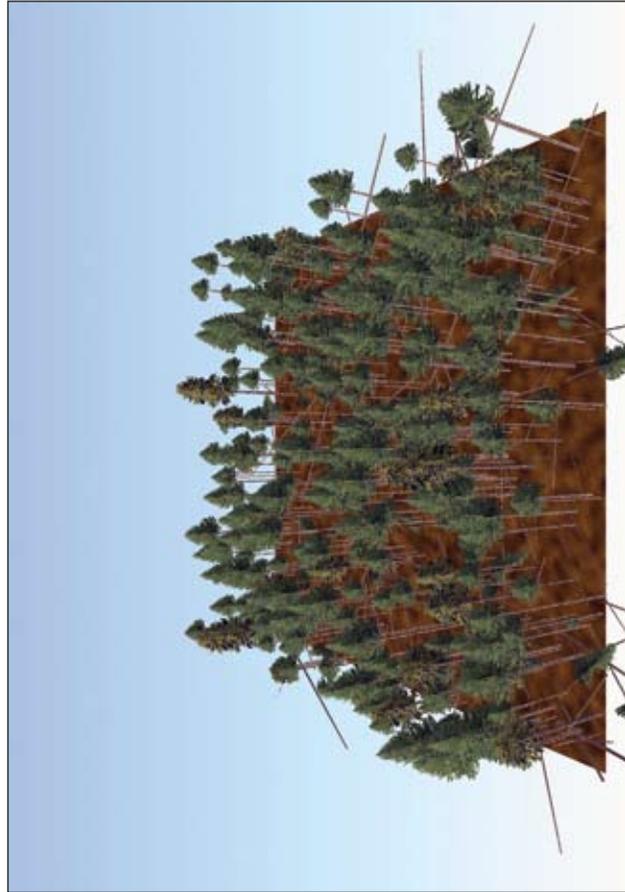
Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has extremely high initial tree density of 6,573 trees per acre (tpa) composed mostly of Douglas-fir with some hardwoods in the understory and ponderosa pine and lodgepole pine in the overstory. The Stand top height is only 54 ft and there are many seedlings. Woody surface fuel loading is 9 tons/ac and litter and duff loading is 13 tons/ac. Canopy base height is 14 ft and canopy bulk density is 0.21 kg/m³ (0.0131 lb/ft³), so initially ladder fuels are not sufficient to enable passive crown fire crown, but crown fire spread is possible under severe fire weather. Potential basal area mortality is about 30 percent for moderate and severe fire weather, likely because the stand is dominated by fire-resistant conifer species. With no action, canopy base height declines and canopy bulk density increases as smaller trees grow into the canopy; active crown fire is predicted in 10 years. Surface fuels accumulate over time but flame lengths remain constant.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment kills many small trees, which raises canopy base height and reduces crown fire potential. Many snags are created, but they are generally small and the contributions to future surface fuel loading are minor. All thinning treatments reduce canopy bulk density and increase canopy base height; the greater the thinning, the greater is the change in forest structure. However, thinning to 200 tpa or less is necessary to prevent conditional crown fire. All thinning treatments generate activity fuels, and these surface fuels are sufficient to increase potential flame lengths in the 50 tpa treatment. The pile and burn treatment reduces woody fuel loading to below initial conditions, and the prescribed fire treatment reduces woody fuel loading even more and consumes some of the duff layer. However, these changes in surface fuel loading do not decrease potential flame lengths and basal area mortality because the opened stands with low woody fuel loading are characterized by fuel model 2, which typically has high flame lengths. Grass fuels are not tracked in FFE and may or may not be an important contributor to fire behavior following surface fuel treatments.

Silvicultural and surface fuel treatments—long-term effects

The 50 tpa treatment has a long-term effect on crown fire potential with the predicted fire type remaining surface fire for the 50-year projection. Regeneration causes a drop in canopy base height in 30 or 40 years, but at this time, potential flame lengths are sufficiently low that passive crown fire is prevented. The 100 tpa and 200 tpa treatments have less of a long-term effect on crown fire potential. Flame lengths decrease as surface fuels decompose, but passive crown fire becomes likely again for severe fire weather in 30 or 40 years when regeneration lowers canopy base height. Canopy bulk density remains high enough in the 300 tpa treatment that conditional crown fire is predicted for the 50-year projection. However, if a prescribed fire surface fuel treatment is applied, fire-caused tree mortality reduces canopy bulk density enough that conditional crown fire is eliminated.

Table 7a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit	
None	Surface fuel loadings (tons/ac)	0-3 in	1	10	8	6	4	
		3-6 in	0	4	4	4	4	
	>12 in	6-12 in	2	3	3	3	3	
		>12 in	0	0	0	0	0	
	Litter	Litter	1	4	4	3	3	
		Duff	10	7	10	10	10	
	Flame length (ft)	Moderate	3	3	4	3	3	
		Severe	4	5	4	4	4	
	Torching index	Severe	42	44	117	196	51	27
		Crowning index	15	20	48	28	17	16
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Conditional	Surface	Surface	Surface	Surface	Conditional	
Potential basal area mortality (%)	Moderate	29	26	19	20	25	27	
	Severe	33	38	19	20	25	30	
Pile and burn	Surface fuel loadings (tons/ac)	0-3 in		3	2	2	1	
		3-6 in		1	1	1	1	
	>12 in	6-12 in		1	1	1	1	
		>12 in		0	0	0	0	
	Litter	Litter		4	4	3	3	
		Duff		9	9	9	9	
	Flame length (ft)	Moderate		3	3	3	3	
		Severe		5	4	5	5	
	Torching index	Severe		36	49	50	51	
		Crowning index		48	28	17	16	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Conditional	Surface	Surface	Surface	Surface	Conditional	
Potential basal area mortality (%)	Moderate	19	19	20	25	27	27	
	Severe	19	38	19	20	31	37	
Prescribed fire	Surface fuel loadings (tons/ac)	0-3 in		0	0	0	0	
		3-6 in		1	1	1	1	
	>12 in	6-12 in		2	2	2	2	
		>12 in		0	0	0	0	
	Litter	Litter		0	1	1	1	
		Duff		7	7	7	7	
	Flame length (ft)	Moderate		4	3	3	3	
		Severe		5	5	4	5	
	Torching index	Severe		40	49	51	42	
		Crowning index		55	32	21	20	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Conditional	Surface	Surface	Surface	Surface	Conditional	
Potential basal area mortality (%)	Moderate	16	16	18	22	25	25	
	Severe	18	38	18	24	34	34	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 7b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	3	5	6	6	6	7	1	5	3	2	2	3
	0–3 in	3	4	4	4	5	5	0	4	4	4	3	3
	3–6 in	3	4	5	6	8	9	2	7	8	8	7	7
	6–12 in	0	0	0	1	1	2	0	0	1	1	1	1
	>12 in	3	3	3	3	4	4	1	2	2	2	2	2
	Litter	10	10	10	11	11	11	7	7	7	8	8	8
	Duff	3	3	3	3	3	3	3	3	3	3	3	3
	Moderate	4	4	4	4	4	4	5	5	4	4	4	4
	Severe	42	0	9	10	10	13	44	54	55	60	11	11
	Severe	15	16	16	16	7	5	20	19	19	19	19	19
None	Surface fuel loadings (tons/ac)	10	10	10	10	10	10	10	10	10	10	10	10
	0–3 in	10	10	10	10	10	10	10	10	10	10	10	10
	3–6 in	4	4	4	4	4	4	4	4	4	4	4	4
	6–12 in	3	4	4	3	3	3	3	4	4	4	3	3
	>12 in	0	0	0	0	0	1	0	0	0	0	1	1
	Litter	4	1	1	1	1	1	4	1	1	1	1	2
	Duff	10	10	10	10	10	10	10	10	10	10	10	10
	Moderate	4	3	3	3	3	3	3	3	3	3	3	3
	Severe	5	5	5	4	4	4	4	5	5	5	5	5
	Severe	117	36	52	54	18	19	196	44	56	15	15	19
None	Surface fuel loadings (tons/ac)	48	49	50	52	54	57	28	29	30	32	33	35
	0–3 in	48	49	50	52	54	57	28	29	30	32	33	35
	3–6 in	37	25	7	6	6	6	38	26	9	9	9	9
	6–12 in	0	0	0	0	0	0	0	0	0	0	0	0
	>12 in	0	0	0	0	0	0	0	0	0	0	0	0
	Litter	0	0	0	0	0	0	0	0	0	0	0	0
	Duff	0	0	0	0	0	0	0	0	0	0	0	0
	Moderate	0	0	0	0	0	0	0	0	0	0	0	0
	Severe	0	0	0	0	0	0	0	0	0	0	0	0
	Severe	0	0	0	0	0	0	0	0	0	0	0	0

Table 7b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	3	2	1	1	1	2	2	1	1	1	1
		3–6 in	1	2	2	2	1	1	1	2	2	2	2
	>12 in	6–12 in	1	1	2	2	2	1	2	2	2	2	2
		>12 in	0	0	0	0	0	0	0	0	0	1	1
	Litter	Litter	4	1	1	1	1	4	1	1	1	2	2
		Duff	9	9	9	9	9	9	9	9	9	9	9
	Flame length (ft)	Moderate	3	3	3	3	3	3	3	3	3	3	3
		Severe	5	5	5	4	4	4	4	4	5	5	5
	Torching index	Severe	36	47	52	17	18	49	53	56	15	15	17
		Severe	48	49	50	52	54	28	28	30	32	33	34
Crowning index	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Passive	Passive	Surface	
Type of fire	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Passive	Passive	Surface	
Hard snags (stems/ac)	0–17.9 in	37	25	7	7	6	38	26	9	9	9	9	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	1	1	1	1	0	2	1	1	1	1
		3–6 in	1	2	2	2	2	1	2	2	2	2	2
	>12 in	6–12 in	2	3	4	4	3	2	4	5	5	5	4
		>12 in	0	0	1	1	1	0	0	1	1	1	1
	Litter	Litter	0	1	1	1	1	4	1	1	1	1	1
		Duff	7	7	7	7	7	9	7	7	7	7	7
	Flame length (ft)	Moderate	4	3	3	3	3	3	3	3	3	3	3
		Severe	5	5	5	5	4	5	4	4	4	5	5
	Torching index	Severe	40	44	49	14	17	49	54	56	14	16	18
		Severe	55	56	56	58	61	32	33	35	36	38	38
Crowning index	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Passive	Passive	Surface	
Type of fire	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Passive	Passive	Surface	
Hard snags (stems/ac)	0–17.9 in	30	17	10	7	6	39	24	14	9	9	9	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	

Table 7b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	0–3 in	6	4	3	2	2	3	4	4	3	3	4	4
		3–6 in	4	4	4	4	3	3	4	4	4	4	4	3
	Flame length (ft)	6–12 in	3	4	4	4	4	4	3	4	4	4	4	4
		>12 in	0	0	0	0	1	1	0	0	0	0	0	1
	Torching index	Litter	3	2	2	2	2	2	3	2	2	2	3	3
		Duff	10	10	10	10	10	11	10	10	10	10	11	11
	Crowning index	Moderate	3	3	3	3	3	3	3	3	3	3	3	3
		Severe	4	5	5	5	4	4	4	4	4	4	4	4
	Type of fire	Severe	51	55	61	73	80	84	27	57	67	76	85	92
		Moderate	17	18	19	19	20	20	16	16	16	15	15	16
Hard snags (stems/ac)	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	39	27	11	11	11	12	40	29	14	14	16	20	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
Pile and burn	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
	Surface fuel loadings (tons/ac)	2	2	2	2	2	3	1	3	3	3	4	4	
	3–6 in	1	2	2	2	2	2	1	2	2	2	2	2	
Flame length (ft)	6–12 in	1	2	2	2	3	3	1	2	2	2	3	3	
	>12 in	0	0	0	0	1	1	0	0	0	0	0	1	
Torching index	Litter	3	2	2	2	2	2	3	2	2	2	3	3	
	Duff	9	9	9	9	9	9	9	9	9	9	10	10	
Crowning index	Moderate	3	3	3	3	3	3	3	3	3	3	3	3	
	Severe	5	5	5	5	5	4	5	4	4	4	4	4	
Type of fire	Severe	50	60	65	76	80	84	51	61	71	78	84	94	
	Moderate	17	18	18	19	20	21	16	16	15	15	15	16	
Hard snags (stems/ac)	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	39	27	11	11	12	12	40	29	14	14	17	21	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
Pile and burn	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 7b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	3	2	2	2	2	0	4	3	2	2	3
		0–3 in											
		3–6 in	1	3	3	3	3	1	4	4	4	4	3
		6–12 in	2	6	7	7	6	2	7	8	8	7	7
		>12 in	0	0	1	1	1	0	0	1	1	1	1
		Litter	1	1	1	2	2	1	2	2	2	2	2
		Duff	7	7	7	7	7	7	7	7	7	7	8
		Moderate	3	3	3	3	3	3	3	3	3	3	3
		Severe	4	5	5	5	5	5	5	5	5	4	4
		Severe	51	48	52	59	14	15	42	47	55	63	71
Crowning index		21	21	23	23	24	26	20	20	20	20	20	20
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Hard snags (stems/ac)		51	27	16	10	10	10	62	28	17	12	12	12
		0–17.9 in											
		18–29.9 in	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	

tpa = trees per acre; d.b.h. = diameter at breast height; cond. = conditional.

Table 7c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	6,573	6,079	5,734	5,263	4,825	4,420	348	381	434	424	419	410
	Quadratic mean diameter (in)	2.2	2.3	2.4	2.5	2.7	2.8	2.2	8	7.8	8.2	8.6	9
	Total volume (ft ³)	3,105	3,451	3,760	4,055	4,317	4,555	2,466	2,694	3,191	3,750	4,360	5,004
	Merchantable volume (ft ³)	2,418	2,824	3,106	3,381	3,675	3,922	2,002	2,239	2,690	3,228	3,826	4,447
	Basal area (ft ²)	172	176	178	182	186	190	127	133	144	156	168	181
	Stand density index	575	575	575	575	575	575	252	266	291	309	328	346
	Canopy closure (percent)	68	68	71	75	77	78	50	52	57	61	64	65
	Crown competition factor	243	244	253	264	274	292	168	173	184	196	209	223
	Canopy base height (ft)	14	3	4	4	4	5	21	24	24	25	5	5
	Canopy bulk density (kg/m ³)	0.21	0.20	0.19	0.19	0.50	0.64	0.15	0.15	0.15	0.15	0.15	0.15

Table 7c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	6,573	50	161	157	153	150	146	100	210	205	200	195	191
	Quadratic mean diameter (in)	2.2	13.6	7.9	8.4	8.8	9.3	9.7	12.5	9.0	9.4	9.9	10.4	10.9
	Total volume (ft ³)	3,105	1,137	1,244	1,475	1,728	1,999	2,280	1,900	2,071	2,441	2,847	3,287	3,747
	Merchantable volume (ft ³)	2,418	980	1,085	1,291	1,552	1,808	2,054	1,616	1,813	2,154	2,534	2,951	3,382
	Basal area (ft ²)	172	51	55	60	65	70	75	85	92	99	107	115	123
	Stand density index	575	82	111	118	125	133	140	143	176	186	197	207	218
	Canopy cover (percent)	68	20	23	26	28	30	32	32	36	39	42	44	46
	Crown competition factor	243	59	63	67	73	79	85	101	106	113	121	129	137
	Canopy base height (ft)	14	28	29	31	31	7	8	28	29	31	7	7	9
	Canopy bulk density (kg/m ³)	0.21	0.05	0.04	0.04	0.04	0.04	0.04	0.10	0.09	0.09	0.08	0.07	0.07
Pile and burn	Trees per acre	6,573	50	172	167	163	159	156	100	221	215	210	205	201
	Quadratic mean diameter (in)	2.2	13.6	7.7	8.1	8.6	9.0	9.4	12.5	8.7	9.2	9.7	10.1	10.6
	Total volume (ft ³)	3,105	1,137	1,244	1,476	1,729	2,001	2,283	1,900	2,071	2,442	2,849	3,287	3,748
	Merchantable volume (ft ³)	2,418	980	1,085	1,291	1,552	1,808	2,054	1,616	1,813	2,154	2,530	2,944	3,390
	Basal area (ft ²)	172	51	55	60	65	70	76	85	92	99	107	115	123
	Stand density index	575	82	112	119	127	135	142	143	178	188	199	210	221
	Canopy cover (percent)	68	20	23	26	28	31	32	32	36	39	42	45	47
	Crown competition factor	243	59	63	68	74	80	85	101	107	113	122	130	138
	Canopy base height (ft)	14	28	29	31	31	7	8	28	29	31	7	7	8
	Canopy bulk density (kg/m ³)	0.21	0.05	0.04	0.04	0.04	0.04	0.04	0.10	0.09	0.09	0.08	0.08	0.07
Prescribed fire	Trees per acre	6,573	50	173	168	164	160	156	100	211	206	201	196	192
	Quadratic mean diameter (in)	2.2	13.6	6.9	7.4	7.8	8.2	8.7	12.5	8	8.5	9.0	9.4	9.9
	Total volume (ft ³)	3,105	938	1,032	1,239	1,467	1,712	1,968	1,538	1,687	2,010	2,367	2,752	3,162
	Merchantable volume (ft ³)	2,418	810	905	1,082	1,314	1,554	1,769	1,311	1,480	1,772	2,104	2,471	2,842
	Basal area (ft ²)	172	51	45	50	54	59	64	85	74	81	88	95	103
	Stand density index	575	82	96	103	110	117	125	143	149	158	169	179	189
	Canopy cover (percent)	68	20	20	22	25	27	29	32	30	34	37	39	42
	Crown competition factor	243	59	50	55	61	66	72	101	85	91	99	107	114
	Canopy base height (ft)	14	28	29	31	31	7	7	28	29	31	6	7	8
	Canopy bulk density (kg/m ³)	0.21	0.04	0.04	0.04	0.04	0.03	0.03	0.08	0.08	0.07	0.07	0.06	0.06

Table 7c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	6,573	200	308	301	295	289	283	300	406	397	389	380	368
	Quadratic mean diameter (in)	2.2	10.9	9.1	9.5	9.9	10.4	10.8	9.8	8.8	9.2	9.6	10.0	10.4
	Total volume (ft ³)	3,105	2,723	2,945	3,421	3,950	4,513	5,101	3,183	3,451	4,027	4,649	5,283	5,880
	Merchantable volume (ft ³)	2,418	2,285	2,512	2,970	3,457	3,984	4,532	2,616	2,905	3,430	4,033	4,653	5,183
	Basal area (ft ²)	172	129	138	148	159	169	180	159	170	183	195	207	217
	Stand density index	575	229	264	277	292	306	319	292	329	347	364	380	391
	Canopy cover (percent)	68	47	50	54	56	58	59	57	61	64	65	66	67
	Crown competition factor	243	164	172	181	191	201	211	213	224	236	248	260	268
	Canopy base height (ft)	14	25	28	30	34	37	41	21	24	27	30	33	37
Canopy bulk density (kg/m ³)	0.21	0.18	0.16	0.16	0.16	0.15	0.14	0.20	0.20	0.20	0.20	0.21	0.20	
Pile and burn	Trees per acre	6,573	200	319	312	306	299	293	300	417	408	399	389	377
	Quadratic mean diameter (in)	2.2	10.9	8.9	9.3	9.8	10.2	10.6	9.8	8.7	9.1	9.5	9.9	10.3
	Total volume (ft ³)	3,105	2,723	2,945	3,421	3,950	4,512	5,100	3,183	3,451	4,027	4,648	5,269	5,865
	Merchantable volume (ft ³)	2,418	2,285	2,512	2,970	3,456	3,984	4,527	2,616	2,905	3,430	4,033	4,639	5,170
	Basal area (ft ²)	172	129	138	148	159	169	180	159	170	183	195	207	216
	Stand density index	575	229	266	279	294	308	322	292	331	348	366	381	393
	Canopy cover (percent)	68	47	50	54	56	58	59	57	61	63	65	66	67
	Crown competition factor	243	164	172	181	192	202	211	213	224	236	249	259	268
	Canopy base height (ft)	14	25	29	30	34	8	8	21	24	27	30	33	37
Canopy bulk density (kg/m ³)	0.21	0.18	0.17	0.16	0.16	0.15	0.14	0.20	0.20	0.20	0.21	0.21	0.20	
Prescribed fire	Trees per acre	6,573	200	275	269	263	257	252	300	334	327	319	312	306
	Quadratic mean diameter (in)	2.2	10.9	8.4	8.8	9.3	9.7	10.2	9.8	8.3	8.7	9.2	9.6	10.1
	Total volume (ft ³)	3,105	2,084	2,272	2,678	3,133	3,625	4,146	2,363	2,583	3,064	3,594	4,164	4,763
	Merchantable volume (ft ³)	2,418	1,757	1,949	2,335	2,745	3,193	3,735	1,959	2,190	2,638	3,128	3,656	4,272
	Basal area (ft ²)	172	129	105	114	123	132	142	159	125	135	147	158	169
	Stand density index	575	229	207	219	232	245	258	292	246	262	278	294	309
	Canopy cover (percent)	68	47	41	45	48	51	53	57	50	53	56	58	60
	Crown competition factor	243	164	128	136	145	154	163	213	159	170	181	192	203
	Canopy base height (ft)	14	27	29	30	32	7	7	21	23	26	29	32	7
Canopy bulk density (kg/m ³)	0.21	0.14	0.13	0.13	0.12	0.11	0.11	0.15	0.15	0.15	0.15	0.15	0.15	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 7d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None	1	2	91	10	9	2	92	1	8				
	10	2	62	10	38	2	53	10	47				
	20	10	53	2	47	2	65	10	35				
	30	10	71	2	29	2	74	10	26				
	40	10	90	2	10	2	78	10	22				
50	10	92	12	8	2	75	10	25					

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None	1	11	82	14	18	11	99	14	1				
	10	1	78	10	22	1	56	2	23	10	22		
	20	1	100			1	54	2	45	10	1		
	30	1	100			2	61	1	39				
	40	1	99	2	1	2	73	1	27				
50	1	90	2	10	2	82	1	18					
Pile and burn	1	1	85	10	15	1	85	2	11	10	5		
	10	1	100			1	71	2	29				
	20	1	100			1	53	2	47				
	30	1	100			2	62	1	38				
	40	1	97	2	3	2	74	1	26				
50	1	88	2	12	2	84	1	16					
Prescribed fire	1	1	100			1	100						
	10	1	100			1	98	2	2				
	20	1	100			1	81	2	19				
	30	1	100			1	65	2	35				
	40	1	100			1	53	2	47				
50	1	100			2	58	1	42					

Table 7d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit										
	Years					Fuel models					Fuel models					Fuel models					
	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	
None	1	11	65	2	29	1	6														
	10	2	78	10	22					2	67	11	33								
	20	2	90	10	10					2	76	10	24								
	30	2	94	10	6					2	81	10	19								
	40	2	94	10	6					2	79	10	21								
	50	2	89	10	11					2	76	10	24								
Pile and burn	1	2	84	1	16					2	100										
	10	2	100							2	100										
	20	2	100							2	100										
	30	2	100							2	95	10	5								
	40	2	100							2	88	10	12								
	50	2	100							2	80	10	20								
Prescribed fire	1	1	64	2	36					2	74	1	26								
	10	2	49	1	37	10	14			2	63	10	36								
	20	2	65	1	21	10	13			2	70	10	30								
	30	2	82	10	10	1	8			2	75	10	25								
	40	2	93	10	7					2	77	10	23								
	50	2	92	10	8					2	76	10	24								

tpa = trees per acre; d.b.h. = diameter at breast height.

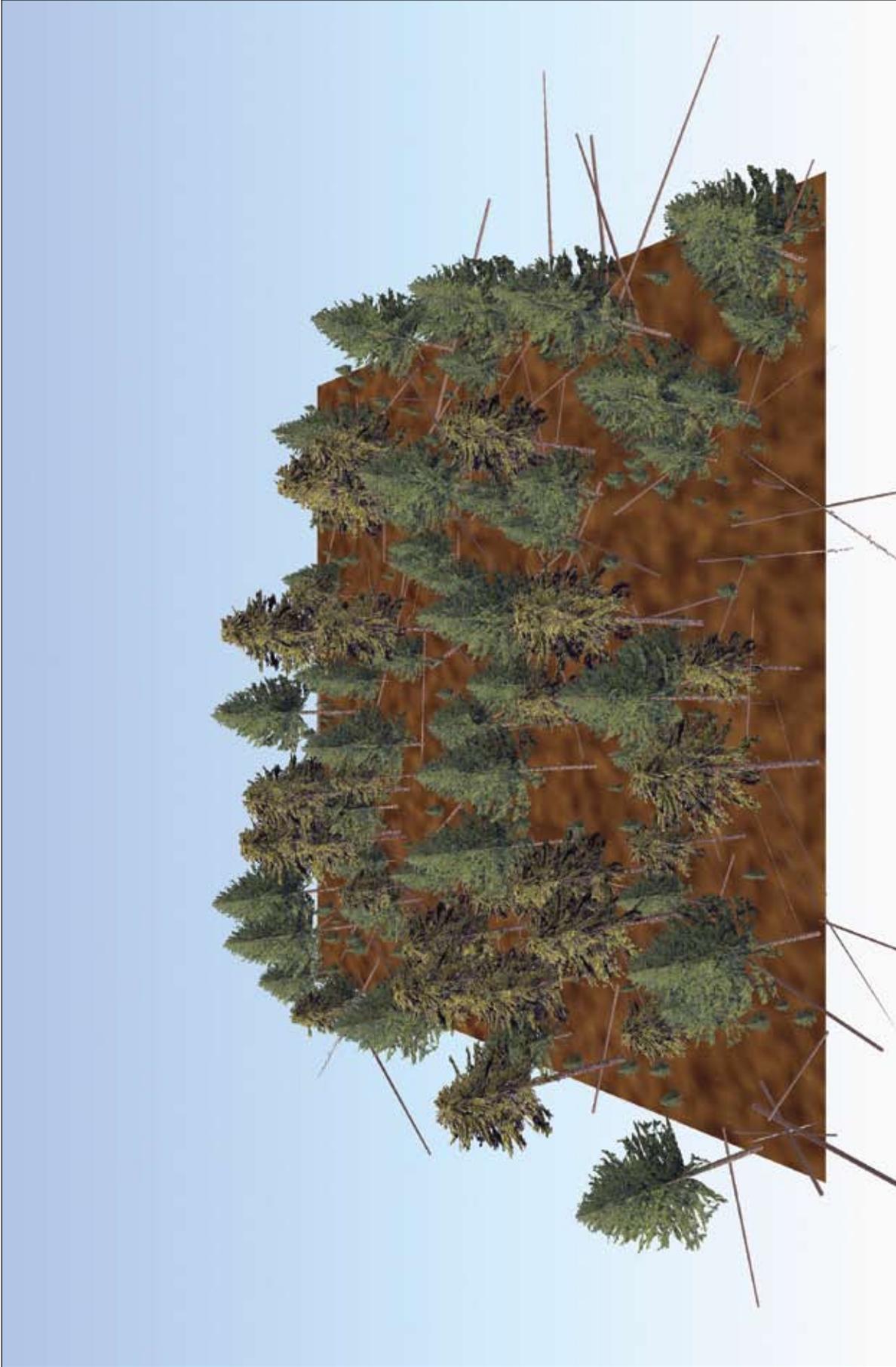
Table 7e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff	Live
Severe—98 th percentile	16	80	4	5	10	15	50	100
Moderate—75 th percentile	11	69	12	12	14	25	125	150

Table 7f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).

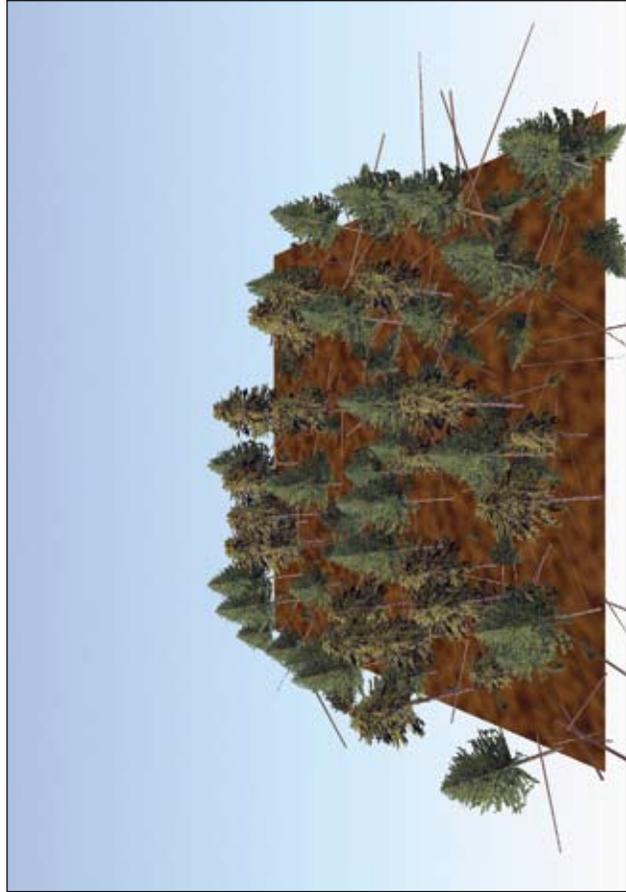


Initial stand conditions

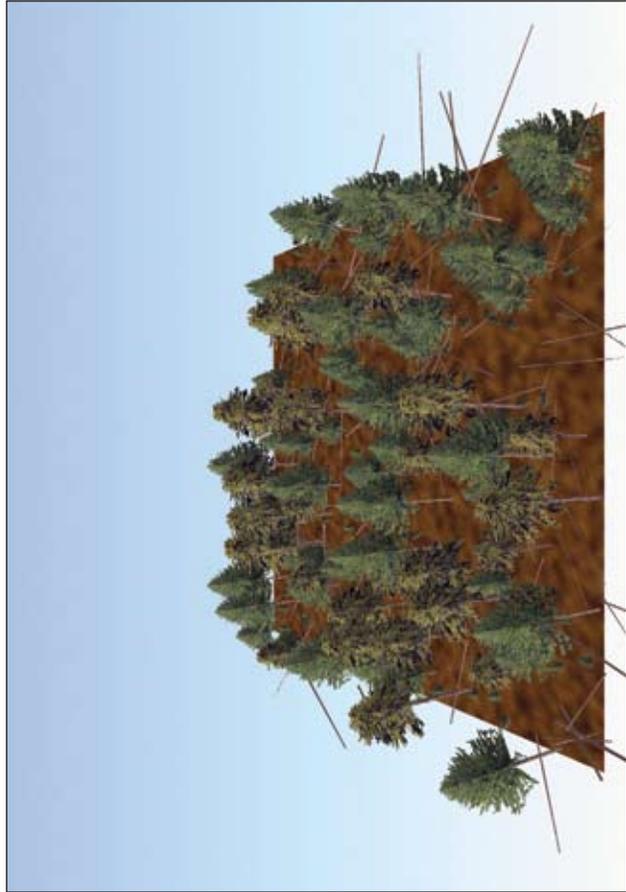
Site: Elevation = 9,200 ft, slope = 20 percent, aspect = 45°.

Species (based on trees per acre): White fir (*Abies concolor*) = 65 percent, Douglas-fir (*Pseudotsuga menziesii*) = 27 percent, ponderosa pine (*Pinus ponderosa*) = 5 percent.

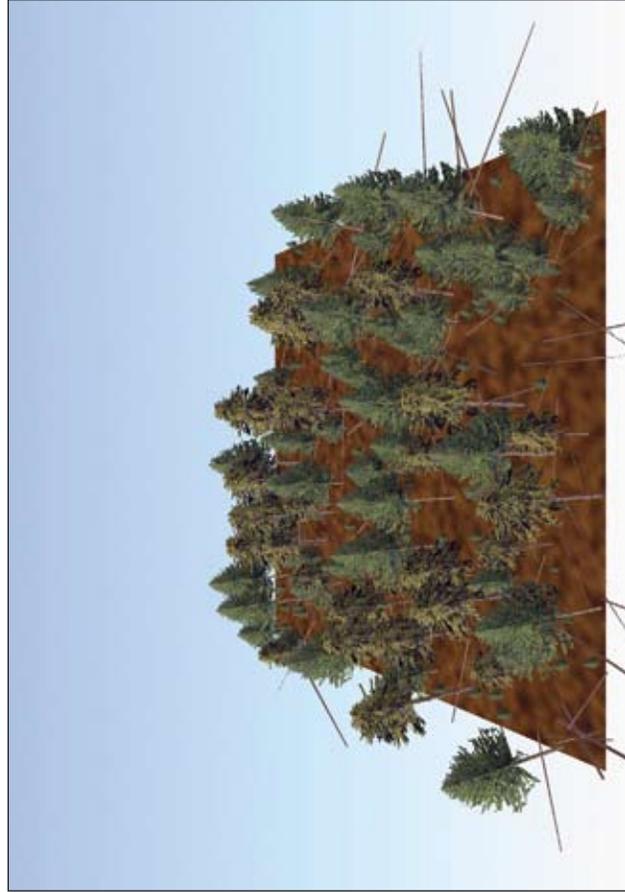
Stand attributes: Stem density = 384 tpa, basal area = 80 ft²/ac, top height = 50 ft, stand density index = 177, quadratic mean diameter = 6.2 in, crown competition factor = 77, canopy cover = 54 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has 384 trees per acre (tpa) composed of Douglas-fir and white fir understory with a low-density ponderosa pine overstory. Canopy bulk density is 0.07 kg/m³ (0.0044 lb/ft³), and canopy base height is 2 ft, so ladder fuels are sufficient to enable passive crown fire, but canopy fuels are not sufficient to enable active crown fire for severe fire weather. Woody fuel loading is 6 tons/ac, and litter and duff loading is 6 tons/ac. Predicted flame lengths are low for severe and moderate fire weather, but potential basal area mortality is 87 percent for severe fire weather. With no action, canopy base height remains low, canopy bulk density increases as smaller trees grow into the overstory, and surface fuels accumulate over time causing higher potential flame lengths. In 20 years, passive crown fire becomes likely for moderate and severe fire weather.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment increases canopy base height and decreases canopy bulk density and surface fuel loading. Potential flame lengths for severe fire weather increase to 5 ft, and passive crown fire remains likely because brush grows, and fire behavior is predicted by using fuel model 5. Brush fuels are not tracked in FFE, and the influences of brush fuels following treatment are site specific. Thinning to 100 tpa or less is required to increase canopy base height and reduce canopy bulk density sufficiently to affect crown fire potential. All thinning treatments increase surface fuels that contribute to higher potential flame lengths. The pile and burn and prescribed fire surface fuel treatments reduce woody surface fuels to below initial levels, and this reduces potential flame lengths and basal area mortality in the more dense treatments. However, potential flame lengths and basal area mortality remain high in the 50 tpa treatment regardless of surface fuel treatment, and in the 100 and 200 tpa treatments with a prescribed fire, because fire behavior is driven by brush fuel models.

Silvicultural and surface fuel treatments—long-term effects

Although the prescribed fire only treatment does not reduce crown fire potential initially, in 10 years, crown fire potential decreases and surface fire is predicted for moderate and severe fire weather. Flame lengths decrease over time as brush fuels decrease and canopy base height continues to increase, so crown fire potential declines over the 50-year trajectory. Thinning to 50 to 100 tpa has a long-term effect on crown fire potential. The predicted fire type in these treatments is surface fire for 50 years, and flame lengths decrease over time as brush fuels decrease. Canopy base height increases over time in the higher density treatments (200, 300 tpa), but the stands remain susceptible to passive crown fire for 50 years. However, in the high-density treatments, the prescribed fire surface fuel treatment further increases canopy base height because additional understory trees are killed. This decreases crown fire potential, and the predicted fire type is surface fire for 50 years.

Table 8a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	0-3 in	1	4	3	3	2
		3-6 in	0	2	2	2	2
		6-12 in	1	2	2	2	2
		>12 in	0	0	0	0	0
		Litter	0	3	2	2	2
		Duff	4	4	4	4	4
		Moderate	2	2	2	2	2
		Severe	3	5	3	3	3
		Severe	7	11	23	7	7
		Severe	37	43	37	37	37
Pile and burn	Flame length (ft)	Moderate	1	2	2	2	2
		Severe	5	5	3	3	3
	Torching index	7	11	23	7	7	7
	Crowning index	37	43	37	37	37	37
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface
		Passive	Passive	Passive	Passive	Passive	Passive
	Potential basal area mortality (%)	18	15	12	17	18	18
		87	96	46	23	88	87
		0-3 in	1	1	1	1	1
		3-6 in	1	1	1	1	1
	6-12 in	1	1	1	1	1	
	>12 in	0	0	0	0	0	
	Litter	2	2	2	2	2	
	Duff	4	4	4	4	4	
	Moderate	1	1	2	2	2	
	Severe	5	5	3	3	3	
	Severe	24	24	28	8	8	
	Severe	43	43	37	37	37	
	Moderate	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Passive	Passive	Passive	Passive	
	Potential basal area mortality (%)	12	12	16	18	18	
	Severe	60	60	21	83	83	
Prescribed fire	Surface fuel loadings (tons/ac)	0-3 in	0	0	0	0	0
		3-6 in	0	0	0	0	0
		6-12 in	1	1	1	1	1
		>12 in	0	0	0	0	0
		Litter	0	0	0	0	0
		Duff	3	3	3	3	3
		Moderate	1	1	1	1	1
		Severe	6	6	5	5	5
		Severe	23	23	11	11	11
		Severe	48	48	43	43	43
	Moderate	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Passive	Passive	Passive	Passive	
	Potential basal area mortality (%)	12	12	15	15	15	
	Severe	65	65	96	96	96	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 8b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	2	2	3	3	3	4	1	2	2	2	2	2
	0–3 in	2	2	3	3	3	4	1	2	2	2	2	2
	3–6 in	2	2	2	2	2	2	0	1	1	1	1	1
	6–12 in	2	2	2	2	2	2	1	2	2	2	2	2
	>12 in	0	0	0	0	1	1	0	0	1	1	1	1
	Litter	2	3	3	4	4	5	0	2	2	2	2	2
	Duff	4	5	5	5	5	5	3	3	3	3	3	3
	Flame length (ft)	2	2	2	2	2	2	1	1	1	1	2	2
	Moderate	3	3	3	3	4	4	5	5	5	3	3	3
	Severe	7	6	0	0	0	3	11	23	24	59	67	67
None	Surface fuel loadings (tons/ac)	37	34	29	25	22	19	43	44	41	41	39	37
	0–3 in	37	34	29	25	22	19	43	44	41	41	39	37
	3–6 in	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	6–12 in	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive
	>12 in	5	7	9	10	10	10	76	5	3	2	2	2
	Litter	0	0	0	0	1	1	1	1	0	0	0	0
	Duff	0	0	0	0	0	0	0	0	0	0	0	0
	Flame length (ft)	0	0	0	0	0	0	0	0	0	0	0	0
	Moderate	0	0	0	0	0	0	0	0	0	0	0	0
	Severe	0	0	0	0	0	0	0	0	0	0	0	0
None	Surface fuel loadings (tons/ac)	4	3	3	2	2	2	3	3	2	3	3	3
	0–3 in	4	3	3	2	2	2	3	3	2	3	3	3
	3–6 in	2	2	2	2	2	2	2	2	2	2	2	2
	6–12 in	2	2	2	2	2	2	2	2	2	2	2	2
	>12 in	0	0	0	0	0	0	0	0	0	0	0	0
	Litter	3	2	2	2	2	2	2	2	3	3	3	3
	Duff	4	5	5	5	5	5	4	5	5	5	5	5
	Flame length (ft)	2	2	1	2	2	2	2	2	2	1	1	1
	Moderate	5	5	5	3	3	3	3	3	3	2	2	2
	Severe	29	26	30	69	71	66	23	37	43	196	213	218
None	Surface fuel loadings (tons/ac)	43	44	43	42	40	39	37	36	34	32	31	30
	0–3 in	43	44	43	42	40	39	37	36	34	32	31	30
	3–6 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	6–12 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	>12 in	2	2	2	2	2	2	2	2	2	3	3	3
	Litter	0	0	0	0	0	0	0	0	0	0	0	0
	Duff	0	0	0	0	0	0	0	0	0	0	0	0
	Flame length (ft)	0	0	0	0	0	0	0	0	0	0	0	0
	Moderate	0	0	0	0	0	0	0	0	0	0	0	0
	Severe	0	0	0	0	0	0	0	0	0	0	0	0

Table 8b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
Pile and burn	Surface fuel loadings (tons/ac)	1	1	2	2	2	2	1	1	2	2	2	2	3
	0–3 in													
	3–6 in	1	1	1	1	1	1	1	1	1	1	1	1	1
	6–12 in	1	1	1	1	1	1	1	1	1	1	1	1	1
	>12 in	0	0	0	0	0	0	0	0	0	0	0	0	0
	Litter	2	2	2	2	2	2	2	2	3	3	3	3	3
	Duff	4	4	4	4	4	4	4	4	4	4	4	4	4
	Flame length (ft)	1	1	1	2	2	2	2	2	2	2	1	1	1
	Moderate	5	5	5	3	3	3	3	3	3	3	1	1	1
	Severe	24	25	29	72	75	72	28	43	51	307	349	318	318
Torching index	43	42	40	42	40	39	37	36	33	32	31	30	30	
Crowning index		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Type of fire		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Prescribed fire	Surface fuel loadings (tons/ac)	2	2	2	2	2	2	2	2	2	2	3	3	3
	0–17.9 in													
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	0
	0–3 in	0	1	1	2	2	2	0	2	2	2	2	2	2
	3–6 in	0	0	1	1	1	1	1	1	1	1	1	1	1
	6–12 in	1	1	2	2	2	2	1	2	2	2	2	2	2
	>12 in	0	0	1	1	1	1	0	0	1	1	1	1	1
	Litter	0	1	2	2	2	2	2	2	2	2	2	2	3
	Duff	3	3	3	3	3	3	4	3	3	3	3	3	4
Flame length (ft)	1	1	1	1	1	1	1	1	1	1	2	2	2	
Moderate	6	5	5	5	5	5	5	5	5	5	3	3	3	
Severe	23	24	25	31	33	33	11	23	24	59	67	65	65	
Torching index	48	45	42	41	40	40	43	41	39	36	36	35	35	
Crowning index		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Type of fire		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Hard snags (stems/ac)	Surface fuel loadings (tons/ac)	8	5	4	3	2	15	5	3	2	2	2	2	
	0–17.9 in													
	18–29.9 in	1	1	0	0	0	1	1	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
	0–3 in	0	1	1	2	2	2	0	2	2	2	2	2	
	3–6 in	0	0	1	1	1	1	1	1	1	1	1	1	
	6–12 in	1	1	2	2	2	2	1	2	2	2	2	2	
	>12 in	0	0	1	1	1	1	0	0	1	1	1	1	
	Litter	0	1	2	2	2	2	2	2	2	2	2	3	
	Duff	3	3	3	3	3	3	4	3	3	3	3	4	
Flame length (ft)	1	1	1	1	1	1	1	1	1	1	2	2		
Moderate	6	5	5	5	5	5	5	5	5	3	3	3		
Severe	23	24	25	31	33	33	11	23	24	59	67	65		
Torching index	48	45	42	41	40	40	43	41	39	36	36	35		
Crowning index		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface		
Type of fire		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface		
Hard snags (stems/ac)	Surface fuel loadings (tons/ac)	8	5	4	3	2	15	5	3	2	2	2	2	
	0–17.9 in													
	18–29.9 in	1	1	0	0	0	1	1	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
	0–3 in	0	1	1	2	2	2	0	2	2	2	2	2	
	3–6 in	0	0	1	1	1	1	1	1	1	1	1	1	
	6–12 in	1	1	2	2	2	2	1	2	2	2	2	2	
	>12 in	0	0	1	1	1	1	0	0	1	1	1	1	
	Litter	0	1	2	2	2	2	2	2	2	2	2	3	
	Duff	3	3	3	3	3	3	4	3	3	3	3	4	
Flame length (ft)	1	1	1	1	1	1	1	1	1	1	2	2		
Moderate	6	5	5	5	5	5	5	5	5	3	3	3		
Severe	23	24	25	31	33	33	11	23	24	59	67	65		
Torching index	48	45	42	41	40	40	43	41	39	36	36	35		
Crowning index		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface		
Type of fire		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface		

Table 8b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	0–3 in	3	2	3	3	3	2	2	3	3	3	3	4
		3–6 in	2	2	2	2	2	2	2	2	2	2	2	2
	Flame length (ft)	6–12 in	2	2	2	2	2	2	2	2	2	2	2	2
		>12 in	0	0	0	0	0	0	0	0	0	0	0	1
	Torching index	Litter	2	3	3	4	4	4	2	3	3	4	4	5
		Duff	4	5	5	5	5	5	4	5	5	5	5	5
	Crowning index	Moderate	2	2	2	2	3	2	2	2	2	2	2	2
		Severe	3	3	3	3	4	4	3	3	3	3	4	4
	Type of fire	Severe	7	6	6	13	10	17	7	6	5	4	11	18
		Severe	37	34	32	30	27	25	37	34	30	26	23	21
Hard snags (stems/ac)	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Surface	
	Severe	3	4	6	7	7	6	5	6	7	9	9	8	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	1	1	2	2	3	1	1	2	2	3	3	
		3–6 in	1	1	1	1	1	1	1	1	1	1	1	
	Flame length (ft)	6–12 in	1	1	1	1	1	1	1	1	1	1	1	
		>12 in	0	0	0	0	0	0	0	0	0	0	0	
	Torching index	Litter	2	3	3	4	4	4	2	3	3	4	4	
		Duff	4	4	4	4	4	5	4	4	4	4	4	
	Crowning index	Moderate	2	2	2	2	3	2	2	2	2	2	2	
		Severe	3	3	3	3	4	4	3	3	2	3	4	
	Type of fire	Severe	8	9	9	18	10	24	8	9	10	8	11	25
		Severe	37	34	32	30	27	24	37	34	30	26	23	20
Hard snags (stems/ac)	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Surface	
	Severe	3	4	6	7	7	6	5	6	7	9	9	8	
None	Surface fuel loadings (tons/ac)	0–17.9 in	0	0	0	0	0	0	0	0	0	0	1	
		18–29.9 in	0	0	0	0	0	0	0	0	0	0	1	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 8b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	2	2	2	2	2	0	2	2	2	2	2
		0	1	1	1	1	1	0	1	1	1	1	1
		1	2	2	2	2	2	1	2	2	2	2	2
		0	0	1	1	1	1	0	0	1	1	1	1
		0	2	2	2	2	2	0	2	2	2	2	3
		3	3	3	3	3	3	3	3	3	3	3	4
		1	1	1	2	2	2	1	1	1	2	2	2
		5	5	5	3	3	3	5	5	5	3	3	3
		11	23	24	59	67	71	11	23	24	59	67	70
		43	43	40	38	36	34	43	43	39	37	36	35
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Passive	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	36	5	3	2	2	2	57	5	3	2	2	2
Hard snags (stems/ac)	0–17.9 in	1	1	0	0	0	1	1	0	0	0	0	0
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 8c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	384	375	367	360	352	344	66	66	65	64	63	63
	Quadratic mean diameter (in)	6.2	6.7	7.2	7.7	8.2	8.7	6.2	14.4	15.4	16.3	17.2	18.0
	Total volume (ft ³)	1,337	1,567	1,799	2,021	2,254	2,515	1,225	1,329	1,530	1,735	1,938	2,135
	Merchantable volume (ft ³)	1,150	1,349	1,508	1,687	1,868	2,087	1,083	1,184	1,358	1,560	1,760	1,955
	Basal area (ft ²)	80	92	104	116	129	143	70	75	84	93	102	111
	Stand density index	177	197	217	236	256	277	112	118	130	141	151	161
	Canopy closure (percent)	54	59	64	69	73	77	46	48	51	55	57	60
	Crown competition factor	77	88	102	117	132	148	62	65	72	79	85	91
	Canopy base height (ft)	2	2	1	1	2	3	6	10	10	10	11	11
	Canopy bulk density (kg/m ³)	0.07	0.07	0.09	0.11	0.13	0.16	0.05	0.05	0.06	0.06	0.06	0.07

Table 8c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	384	50	64	63	63	62	61	100	107	105	104	102	101
	Quadratic mean diameter (in)	6.2	15.5	14.5	15.4	16.2	17.0	17.8	12	12.4	13.2	14.0	14.7	15.5
	Total volume (ft ³)	1,337	1,269	1,368	1,552	1,737	1,916	2,092	1,432	1,548	1,779	2,010	2,245	2,479
	Merchantable volume (ft ³)	1,150	1,135	1,230	1,409	1,590	1,765	1,938	1,258	1,370	1,563	1,784	2,010	2,244
	Basal area (ft ²)	80	65	74	82	90	97	105	78	89	100	111	121	131
	Stand density index	177	101	117	127	136	145	153	134	150	164	178	190	203
	Canopy cover (percent)	54	44	47	49	52	54	57	52	55	59	63	65	68
	Crown competition factor	77	57	63	68	73	78	83	72	81	89	98	106	113
	Canopy base height (ft)	2	11	11	12	13	13	12	5	7	8	9	10	11
	Canopy bulk density (kg/m ³)	0.07	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.08
Pile and burn	Trees per acre	384	50	72	71	70	70	69	100	111	109	108	106	105
	Quadratic mean diameter (in)	6.2	15.5	13.7	14.5	15.3	16.0	16.8	12.0	12.2	13.0	13.7	14.5	15.2
	Total volume (ft ³)	1,337	1,269	1,368	1,552	1,739	1,920	2,097	1,432	1,548	1,779	2,010	2,247	2,482
	Merchantable volume (ft ³)	1,150	1,135	1,230	1,409	1,590	1,766	1,940	1,258	1,370	1,563	1,784	2,011	2,246
	Basal area (ft ²)	80	65	74	82	90	98	105	78	89	100	111	121	132
	Stand density index	177	101	120	129	139	148	157	134	151	165	179	192	205
	Canopy cover (percent)	54	44	47	49	52	54	57	52	55	59	63	65	68
	Crown competition factor	77	57	63	68	73	79	84	72	81	89	98	106	114
	Canopy base height (ft)	2	11	11	12	13	13	12	5	7	8	9	10	11
	Canopy bulk density (kg/m ³)	0.07	0.05	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.09
Prescribed fire	Trees per acre	384	50	87	86	85	84	83	100	89	88	87	86	85
	Quadratic mean diameter (in)	6.2	15.5	11.7	12.4	13.1	13.8	14.5	12.0	12.4	13.2	14.0	14.7	15.5
	Total volume (ft ³)	1,337	1,121	1,211	1,381	1,556	1,724	1,892	1,225	1,332	1,534	1,741	1,946	2,147
	Merchantable volume (ft ³)	1,150	1,003	1,090	1,256	1,422	1,584	1,748	1,084	1,187	1,363	1,564	1,764	1,960
	Basal area (ft ²)	80	65	65	72	80	87	94	78	75	84	93	102	111
	Stand density index	177	101	112	121	131	141	150	134	126	138	150	161	172
	Canopy cover (percent)	54	44	42	45	48	50	53	52	48	51	55	58	60
	Crown competition factor	77	57	55	59	64	70	75	72	65	72	80	86	92
	Canopy base height (ft)	2	11	11	11	13	13	12	6	10	10	10	11	12
	Canopy bulk density (kg/m ³)	0.07	0.05	0.05	0.06	0.06	0.06	0.06	0.05	0.06	0.06	0.07	0.07	0.07

Table 8c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	384	200	200	196	191	187	183	300	297	291	284	278	272
	Quadratic mean diameter (in)	6.2	8.5	9.1	9.8	10.4	11.1	11.7	7.0	7.5	8.1	8.7	9.2	9.8
	Total volume (ft ³)	1,337	1,449	1,556	1,779	2,002	2,234	2,471	1,463	1,573	1,799	2,024	2,265	2,520
	Merchantable volume (ft ³)	1,150	1,253	1,352	1,525	1,720	1,917	2,175	1,252	1,353	1,519	1,707	1,897	2,141
	Basal area (ft ²)	80	80	91	102	114	125	137	80	92	104	116	129	142
	Stand density index	177	155	173	189	205	220	235	169	189	207	226	244	263
	Canopy cover (percent)	54	53	58	62	66	70	73	54	59	64	68	73	76
	Crown competition factor	77	76	86	97	109	120	130	77	89	101	115	129	143
	Canopy base height (ft)	2	2	2	2	3	4	6	2	2	2	2	4	6
Canopy bulk density (kg/m ³)	0.07	0.07	0.07	0.08	0.09	0.10	0.12	0.07	0.07	0.09	0.11	0.13	0.15	
Pile and burn	Trees per acre	384	200	202	198	193	189	185	300	299	293	286	280	274
	Quadratic mean diameter (in)	6.2	8.5	9.1	9.8	10.4	11.0	11.6	7.0	7.5	8.1	8.6	9.2	9.8
	Total volume (ft ³)	1,337	1,449	1,556	1,779	2,003	2,236	2,474	1,463	1,573	1,799	2,024	2,266	2,522
	Merchantable volume (ft ³)	1,150	1,253	1,352	1,525	1,720	1,918	2,176	1,252	1,353	1,519	1,707	1,898	2,141
	Basal area (ft ²)	80	80	91	102	114	125	137	80	92	104	116	129	143
	Stand density index	177	155	173	190	205	221	236	169	189	208	226	245	264
	Canopy cover (percent)	54	53	58	62	66	70	73	54	59	64	69	73	76
	Crown competition factor	77	76	86	97	109	120	130	77	89	101	116	129	143
	Canopy base height (ft)	2	2	2	2	3	4	6	2	2	2	2	4	6
Canopy bulk density (kg/m ³)	0.07	0.07	0.07	0.08	0.09	0.10	0.12	0.07	0.07	0.09	0.11	0.13	0.15	
Prescribed fire	Trees per acre	384	200	78	77	76	75	74	300	78	77	76	75	74
	Quadratic mean diameter (in)	6.2	8.5	13.3	14.2	15.0	15.8	16.6	7.0	13.2	14.2	15.0	15.8	16.6
	Total volume (ft ³)	1,337	1,225	1,329	1,533	1,738	1,940	2,140	1,225	1,328	1,534	1,738	1,939	2,139
	Merchantable volume (ft ³)	1,150	1,083	1,183	1,363	1,561	1,760	1,956	1,083	1,183	1,362	1,562	1,758	1,955
	Basal area (ft ²)	80	80	75	84	93	102	111	80	74	84	93	102	111
	Stand density index	177	155	122	134	145	156	166	169	122	134	145	156	166
	Canopy cover (percent)	54	53	48	51	55	58	60	54	48	51	55	58	60
	Crown competition factor	77	76	65	72	80	86	92	77	65	72	79	86	91
	Canopy base height (ft)	2	6	10	10	10	11	12	6	10	10	10	11	12
Canopy bulk density (kg/m ³)	0.07	0.05	0.05	0.06	0.06	0.07	0.07	0.05	0.05	0.06	0.07	0.07	0.07	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 8d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None	1	9	97	10	3	5	100						
	10	9	92	10	8	5	100						
	20	9	85	10	15	5	100						
	30	9	76	10	24	9	100						
	40	10	100			9	100						
50	10	100			9	98	10	2					

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None	1	5	75	11	25	9	90	10	10				
	10	5	94	10	6	9	94	10	6				
	20	5	97	10	3	9	92	10	8				
	30	9	99	10	1	8	89	10	11				
	40	9	98	10	2	8	87	10	13				
50	9	96	10	4	8	83	10	17					
Pile and burn	1	5	100			9	100						
	10	5	100			9	100						
	20	5	100			9	100						
	30	9	100			8	100						
	40	9	100			8	99	10	1				
50	9	100			8	94	10	6					
Prescribed fire	1	5	100			5	100						
	10	5	100			5	100						
	20	5	100			5	100						
	30	5	100			9	100						
	40	5	100			9	100						
50	9	100			9	97	10	3					

Table 8d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit											
	Years					Fuel models					Fuel models					Fuel models						
	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight		
None		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent		
	1	9	96	10	4	9	97	10	3	9	97	10	3	9	97	10	3	9	97	10	3	
	10	9	92	10	8	9	92	10	8	9	92	10	8	9	92	10	8	9	92	10	8	
	20	9	87	10	13	9	85	10	15	9	85	10	15	9	85	10	15	9	85	10	15	
	30	9	80	10	20	9	77	10	23	9	77	10	23	9	77	10	23	9	77	10	23	
40	10	100			10	100				10	100			10	100				10	100		
50	10	100			10	100				10	100			10	100				10	100		
Pile and burn	1	9	100			9	100			9	100			9	100				9	100		
	10	9	100			9	100			9	100			9	100				9	100		
	20	9	100			9	100			9	100			9	100				9	100		
	30	9	95	10	5	9	92	10	8	9	92	10	8	9	92	10	8		9	92	10	8
	40	10	100			10	100			10	100			10	100				10	100		
50	10	100			10	100				10	100			10	100				10	100		
Prescribed fire	1	5	100			5	100			5	100			5	100				5	100		
	10	5	100			5	100			5	100			5	100				5	100		
	20	5	100			5	100			5	100			5	100				5	100		
	30	9	100			9	100			9	100			9	100				9	100		
	40	9	100			9	100			9	100			9	100				9	100		
50	9	97	10	3	9	96	10	4	9	96	10	4	9	96	10	4		9	96	10	4	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 8e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff	Live
Severe—98 th percentile	18	87	3	5	13	16	50	100
Moderate—75 th percentile	10	69	5	7	16	19	125	150

Table 8f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

Site: Elevation = 9,000 ft, slope = 35 percent, aspect = 180°.

Species (based on trees per acre): White fir (*Abies concolor*) = 43 percent, Douglas-fir (*Pseudotsuga menziesii*) = 42 percent, ponderosa pine (*Pinus ponderosa*) = 12 percent.

Stand attributes: Stem density = 953 tpa, basal area = 157 ft²/ac, top height = 65 ft, stand density index = 365, quadratic mean diameter = 5.5 in, crown competition factor = 174, canopy cover = 82 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has 953 trees per acre (tpa) composed of Douglas-fir and white fir understory with a low-density ponderosa pine overstory. Canopy bulk density is 0.24 kg/m³ (0.015 lb/ft³), and canopy base height is 3 ft, so ladder fuels are sufficient to enable passive crown fire, but canopy fuels are not sufficient to enable active crown fire for severe fire weather. Surface fire is predicted for moderate fire weather. Woody fuel loading is 9 tons/ac, and litter and duff loading is 7 tons/ac. Predicted flame lengths are low for severe and moderate fire weather, but potential basal area mortality is 100 percent for severe fire weather. With no action, canopy base height and canopy bulk density increase slightly as trees grow, but surface fuels accumulate causing higher potential flame lengths and increasing crown fire hazard. Passive crown fire is predicted in 10 years for moderate fire weather. Active crown fire remains likely for severe fire weather for the duration of the 50-year projection.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment increases canopy base height and decreases canopy bulk density sufficiently enough to reduce the predicted fire type to surface fire for moderate and severe fire weather. Surface fuels are also reduced, and flame lengths remain similar to initial conditions. All thinning treatments increase canopy base height and reduce canopy bulk density, but thinning to 200 tpa or less is necessary to decrease crown fire potential. All thinning treatments increase surface fuels, which contribute to higher potential flame lengths. The pile and burn and prescribed fire surface fuel treatments reduce woody surface fuels to below initial levels, and this reduces potential flame lengths and basal area mortality in the more dense treatments. Potential flame lengths and basal area mortality remain high in the more open treatments (50 to 100 tpa), even with surface fuel treatments because fire behavior is driven by grass and brush fuel models. The presence of grass and brush fuels following treatment is site specific, and these results should be interpreted cautiously because grass and brush fuels are not tracked in FFE.

Silvicultural and surface fuel treatments—long-term effects

All treatments have a long-term effect on crown fire potential, and surface fire remains the predicted fire type for moderate and severe fire weather for the duration of the 50-year projection. Regeneration is low in all treatments, so canopy base height increases over time as trees grow and crowns rise. In stands that had a surface fuel treatment, surface fuels accumulate over time contributing to higher potential flame lengths; all treatments have flame lengths of at least 4 ft for severe fire weather in 50 years. A second treatment may be necessary to reduce surface fuels.

Table 9a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	3	1	10	8	7	5
		3	0	4	4	4	3
		3	1	2	3	3	3
		0	0	0	0	0	0
		2	1	5	5	4	3
		5	4	4	5	5	5
		2	2	4	3	3	3
		3	3	6	5	4	4
		14	49	45	62	46	25
		13	26	50	31	24	18
Pile and burn	Flame length (ft)	Surface	Surface	Surface	Surface	Surface	Surface
	Torching index	Active	Surface	Surface	Surface	Surface	Surface
	Crowning index	30	22	13	16	21	25
	Type of fire	100	23	33	34	33	32
	Potential basal area mortality (%)						
		0-3 in	2	2	2	2	2
		3-6 in	1	1	1	1	1
		6-12 in	1	1	1	1	1
		>12 in	0	0	0	0	0
		Litter	5	4	5	4	3
Prescribed fire	Flame length (ft)	Duff	4	4	5	5	5
	Torching index	Moderate	6	6	2	2	2
	Crowning index	Severe	34	88	87	87	52
	Type of fire	Severe	50	31	24	24	18
	Potential basal area mortality (%)	Moderate	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Surface
		0-3 in	12	16	16	21	25
		3-6 in	35	16	16	21	25
		6-12 in	0	0	0	0	0
		>12 in	0	0	0	0	0
Pile and burn	Flame length (ft)	Litter	0	0	0	0	0
	Torching index	Duff	3	4	4	4	4
	Crowning index	Moderate	4	4	2	2	2
	Type of fire	Severe	6	6	5	3	3
	Potential basal area mortality (%)	Severe	33	37	39	85	85
		0-3 in	57	40	35	29	29
		3-6 in	Surface	Surface	Surface	Surface	Surface
		6-12 in	Surface	Surface	Surface	Surface	Surface
		>12 in	11	15	18	20	20
		Litter	38	41	43	20	20

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 9b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	3	4	6	8	8	9	1	5	5	5	5	6
	0–3 in	3	3	3	4	4	5	0	3	3	3	3	4
	3–6 in	3	3	3	4	4	5	1	4	4	4	4	4
	6–12 in	0	0	1	1	2	2	0	1	1	2	2	2
	>12 in	2	6	7	8	8	9	1	4	4	5	5	5
	Litter	5	5	6	6	6	7	4	4	4	4	4	4
	Duff	2	3	3	4	4	4	2	3	3	3	3	3
	Moderate	3	4	4	5	5	6	3	4	4	4	4	4
	Severe	14	0	0	0	0	0	49	33	41	46	45	51
	Torching index	13	14	14	13	12	12	26	29	26	24	23	22
	Crowning index	Surface	Passive	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	Type of fire	Active	Active	Active	Active	Active	Active	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	43	46	53	51	49	62	189	12	10	10	10	12
0–17.9 in	1	1	2	2	2	2	1	1	2	2	2	2	
18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
30–36 in													
None	Surface fuel loadings (tons/ac)	10	7	5	5	4	4	8	6	5	5	5	5
	0–3 in	4	4	4	4	4	4	4	4	4	4	4	4
	3–6 in	2	2	2	3	3	3	3	3	3	3	3	3
	6–12 in	0	0	1	1	2	2	0	0	1	1	1	2
	>12 in	5	2	2	2	2	2	5	3	3	3	4	4
	Litter	4	4	4	4	5	5	5	5	5	6	6	6
	Duff	4	3	3	2	2	2	3	3	3	3	3	3
	Moderate	6	5	5	5	5	5	5	4	4	4	4	4
	Severe	45	51	52	58	60	58	62	71	81	85	94	104
	Torching index	50	52	49	48	47	46	31	33	32	31	30	30
	Crowning index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	8	6	6	6	6	6	8	7	7	7	8	8
0–17.9 in	1	1	2	2	3	3	1	1	2	2	2	3	
18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
30–36 in													

Table 9b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	2	2	3	3	3	2	2	3	4	4	5
		3–6 in	1	1	1	2	2	1	1	2	2	2	2
		6–12 in	1	1	1	1	2	1	1	1	2	2	2
		>12 in	0	0	1	1	2	0	0	1	1	1	2
		Litter	5	2	2	2	2	4	3	3	3	3	4
		Duff	4	4	4	4	4	5	5	5	5	5	5
		Moderate	4	2	2	2	2	2	2	2	2	2	3
		Severe	6	6	5	5	5	3	3	3	3	3	3
		Torching index	34	48	50	57	59	88	109	104	98	101	107
		Crowning index	50	50	47	46	44	31	33	32	31	30	30
Prescribed fire	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	8	6	6	6	6	8	7	7	8	8	8
		18–29.9 in	1	1	2	2	2	1	1	2	2	2	2
		30–36 in	0	0	0	0	0	0	0	0	0	0	0
		0–3 in	0	1	2	3	3	0	2	3	3	4	4
		3–6 in	0	1	1	1	2	1	1	1	2	2	2
		6–12 in	1	2	2	2	2	1	3	4	4	4	4
		>12 in	0	1	1	2	2	0	1	1	2	2	3
		Litter	0	2	2	2	2	4	2	3	3	3	3
Pile and burn	Duff	3	3	3	3	3	5	4	4	4	4	4	
	Moderate	4	2	2	2	2	4	2	2	2	3	3	
	Severe	6	6	6	5	5	6	5	5	5	4	4	
	Torching index	33	48	52	59	62	37	54	59	86	86	89	
	Crowning index	57	54	52	50	48	40	41	39	37	36	36	
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	18	11	8	7	7	24	11	8	7	7	7
		18–29.9 in	1	1	2	2	3	1	1	2	2	2	3
		30–36 in	0	0	0	0	0	0	0	0	0	0	0

Table 9b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	0–3 in	7	6	5	5	6	6	5	5	5	6	7	7
		3–6 in	4	4	4	4	4	4	3	3	3	4	4	4
		6–12 in	3	3	3	3	3	4	3	3	3	3	4	5
	Flame length (ft)	>12 in	0	0	1	1	1	2	0	0	1	1	1	2
		Litter	4	4	4	5	5	5	3	5	5	6	6	6
		Duff	5	5	5	6	6	6	5	5	5	6	6	6
	Torching index	Moderate	3	3	3	3	3	3	3	3	3	3	3	4
		Severe	4	4	4	4	4	4	4	4	4	4	4	5
		Severe	46	52	58	63	63	75	25	23	22	33	35	33
	Crowning index	Severe	24	26	25	24	24	23	18	19	18	18	18	18
		Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Surface	Surface	Conditional	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	9	8	9	9	10	14	10	10	15	22	23	21
		18–29.9 in	1	1	2	2	2	2	1	1	2	2	2	2
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	2	2	3	4	5	6	1	3	4	5	6	7
		3–6 in	1	1	2	2	2	2	1	1	1	2	2	3
		6–12 in	1	1	1	2	2	2	1	1	1	2	2	3
	Flame length (ft)	>12 in	0	0	1	1	1	2	0	0	1	1	1	2
		Litter	4	4	4	5	5	5	3	5	5	6	6	6
		Duff	5	5	5	5	5	6	5	5	5	5	5	6
	Torching index	Moderate	2	2	2	2	3	3	2	2	2	3	3	3
		Severe	3	3	3	3	4	4	3	3	3	4	4	4
		Severe	87	77	70	69	65	69	52	37	29	36	39	49
	Crowning index	Severe	24	26	25	24	24	23	18	19	18	18	19	18
		Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Surface	Surface	Conditional	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	9	8	9	9	10	15	10	10	15	22	24	21
		18–29.9 in	1	1	2	2	2	2	1	1	2	2	2	2
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

Table 9b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
Prescribed fire	Surface fuel loadings (tons/ac)	0	3	3	4	4	5	0	4	4	4	4	5	5
		0	2	2	2	3	3	0	3	3	3	3	3	3
		1	4	4	4	4	4	1	4	4	4	4	4	4
		0	1	1	2	2	3	0	1	1	2	2	2	3
	Litter	1	3	3	3	4	4	1	3	4	4	4	4	4
	Duff	4	4	4	4	4	4	4	4	4	4	4	4	4
	Moderate	2	2	2	3	3	3	2	2	3	3	3	3	3
	Severe	5	3	3	4	4	4	3	3	4	4	4	4	4
Torching index		39	67	75	81	91	96	85	60	62	70	80	86	
		35	36	34	33	31	30	29	31	30	29	28	27	
Crowning index		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Type of fire		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Hard snags (stems/ac)		34	11	9	8	8	8	50	12	10	9	9	9	
		1	1	2	2	2	2	1	2	2	2	2	2	
		0	0	0	0	0	0	0	0	0	0	0	0	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 9c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	953	896	845	798	753	697	233	230	225	219	213	206
	Quadratic mean diameter (in)	5.5	6.1	6.7	7.2	7.8	8.4	5.5	10.2	11.0	11.8	12.6	13.3
	Total volume (ft ³)	3,149	3,694	4,267	4,856	5,481	6,035	2,708	2,944	3,426	3,908	4,389	4,860
	Merchantable volume (ft ³)	2,482	2,941	3,422	3,933	4,443	4,966	2,292	2,483	2,935	3,360	3,792	4,236
	Basal area (ft ²)	157	181	204	228	250	268	120	129	148	166	184	200
	Stand density index	365	404	440	474	506	527	222	236	262	286	308	327
	Canopy closure (percent)	82	86	90	92	94	95	68	71	76	79	83	85
	Crown competition factor	174	200	227	253	278	299	115	124	143	158	175	188
	Canopy base height (ft)	3	3	3	4	4	5	7	8	9	10	10	11
	Canopy bulk density (kg/m ³)	0.24	0.21	0.22	0.23	0.25	0.25	0.10	0.09	0.10	0.11	0.12	0.13

Table 9c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	953	50	63	61	59	57	55	100	105	102	99	97	94
	Quadratic mean diameter (in)	5.5	17.1	16.0	16.9	17.8	18.7	19.6	13.9	14.4	15.3	16.2	17.1	17.9
	Total volume (ft ³)	3,149	2,224	2,356	2,600	2,833	3,052	3,257	2,782	2,980	3,363	3,736	4,101	4,448
	Merchantable volume (ft ³)	2,482	1,961	2,086	2,316	2,529	2,727	2,907	2,417	2,586	2,942	3,291	3,627	3,945
	Basal area (ft ²)	157	80	88	95	102	109	116	106	119	131	143	154	164
	Stand density index	365	118	134	142	149	156	163	170	189	203	216	228	239
	Canopy cover (percent)	82	47	50	52	54	56	58	61	64	67	70	72	74
	Crown competition factor	174	64	69	74	78	83	87	93	103	112	119	127	135
Pile and burn	Canopy base height (ft)	3	19	19	19	20	20	19	18	19	19	19	20	21
	Canopy bulk density (kg/m ³)	0.24	0.04	0.04	0.04	0.05	0.05	0.05	0.08	0.07	0.08	0.08	0.08	0.08
Pile and burn	Trees per acre	953	50	71	69	67	64	62	100	109	106	103	100	98
	Quadratic mean diameter (in)	5.5	17.1	15.1	15.9	16.8	17.7	18.5	13.9	14.1	15.0	15.9	16.8	17.6
	Total volume (ft ³)	3,149	2,224	2,356	2,600	2,837	3,059	3,268	2,782	2,980	3,363	3,738	4,104	4,454
	Merchantable volume (ft ³)	2,482	1,961	2,086	2,316	2,531	2,730	2,912	2,417	2,586	2,942	3,292	3,629	3,949
	Basal area (ft ²)	157	80	88	95	103	110	116	106	119	131	143	154	164
	Stand density index	365	118	137	145	153	161	167	170	190	204	218	230	241
	Canopy cover (percent)	82	47	50	52	54	57	59	61	64	67	70	72	74
	Crown competition factor	174	64	69	74	79	83	88	93	103	112	119	127	135
Prescribed fire	Canopy base height (ft)	3	19	19	19	20	20	19	18	18	19	19	20	21
	Canopy bulk density (kg/m ³)	0.24	0.04	0.04	0.05	0.05	0.05	0.05	0.08	0.07	0.08	0.08	0.08	0.09
	Trees per acre	953	50	85	83	80	77	74	100	99	97	94	91	88
	Quadratic mean diameter (in)	5.5	17.1	13.0	13.7	14.5	15.3	16.1	13.9	13.6	14.5	15.4	16.2	17.1
	Total volume (ft ³)	3,149	2,031	2,153	2,375	2,597	2,803	2,999	2,422	2,594	2,923	3,250	3,557	3,862
	Merchantable volume (ft ³)	2,482	1,810	1,927	2,142	2,342	2,528	2,701	2,127	2,281	2,594	2,899	3,184	3,465
	Basal area (ft ²)	157	80	79	85	92	99	106	106	101	111	121	131	140
	Stand density index	365	118	130	138	146	154	161	170	163	176	187	198	208
Prescribed fire	Canopy cover (percent)	82	47	45	48	50	53	55	61	57	60	63	65	67
	Crown competition factor	174	64	60	64	70	75	80	93	84	91	98	105	111
Prescribed fire	Canopy base height (ft)	3	19	20	21	22	22	21	18	19	19	20	20	21
	Canopy bulk density (kg/m ³)	0.24	0.04	0.04	0.04	0.04	0.04	0.05	0.06	0.06	0.06	0.06	0.07	0.07

Table 9c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	953	200	200	195	190	185	176	300	297	286	269	253	241
	Quadratic mean diameter (in)	5.5	10.9	11.7	12.6	13.4	14.1	14.9	9.3	10.1	10.9	11.7	12.5	13.2
	Total volume (ft ³)	3,149	3,136	3,388	3,894	4,393	4,882	5,292	3,292	3,572	4,109	4,586	5,048	5,516
	Merchantable volume (ft ³)	2,482	2,696	2,879	3,348	3,769	4,201	4,582	2,765	2,995	3,493	3,908	4,294	4,727
	Basal area (ft ²)	157	130	149	168	185	201	213	143	166	186	202	216	230
	Stand density index	365	230	257	281	302	322	334	269	303	329	347	363	378
	Canopy cover (percent)	82	71	75	79	82	84	85	76	81	84	86	88	89
	Crown competition factor	174	123	140	156	169	184	191	144	166	186	199	212	223
	Canopy base height (ft)	3	11	11	12	13	13	14	6	6	6	8	9	11
	Canopy bulk density (kg/m ³)	0.24	0.11	0.10	0.11	0.11	0.11	0.12	0.16	0.15	0.16	0.16	0.16	0.16
Pile and burn	Trees per acre	953	200	202	197	192	187	178	300	299	289	271	255	243
	Quadratic mean diameter (in)	5.5	10.9	11.7	12.5	13.3	14.0	14.8	9.3	10.1	10.9	11.7	12.5	13.2
	Total volume (ft ³)	3,149	3,136	3,388	3,894	4,393	4,879	5,289	3,292	3,572	4,121	4,600	5,059	5,528
	Merchantable volume (ft ³)	2,482	2,696	2,879	3,348	3,769	4,198	4,579	2,765	2,995	3,503	3,926	4,304	4,741
	Basal area (ft ²)	157	130	149	168	185	201	213	143	166	187	202	216	231
	Stand density index	365	230	258	281	303	322	334	269	303	331	349	364	379
	Canopy cover (percent)	82	71	75	79	82	84	85	76	81	84	86	88	89
	Crown competition factor	174	123	140	156	169	184	191	144	166	186	199	212	223
	Canopy base height (ft)	3	11	11	12	13	13	14	6	6	6	8	9	11
	Canopy bulk density (kg/m ³)	0.24	0.11	0.10	0.11	0.11	0.11	0.12	0.16	0.15	0.16	0.16	0.15	0.16
Prescribed fire	Trees per acre	953	200	138	135	131	128	124	300	173	169	164	159	155
	Quadratic mean diameter (in)	5.5	10.9	12.5	13.4	14.3	15.1	15.9	9.3	11.4	12.3	13.2	14.0	14.8
	Total volume (ft ³)	3,149	2,609	2,814	3,223	3,627	4,028	4,421	2,667	2,888	3,327	3,763	4,197	4,629
	Merchantable volume (ft ³)	2,482	2,275	2,434	2,822	3,171	3,540	3,908	2,302	2,482	2,898	3,278	3,661	4,062
	Basal area (ft ²)	157	130	117	132	146	159	172	143	124	140	155	170	184
	Stand density index	365	230	197	215	232	248	262	269	215	236	255	273	289
	Canopy cover (percent)	82	71	64	69	72	74	77	76	68	72	75	78	80
	Crown competition factor	174	123	103	116	126	137	145	144	113	128	139	152	163
	Canopy base height (ft)	3	14	14	16	17	18	19	13	13	13	14	16	17
	Canopy bulk density (kg/m ³)	0.24	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.08	0.09	0.09	0.09	0.10

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 9d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	Years	No action						Prescribed fire only					
		Fuel models			Fuel models			Fuel models			Fuel models		
		Model	Weight	Percent	Model	Weight	Percent	Model	Weight	Percent	Model	Weight	Percent
None	1	9	93	10	7	9	100	9	42	9	42	9	
	10	10	60	9	40	10	58	10	31	9	31	10	
	20	10	95	9	5	10	69	10	25	9	25	10	
	30	10	87	12	13	10	75	10	17	9	17	10	
	40	10	74	12	26	10	83	10	8	9	8	10	
50	10	62	12	38	10	92	10		9		10		

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Years	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit					
		Fuel models			Fuel models			Fuel models			Fuel models		
		Model	Weight	Percent	Model	Weight	Percent	Model	Weight	Percent	Model	Weight	Percent
None	1	10	87	12	13	10	96	12	4	10	96	12	4
	10	10	60	5	40	10	66	9	34	10	66	9	34
	20	5	53	10	47	10	59	9	41	10	59	9	41
	30	5	57	10	43	10	59	9	41	10	59	9	41
	40	5	57	10	43	10	64	9	36	10	64	9	36
50	5	56	10	44	10	70	9	30	10	70	9	30	
Pile and burn	1	2	80	10	20	9	88	10	12	9	88	10	12
	10	5	100			9	96	10	4	9	96	10	4
	20	5	97	10	3	9	86	10	14	9	86	10	14
	30	5	89	10	11	9	75	10	25	9	75	10	25
	40	5	81	10	19	9	64	10	36	9	64	10	36
50	5	75	10	25	9	53	10	47	9	53	10	47	
Prescribed fire	1	2	100			2	100			2	100		
	10	5	100			5	99	10	1	5	99	10	1
	20	5	100			5	83	10	17	5	83	10	17
	30	5	91	10	9	9	72	10	28	9	72	10	28
	40	5	83	10	17	9	62	10	38	9	62	10	38
50	5	76	10	24	9	54	10	46	9	54	10	46	

Table 9d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 200 tpa, 18-in. d.b.h. limit										
	Years					Fuel models					Fuel models					Fuel models					
	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	
None		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent	
	1	10	80	9	20	10	51	9	49	10	51	9	49	10	51	9	49	10	51	9	49
	10	10	66	9	34	10	60	9	40	10	60	9	40	10	60	9	40	10	60	9	40
	20	10	67	9	33	10	70	9	30	10	70	9	30	10	70	9	30	10	70	9	30
	30	10	73	9	27	10	86	9	14	10	86	9	14	10	86	9	14	10	86	9	14
	40	10	83	9	17	10	97	12	3	10	97	12	3	10	97	12	3	10	97	12	3
50	10	95	9	5	10	86	12	14	10	86	12	14	10	86	12	14	10	86	12	14	
Pile and burn	1	9	99	10	1	9	100	9	16	9	100	9	16	9	100	9	16	9	100	9	16
	10	9	89	10	11	9	84	10	16	9	84	10	16	9	84	10	16	9	84	10	16
	20	9	73	10	27	9	63	10	37	9	63	10	37	9	63	10	37	9	63	10	37
	30	9	58	10	42	10	59	9	41	10	59	9	41	10	59	9	41	10	59	9	41
	40	10	56	9	44	10	81	9	19	10	81	9	19	10	81	9	19	10	81	9	19
	50	10	72	9	28	10	99	12	1	10	99	12	1	10	99	12	1	10	99	12	1
Prescribed fire	1	5	100	10	1	9	100	9	34	9	100	9	34	9	100	9	34	9	100	9	34
	10	9	78	10	22	9	66	10	34	9	66	10	34	9	66	10	34	9	66	10	34
	20	9	63	10	37	9	51	10	49	9	51	10	49	9	51	10	49	9	51	10	49
	30	9	53	10	47	10	58	9	42	10	58	9	42	10	58	9	42	10	58	9	42
	40	10	56	9	44	10	67	9	33	10	67	9	33	10	67	9	33	10	67	9	33
	50	10	66	9	34	10	77	9	23	10	77	9	23	10	77	9	23	10	77	9	23

tpa = trees per acre, d.b.h. = diameter at breast height.

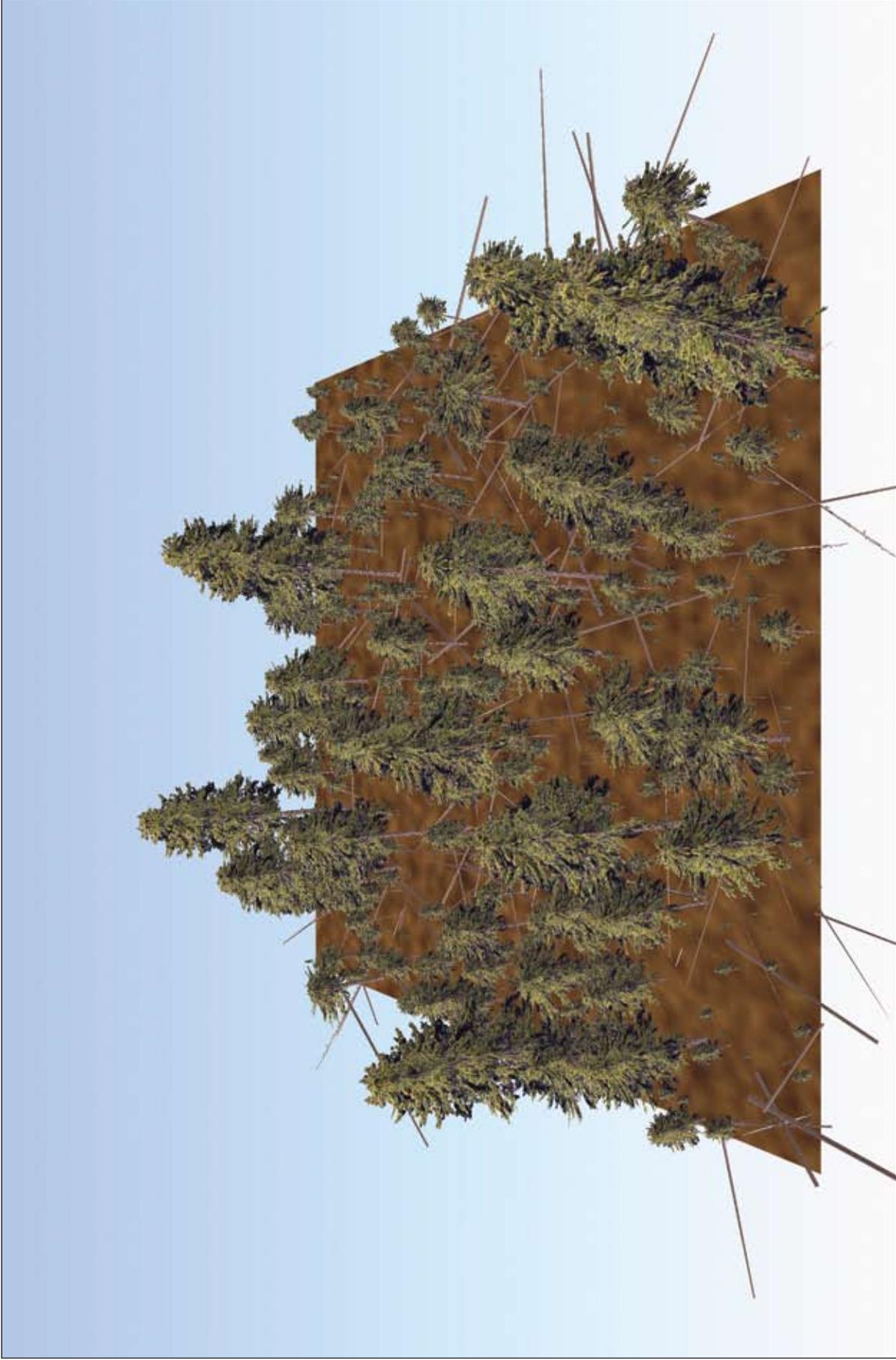
Table 9e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff	Live
Severe—98 th percentile	18	84	3	5	13	16	50	100
Moderate—75 th percentile	10	75	5	7	16	19	125	150

Table 9f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).

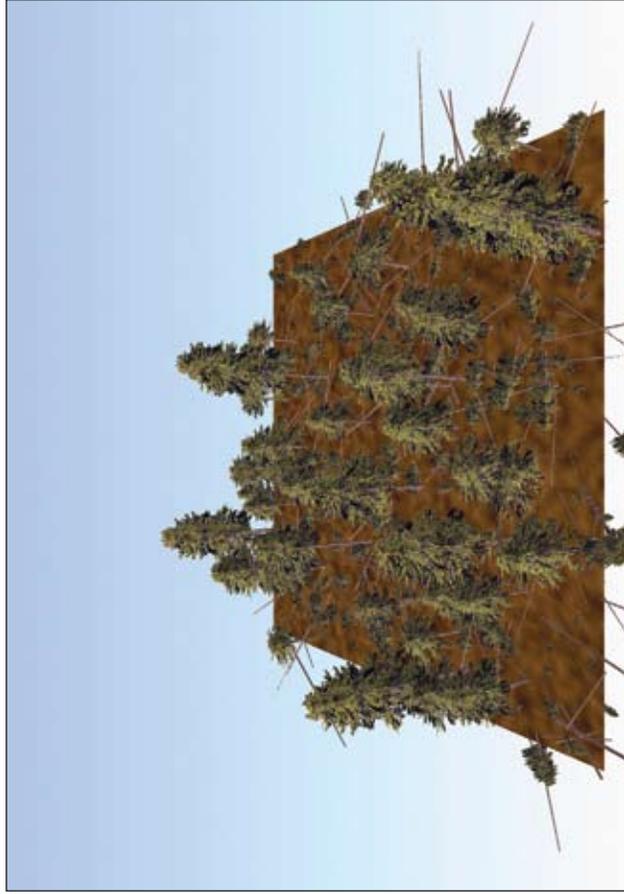


Initial stand conditions

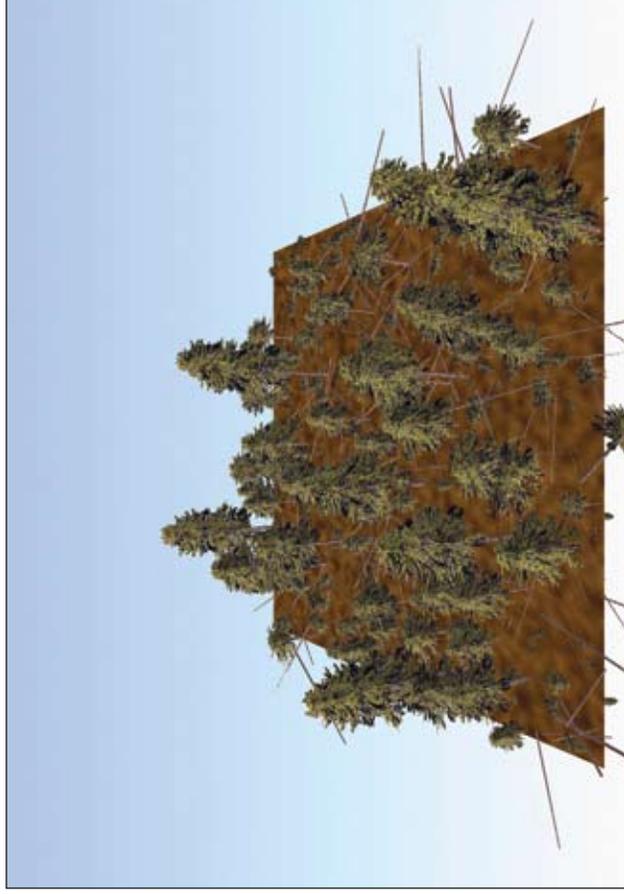
Site: Elevation = 7,000 ft, slope = 1 percent, aspect = 270°.

Species (based on trees per acre): Ponderosa pine (*Pinus ponderosa*) = 100 percent.

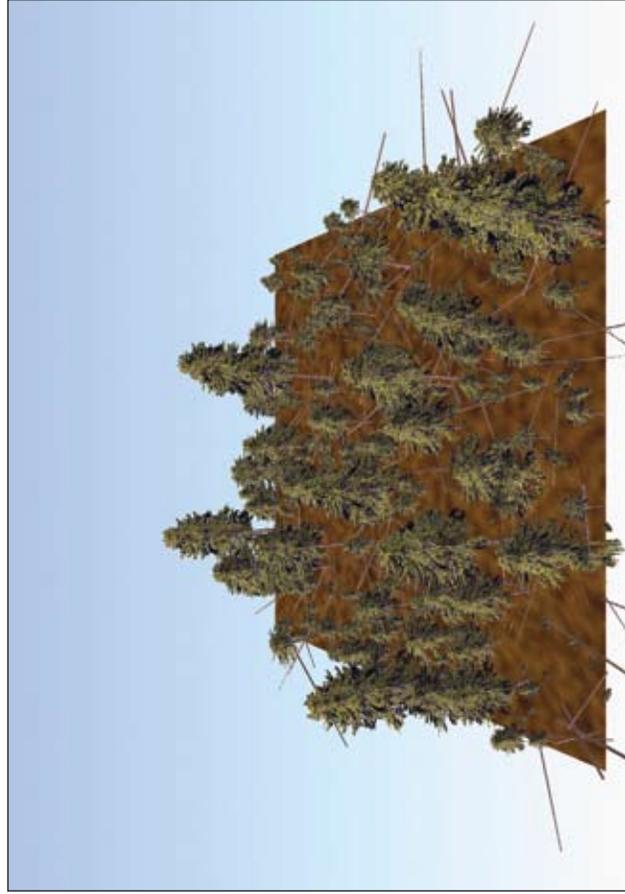
Stand attributes: Stem density = 496 tpa, basal area = 106 ft²/ac, top height = 41 ft, stand density index = 234, quadratic mean diameter = 6.3 in, crown competition factor = 84, canopy cover = 57 percent.



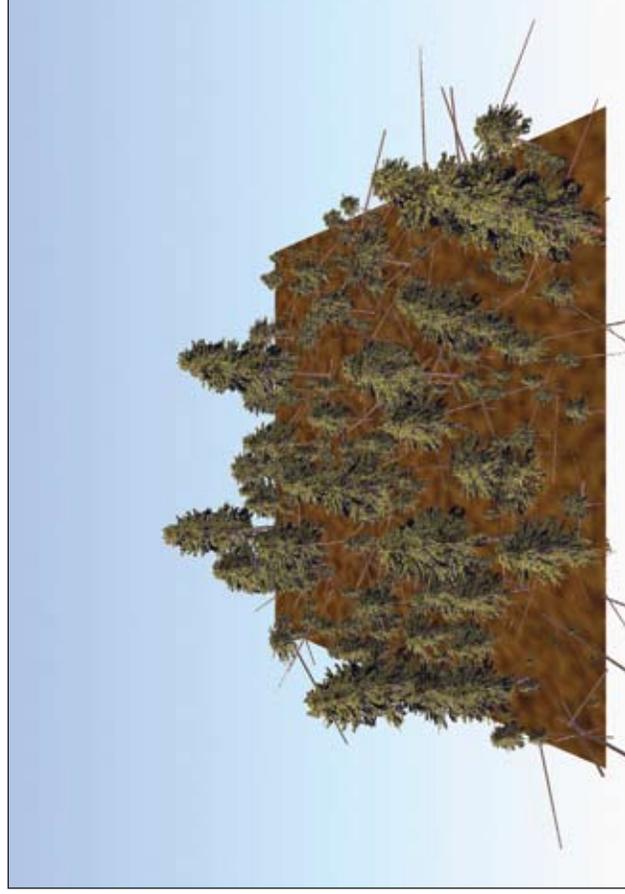
Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This is a pure ponderosa pine stand with 496 trees per acre (tpa). Canopy bulk density is 0.10 kg/m^3 (0.0062 lb/ft^3), and canopy base height is 4 ft, so ladder fuels are sufficient to enable passive crown fire, and canopy fuels are sufficient to enable active crown fire for severe fire weather. Woody fuel loading is 7 tons/ac, and litter and duff loading is 7 tons/ac. Despite the relatively low woody fuel loading, potential flame lengths are 6 ft and potential basal area mortality is 100 percent for severe fire weather because the predominant fuel model is 5 (fire behavior is driven by brush fuels). Brush fuels are not entered and tracked in the FFE, so these results should be interpreted with caution. With no action, canopy base height increases as the trees grow and crown fire potential declines; fire type changes from active crown fire to conditional crown fire in 30 years and to surface fire in 50 years. Surface fuels accumulate, but flame lengths decrease over time as the predominant fuel model shifts from model 5 to fuel models 9 and 10.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment effectively reduces surface fuels, but does not affect canopy base height and canopy bulk density enough to decrease crown fire potential. Thinning to 50 tpa is required to increase canopy base height and decrease canopy bulk density, but even with this treatment, potential flame lengths and basal area mortality remain high, and the predicted fire type is passive crown fire for severe fire weather. The 200 and 300 tpa treatments have essentially no effect on forest structure, and basal area mortality remains 100 percent for severe fire weather. All treatments have flame lengths of 1 ft and low basal area mortality for moderate fire weather. The pile and burn and prescribed fire treatments reduce woody surface fuels in all size classes; potential flame lengths and basal area mortality remain high for severe fire weather because the predominant fuel model is 5, suggesting that brush fuels would drive fire behavior in these open stands with low woody fuels. The FFE model does not track brush fuels directly so these results should be interpreted with caution.

Silvicultural and surface fuel treatments—long-term effects

Although the treatments have little effect on crown fire potential in the short term, they do reduce crown fire potential in the long term. In all treatments, canopy base height increases over time as the trees grow and the stand self-thins. Flame lengths remain high for severe fire weather, but the increase in canopy base height causes the predicted fire type to shift to surface fire in 10 years for the prescribed fire only, 50 tpa, 100 tpa, and 200 tpa treatments. The predicted fire type remains surface fire for the 50-year trajectory although fuel model 5 still drives fire behavior, and flame lengths remain at least 4 ft for severe fire weather. Crown fire potential remains high in the 300 tpa treatment for 40 years. The 300 tpa treatment with prescribed fire has a greater long-term effect on crown fire potential because fire-caused mortality of overstory trees increases canopy base height enough that the predicted fire type changes from active to passive crown fire initially and then to surface fire in 30 years.

Table 10a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	0–3 in	1	4	4	3	3
		3–6 in	0	2	2	2	2
		6–12 in	1	2	2	2	2
		>12 in	0	0	0	0	0
		Litter	2	2	2	2	2
		Duff	5	3	4	5	5
		Moderate	1	1	2	1	1
		Severe	6	6	6	6	6
		Torching index	11	12	26	13	14
		Crowning index	29	39	41	35	29
Pile and burn	Type of fire	Surface Active	Surface Passive	Surface Passive	Surface Passive	Surface Active	Surface Active
	Potential basal area mortality (%)	20	16	10	14	19	20
		100	98	96	98	100	100
	Surface fuel loadings (tons/ac)	0–3 in	1	1	1	1	1
		3–6 in	1	1	1	1	1
		6–12 in	1	1	1	1	1
Prescribed fire		>12 in	0	0	0	0	0
		Litter	2	2	2	2	2
		Duff	3	3	4	4	4
		Moderate	1	1	1	1	1
		Severe	7	7	6	6	6
		Torching index	25	25	12	14	11
		Crowning index	41	41	35	29	29
		Type of fire	Surface Passive	Surface Passive	Surface Passive	Surface Active	Surface Active
	Potential basal area mortality (%)	10	10	14	14	19	20
		96	96	98	98	100	100
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	0	0	0	0	0
		3–6 in	0	0	0	0	0
		6–12 in	1	1	1	1	1
		>12 in	0	0	0	0	0
		Litter	1	1	1	1	1
		Duff	3	3	3	3	3
		Moderate	1	1	1	1	1
		Severe	7	7	6	6	6
		Torching index	24	24	11	12	12
		Crowning index	45	45	41	39	39
Prescribed fire	Type of fire	Surface Passive	Surface Passive	Surface Passive	Surface Passive	Surface Active	Surface Active
	Potential basal area mortality (%)	9	9	12	15	16	16
		96	96	98	98	98	98

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 10b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	1	2	3	3	4	4	1	2	3	4	5	
	0–3 in	1	1	1	1	2	2	1	1	1	2	2	
	3–6 in	1	1	1	1	1	1	1	1	1	1	1	
	6–12 in	0	0	0	0	0	0	0	0	0	0	0	
	>12 in	2	2	2	2	3	3	2	3	3	3	4	
	Litter	3	3	3	3	4	4	4	4	4	4	4	
	Duff	1	1	1	1	2	2	1	1	1	2	2	
	Moderate	7	6	6	6	6	6	6	6	6	3	4	
	Severe	25	42	50	60	63	69	12	37	40	57	68	
	Severe	41	53	51	52	49	51	35	41	42	40	41	
Prescribed fire	Surface fuel loadings (tons/ac)	0	2	3	3	3	3	0	3	3	4	4	
	0–3 in	0	1	1	1	2	2	0	1	1	1	2	
	3–6 in	1	1	1	1	1	1	1	1	1	1	1	
	6–12 in	0	0	1	1	1	1	0	0	1	1	1	
	>12 in	1	2	2	3	3	3	2	2	3	3	3	
	Litter	3	3	3	3	3	3	4	3	3	3	4	
	Duff	1	1	1	1	2	2	1	1	1	2	2	
	Moderate	7	7	6	6	6	6	6	6	6	6	5	
	Severe	24	40	45	48	50	51	11	37	43	35	48	
	Severe	45	47	46	46	43	43	41	45	45	43	44	
Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	
	Severe	9	8	5	3	3	3	15	8	5	3	3	
	0–17.9 in	1	1	1	1	1	1	1	1	1	1	0	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	
	Flame length (ft)	Surface fuel loadings (tons/ac)	0	2	3	3	3	3	0	3	3	4	4
		0–3 in	0	1	1	1	2	2	0	1	1	1	2
		3–6 in	1	1	1	1	1	1	1	1	1	1	1
		6–12 in	0	0	1	1	1	1	0	0	1	1	1
>12 in		1	2	2	3	3	3	2	2	3	3	3	
Litter		3	3	3	3	3	3	4	3	3	3	4	
Duff		1	1	1	1	2	2	1	1	1	2	2	
Moderate		7	7	6	6	6	6	6	6	6	6	5	
Severe		24	40	45	48	50	51	11	37	43	35	48	
Severe		45	47	46	46	43	43	41	45	45	43	44	
Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	
	Severe	9	8	5	3	3	3	15	8	5	3	3	
	0–17.9 in	1	1	1	1	1	1	1	1	1	1	0	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	

Table 10b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	0–3 in	3	4	5	5	6	7	3	4	5	5	6	7
		3–6 in	2	3	3	3	4	4	2	3	3	3	4	4
	6–12 in	2	2	2	2	2	2	2	2	2	2	2	2	2
		>12 in	0	0	0	0	0	0	0	0	0	0	0	0
	Litter	2	4	4	4	4	4	4	2	4	4	5	5	5
		Duff	5	5	5	5	5	6	5	5	5	5	6	6
	Flame length (ft)	Moderate	1	2	2	2	2	2	1	2	2	2	2	2
		Severe	6	4	4	4	4	4	6	4	4	4	4	4
	Torching index	Severe	14	39	38	49	68	70	11	30	29	46	54	61
		Crowning index	29	34	32	33	34	35	29	28	29	29	30	31
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Active	Surface	Surface	Surface	Surface	Surface	Active	Active	Active	Active	Active	Active	
Hard snags (stems/ac)	0–17.9 in	3	4	5	5	5	4	4	6	7	4	13	17	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	1	2	4	5	6	6	1	2	4	5	6	7
		3–6 in	1	1	1	2	2	3	1	1	1	2	2	3
	6–12 in	1	1	1	1	1	1	1	1	1	1	1	1	
		>12 in	0	0	0	0	0	0	0	0	0	0	0	0
	Litter	2	4	4	4	4	4	4	2	4	4	5	5	5
		Duff	4	4	4	5	5	5	4	4	5	5	5	5
	Flame length (ft)	Moderate	1	1	2	2	2	2	1	1	2	2	2	2
		Severe	6	3	3	3	4	4	6	3	3	3	4	4
	Torching index	Severe	14	58	45	53	65	79	11	44	34	49	55	63
		Crowning index	29	34	32	33	34	35	29	28	29	29	30	31
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Active	Surface	Surface	Surface	Surface	Surface	Active	Active	Active	Active	Active	Active	
Hard snags (stems/ac)	0–17.9 in	3	4	5	5	5	4	4	6	7	5	14	17	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 10b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	3	3	4	5	5	0	3	4	4	5	5
		0	1	1	2	2	3	0	1	1	2	2	3
		1	2	2	2	2	2	1	2	2	2	2	2
		0	0	1	1	1	1	0	0	1	1	1	1
		1	3	3	4	4	4	1	3	3	4	4	4
Flame length (ft)	Duff	3	3	3	4	4	4	3	3	4	4	4	4
	Moderate	1	1	2	2	2	2	1	1	2	2	2	2
Torching index	Severe	6	6	6	5	4	4	6	6	6	4	4	4
	Severe	12	30	28	38	64	75	12	26	25	46	60	67
Crowning index	Severe	39	42	39	40	41	41	39	41	37	38	39	39
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Type of fire	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface
	Severe	30	8	6	4	4	4	52	8	6	4	4	4
Hard snags (stems/ac)	0–17.9 in	1	1	1	1	0	0	1	1	1	0	0	0
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

tpa = trees per acre; d.b.h. = diameter at breast height; Cond. = conditional.

Table 10c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	496	486	475	450	429	412	139	137	135	132	129	127
	Quadratic mean diameter (in)	6.3	6.9	7.5	8.1	8.6	9.1	6.3	11.4	12.3	13.2	13.9	14.6
	Total volume (ft ³)	1,410	1,879	2,354	2,817	3,275	3,720	1,380	1,572	1,966	2,372	2,771	3,156
	Merchantable volume (ft ³)	1,176	1,596	2,038	2,461	2,836	3,277	1,204	1,390	1,777	2,124	2,521	2,913
	Basal area (ft ²)	106	127	145	160	174	186	91	98	112	125	137	148
	Stand density index	234	269	298	319	338	355	160	170	189	205	220	233
	Canopy closure (percent)	57	63	68	71	74	77	57	50	54	58	62	65
	Crown competition factor	84	101	114	125	135	145	68	74	83	92	101	108
	Canopy base height (ft)	4	5	6	8	9	10	5	9	8	10	13	15
	Canopy bulk density (kg/m ³)	0.10	0.11	0.11	0.10	0.10	0.09	0.07	0.06	0.07	0.07	0.07	0.06

Table 10c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	496	496	50	64	63	62	61	100	106	104	102	100	98
	Quadratic mean diameter (in)	6.3	6.3	16.7	15.7	16.7	17.5	18.4	12.9	13.4	14.3	15.1	15.9	16.6
	Total volume (ft ³)	1,410	1,410	1,356	1,520	1,842	2,163	2,477	1,492	1,686	2,073	2,465	2,849	3,215
	Merchantable volume (ft ³)	1,176	1,176	1,209	1,375	1,700	2,024	2,347	1,311	1,504	1,887	2,224	2,611	2,987
	Basal area (ft ²)	106	106	76	86	95	103	111	90	104	116	127	138	147
	Stand density index	234	234	114	132	143	152	161	150	169	184	198	210	221
	Canopy cover (percent)	57	57	42	46	49	51	53	49	54	57	60	63	65
	Crown competition factor	84	84	55	61	67	72	76	68	77	85	92	100	106
	Canopy base height (ft)	4	4	10	15	17	20	20	5	12	12	12	14	19
	Canopy bulk density (kg/m ³)	0.10	0.10	0.06	0.04	0.04	0.04	0.04	0.08	0.06	0.06	0.06	0.06	0.06
Pile and burn	Trees per acre	496	50	72	71	70	68	67	100	110	108	106	104	102
	Quadratic mean diameter (in)	6.3	16.7	14.8	15.7	16.5	17.3	18.0	12.9	13.1	14.0	14.8	15.6	16.3
	Total volume (ft ³)	1,410	1,356	1,520	1,842	2,165	2,482	2,783	1,492	1,686	2,073	2,466	2,852	3,219
	Merchantable volume (ft ³)	1,176	1,209	1,375	1,700	2,023	2,348	2,662	1,311	1,504	1,887	2,224	2,611	2,989
	Basal area (ft ²)	106	76	86	95	104	112	119	90	104	116	127	138	147
	Stand density index	234	114	135	146	156	165	173	150	171	186	200	212	223
	Canopy cover (percent)	57	42	46	49	51	54	56	49	54	57	60	63	65
	Crown competition factor	84	55	61	67	72	77	82	68	77	85	92	100	106
	Canopy base height (ft)	4	10	15	17	19	19	20	5	12	12	11	14	19
	Canopy bulk density (kg/m ³)	0.10	0.06	0.04	0.05	0.04	0.05	0.05	0.08	0.06	0.06	0.06	0.06	0.06
Prescribed fire	Trees per acre	496	50	88	86	85	84	82	100	97	95	93	92	90
	Quadratic mean diameter (in)	6.3	16.7	12.8	13.6	14.3	15.1	15.8	12.9	13.0	13.9	14.7	15.5	16.2
	Total volume (ft ³)	1,410	1,239	1,392	1,697	2,008	2,312	2,606	1,322	1,495	1,841	2,199	2,546	2,875
	Merchantable volume (ft ³)	1,176	1,109	1,264	1,570	1,878	2,187	2,488	1,169	1,344	1,678	2,010	2,362	2,702
	Basal area (ft ²)	106	76	78	87	95	104	112	90	89	99	110	120	129
	Stand density index	234	114	130	141	152	162	171	150	147	160	173	185	195
	Canopy cover (percent)	57	42	42	45	49	51	54	49	48	51	55	57	60
	Crown competition factor	84	55	55	61	66	72	77	68	65	72	79	86	91
	Canopy base height (ft)	4	10	15	16	16	16	18	5	13	14	11	14	19
	Canopy bulk density (kg/m ³)	0.10	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.05	0.05	0.06	0.06	0.06

Table 10c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	496	200	200	196	192	189	186	300	298	293	289	276	263
	Quadratic mean diameter (in)	6.3	9.7	10.5	11.3	12.0	12.7	13.2	8.0	8.7	9.4	10.0	10.7	11.3
	Total volume (ft ³)	1,410	1,608	1,831	2,290	2,752	3,212	3,662	1,629	1,857	2,332	2,828	3,281	3,705
	Merchantable volume (ft ³)	1,176	1,381	1,594	2,030	2,459	2,853	3,307	1,381	1,595	2,043	2,480	2,877	3,304
	Basal area (ft ²)	106	104	121	137	152	165	178	106	125	142	159	172	183
	Stand density index	234	192	217	239	259	276	292	211	241	267	291	307	320
	Canopy cover (percent)	57	55	61	65	68	71	74	57	62	67	71	73	75
	Crown competition factor	84	81	93	105	115	125	135	83	98	110	123	132	140
	Canopy base height (ft)	4	5	8	8	10	13	14	4	6	6	9	10	11
	Canopy bulk density (kg/m ³)	0.10	0.10	0.08	0.09	0.08	0.08	0.08	0.10	0.10	0.10	0.10	0.10	0.09
Pile and burn	Trees per acre	496	200	202	198	194	191	188	300	300	295	291	278	265
	Quadratic mean diameter (in)	6.3	9.7	10.5	11.3	12.0	12.6	13.2	8.0	8.7	9.4	10.0	10.7	11.2
	Total volume (ft ³)	1,410	1,608	1,831	2,290	2,753	3,209	3,658	1,629	1,857	2,332	2,828	3,279	3,699
	Merchantable volume (ft ³)	1,176	1,381	1,594	2,030	2,453	2,850	3,302	1,381	1,595	2,043	2,480	2,874	3,299
	Basal area (ft ²)	106	104	121	137	152	165	178	106	125	142	159	172	183
	Stand density index	234	192	218	240	259	276	292	211	241	267	292	307	320
	Canopy cover (percent)	57	55	61	65	68	71	74	57	62	67	71	73	75
	Crown competition factor	84	81	93	105	115	125	134	83	98	110	123	132	140
	Canopy base height (ft)	4	5	8	8	10	12	14	4	6	6	9	10	11
	Canopy bulk density (kg/m ³)	0.10	0.10	0.08	0.09	0.08	0.08	0.08	0.10	0.10	0.10	0.10	0.10	0.09
Prescribed fire	Trees per acre	496	200	125	123	121	119	116	300	145	143	140	137	135
	Quadratic mean diameter (in)	6.3	9.7	11.9	12.8	13.6	14.4	15.1	8.0	11.1	12.0	12.8	13.5	14.2
	Total volume (ft ³)	1,410	1,376	1,565	1,953	2,348	2,739	3,118	1,380	1,572	1,966	2,372	2,770	3,158
	Merchantable volume (ft ³)	1,176	1,204	1,391	1,766	2,105	2,500	2,888	1,204	1,391	1,773	2,118	2,517	2,912
	Basal area (ft ²)	106	104	97	110	123	134	145	106	98	112	125	137	148
	Stand density index	234	192	166	183	199	213	226	211	172	191	208	223	236
	Canopy cover (percent)	57	55	52	56	59	63	65	57	52	56	60	64	66
	Crown competition factor	84	81	73	82	90	99	105	83	74	83	92	101	109
	Canopy base height (ft)	4	5	10	9	11	14	16	5	9	8	10	13	14
	Canopy bulk density (kg/m ³)	0.10	0.07	0.06	0.07	0.06	0.06	0.06	0.07	0.06	0.07	0.07	0.07	0.07

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 10d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None	1	5	96	10	4	5	100						
	10	9	65	10	35	5	87	10	13				
	20	10	53	9	47	5	74	10	26				
	30	10	67	9	33	9	65	10	35				
	40	10	79	9	21	9	55	10	45				
50	10	89	9	11	10	52	9	48					

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None	1	5	75	10	25	5	84	10	16				
	10	5	82	10	18	5	77	10	23				
	20	5	80	10	20	5	70	10	30				
	30	5	79	10	21	9	63	10	37				
	40	5	74	10	26	9	54	10	46				
50	5	67	10	33	10	54	9	46					
Pile and burn	1	5	100			5	100						
	10	5	100			5	100						
	20	5	100			5	91	10	9				
	30	5	94	10	6	9	80	10	20				
	40	5	84	10	16	9	66	10	34				
50	5	76	10	24	9	57	10	43					
Prescribed fire	1	5	100			5	100						
	10	5	100			5	100						
	20	5	98	10	2	5	90	10	10				
	30	5	90	10	10	5	81	10	19				
	40	5	81	10	19	5	70	10	30				
50	5	72	10	28	5	62	10	38					

Table 10d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit						Thin from below to 300 tpa, 18-in. d.b.h. limit					
	Fuel models			Fuel models			Fuel models			Fuel models		
	Years	Model	Weight	Model	Weight	Model	Model	Weight	Model	Weight	Model	Weight
None			Percent			Percent						Percent
	1	5	93	10	7		5	95	10	5		5
	10	9	70	10	30		9	69	10	31		31
	30	10	55	9	45		10	62	9	38		38
	40	10	65	9	35		10	72	9	28		28
50	10	74	9	26		10	83	9	17		17	
Pile and burn	1	5	100				5	100				
	10	9	98	10	2		9	96	10	4		4
	20	9	77	10	23		9	72	10	28		28
	30	9	62	10	38		9	56	10	44		44
	40	10	50	9	50		10	57	9	43		43
50	10	60	9	40		10	70	9	30		30	
Prescribed fire	1	5	100				5	100				
	10	5	94	10	6		5	91	10	9		9
	20	5	80	10	20		5	77	10	23		23
	30	5	69	10	31		9	66	10	34		34
	40	9	59	10	41		9	56	10	44		44
50	9	50	10	50		10	52	9	48		48	

tpa = trees per acre, d.b.h. = diameter at breast height.

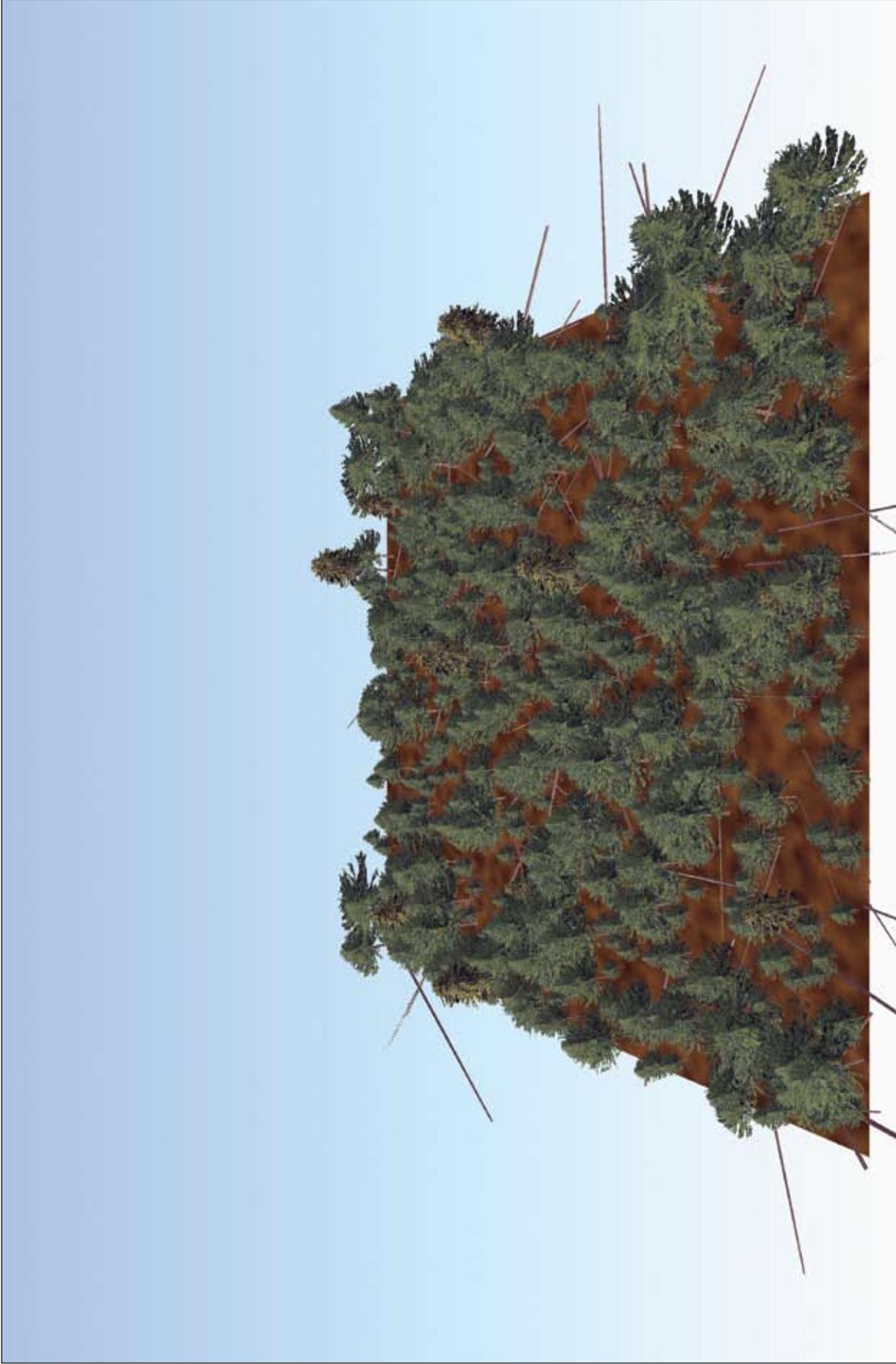
Table 10e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff	Live
Severe—98 th percentile	30	74	4	6	12	15	50	100
Moderate—75 th percentile	12	57	8	10	19	26	125	150

Table 10f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).

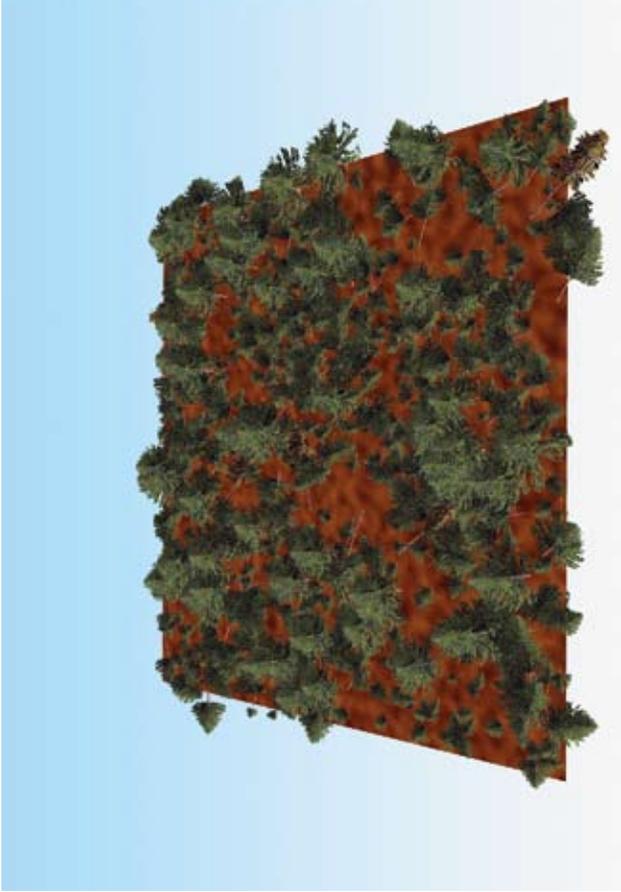


Initial stand conditions

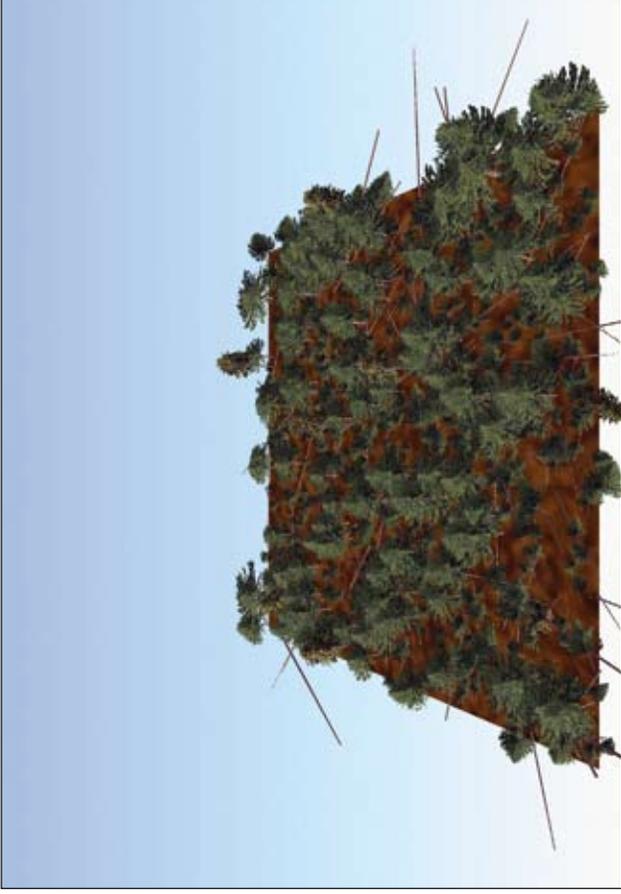
Site: Elevation = 7,100 ft, slope = 35 percent, aspect = 10°.

Species (based on trees per acre): Pinyon pine (*Pinus edulis*) = 86 percent, hardwoods = 12 percent, ponderosa pine (*Pinus ponderosa*) = 2 percent.

Stand attributes: Stem density = 733 tpa, basal area = 162 ft²/ac, top height = 23 ft, stand density index = 356, quadratic mean diameter = 6.4 in, crown competition factor = 190, canopy cover = 85 percent.



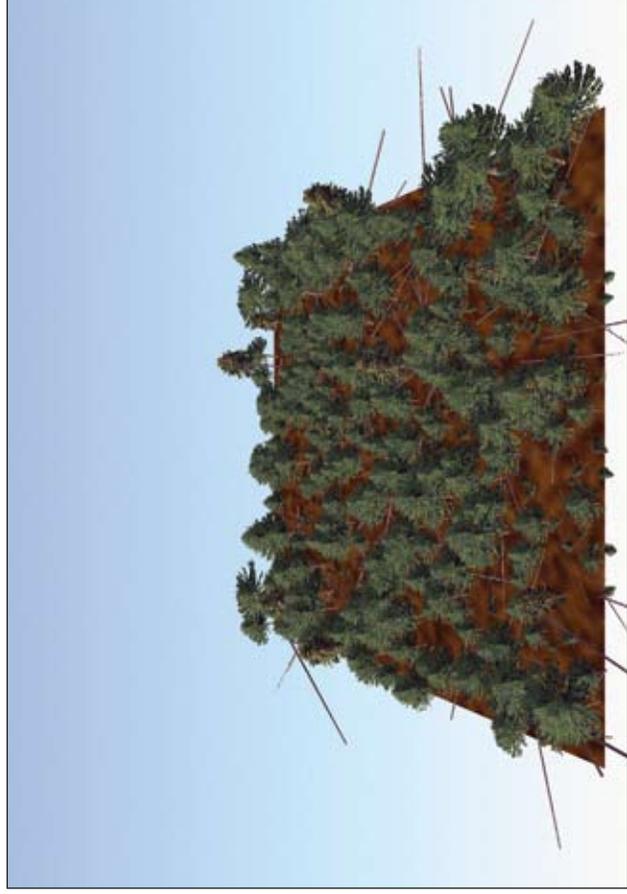
Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This has 733 trees per acre (tpa) composed of pinyon pine, hardwoods, and a small component of ponderosa pine. Canopy bulk density is 0.07 kg/m^3 (0.0044 lb/ft^3), and canopy base height is 4 ft, so ladder fuels are sufficient to enable passive crown fire, but canopy fuels are not sufficient to enable active crown fire spread. Woody fuel loading is 7 tons/ac, litter loading is 8 tons/ac, and duff is negligible in this stand. Potential flame lengths are 5 ft, and potential basal area mortality is 99 percent for severe fire weather and 93 percent for moderate fire weather. With no action, canopy base height and canopy bulk density change little over time, and passive crown fire remains likely under severe fire weather for the 50-year projection. Surface fuels accumulate slowly causing slight increases in potential flame lengths, but flame lengths generally remain around 3 ft for moderate fire weather and 5 ft for severe fire weather.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment greatly increases canopy base height and decreases canopy bulk density because fire-caused tree mortality is high. Only 26 trees per acre remain after treatment. Surface fuels are consumed in the prescribed fire treatment, but then greatly increase in 10 years, likely the result of fallen snags. All thinning treatments increase canopy base height and decrease canopy bulk density; the greater the thinning, the greater is the change in forest structure. All treatments eliminate the potential for passive crown fire for moderate and severe fire weather. However, all thinning treatments increase surface fuel loading, so potential flame lengths and basal area mortality remain high. The pile and burn treatment reduces woody surface fuels, and this decreases potential flame lengths and basal area mortality in the higher density stands (100 tpa, 200 tpa, and 300 tpa). Potential flame lengths and basal area mortality remain high in the 50 tpa treatment following the pile and burn, because the more open stand with low woody surface fuels is characterized by fuel model 5. Brush fuels are not tracked in FFE directly and may or may not be an important contributor to fire behavior depending on the location. The prescribed fire treatment reduces woody surface fuels more than the pile and burn treatment, but all stands are characterized as fuel model 2 following the prescribed burn, so potential flame lengths and basal area mortality remain high. Grass fuels are not tracked in FFE and may or may not be important following prescribed fire depending on the location.

Silvicultural and surface fuel treatments—long-term effects

Regeneration is low in all treatments, so canopy base height continues to increase over time as the trees grow and the stand self-thins. Crown fire remains unlikely for the duration of the 50-year projection in all treatments. However, flame lengths remain high, especially in stands treated with a prescribed fire, so another treatment may be necessary to reduce grass and brush fuels that accumulate following surface fuel treatments.

Table 11a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	0–3 in	1	8	5	4	4
		3–6 in	0	12	5	5	2
	>12 in	6–12 in	1	13	6	6	3
		>12 in	0	0	0	0	0
	Litter	Litter	8	1	3	2	8
		Duff	0	0	17	17	0
	Flame length (ft)	Moderate	3	4	3	2	3
		Severe	5	7	4	3	4
	Torching index	Severe	0	31	61	66	23
		Crowning index	34	169	146	89	57
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Surface	Surface	Surface	Surface	
Potential basal area mortality (%)	Moderate	93	88	66	44	72	
	Severe	99	98	98	97	99	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in		2	1	1	1
		3–6 in		1	1	1	1
	>12 in	6–12 in		1	2	2	1
		>12 in		0	0	0	0
	Litter	Litter		2	2	2	8
		Duff		12	15	15	0
	Flame length (ft)	Moderate		2	1	1	2
		Severe		6	1	1	3
	Torching index	Severe		22	323	296	82
		Crowning index		146	89	57	50
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Surface	Surface	Surface	Surface	
Potential basal area mortality (%)	Moderate	93	88	32	37	43	
	Severe	99	98	98	37	43	
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in		0	0	0	0
		3–6 in		0	0	0	0
	>12 in	6–12 in		2	3	3	1
		>12 in		0	0	0	0
	Litter	Litter		0	1	1	0
		Duff		9	12	12	0
	Flame length (ft)	Moderate		3	3	2	3
		Severe		6	4	3	4
	Torching index	Severe		26	61	66	23
		Crowning index		146	89	57	50
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Surface	Surface	Surface	Surface	
Potential basal area mortality (%)	Moderate	93	88	66	44	72	
	Severe	99	98	98	97	99	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 11b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	3	3	5	6	7	7	1	5	3	3	2	2
	0–3 in												
	3–6 in	1	2	2	4	5	5	0	5	5	5	5	4
	6–12 in	3	3	3	4	5	6	1	8	8	7	7	6
	>12 in	0	0	0	0	1	1	0	2	2	2	2	2
	Litter	8	6	6	6	6	6	0	1	1	2	2	2
	Duff	0	0	1	1	1	2	0	0	0	0	0	1
	Moderate	3	4	3	3	3	4	4	4	4	4	4	4
	Severe	5	5	5	5	5	5	7	7	7	7	7	7
	Torching index	0	0	0	6	4	0	31	24	27	27	28	29
None	Crowning index	34	35	37	37	40	42	169	152	143	139	139	137
	Severe												
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Passive	Passive	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	0–17.9 in	26	62	98	82	64	50	196	11	4	1	1	1
	18–29.9 in	0	0	0	0	0	0	2	0	0	0	0	0
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
	Hard snags (stems/ac)												
None	Surface fuel loadings (tons/ac)	8	3	1	1	1	1	5	4	4	4	4	5
	0–3 in												
	3–6 in	12	10	9	8	7	6	5	5	5	5	5	5
	6–12 in	13	12	10	9	8	7	6	6	5	5	5	5
	>12 in	0	0	0	1	1	1	0	0	0	0	0	1
	Litter	1	0	0	1	1	1	3	4	4	4	5	5
	Duff	22	21	21	21	20	20	17	17	17	17	17	17
	Moderate	3	3	3	4	4	4	3	2	2	3	3	3
	Severe	6	6	6	6	6	6	4	4	4	4	4	4
	Torching index	26	28	30	34	35	39	61	80	77	79	72	65
None	Crowning index	146	146	143	143	141	139	89	86	85	86	87	87
	Severe												
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	0–17.9 in	1	2	3	3	3	3	1	2	4	4	5	5
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
	Hard snags (stems/ac)												

Table 11b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	2	1	2	2	2	3	1	1	2	3	4	4
	0–3 in												
	3–6 in	1	1	1	2	2	2	1	1	2	2	2	3
	6–12 in	1	1	1	1	1	1	2	2	2	2	2	2
	>12 in	0	0	0	0	0	1	0	0	0	0	0	1
	Litter	2	3	3	3	3	3	2	4	4	4	5	5
	Duff	12	12	12	12	12	12	15	15	15	15	15	16
	Moderate	2	3	4	4	4	4	1	1	1	2	2	2
	Severe	6	6	6	6	6	6	1	1	2	3	3	3
	Torching index	22	25	26	30	32	38	323	384	226	174	135	111
Prescribed fire	Crowning index	146	146	143	143	140	136	89	86	85	86	87	87
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	1	2	3	3	3	3	1	2	4	4	5	5
	0–17.9 in												
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
	Surface fuel loadings (tons/ac)	0	1	1	1	1	2	0	2	2	2	3	3
	0–3 in												
	3–6 in	0	1	1	2	2	2	1	2	2	2	2	2
6–12 in	2	4	4	4	4	3	3	5	5	5	5	5	
>12 in	0	2	2	2	2	2	0	1	1	1	1	1	
Litter	0	1	2	2	2	2	2	2	3	3	3	3	
Duff	9	9	9	9	9	9	15	12	12	12	12	12	
Moderate	5	4	4	4	4	4	4	4	4	3	3	4	
Severe	8	8	8	8	8	7	7	6	6	5	4	6	
Torching index	16	14	12	16	21	21	28	28	45	76	115	139	
Crowning index	346	325	341	308	194	170	134	131	130	129	128	128	
Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Severe	Passive	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Hard snags (stems/ac)	22	11	5	2	2	2	22	8	5	3	3	3	
0–17.9 in													
18–29.9 in	1	0	0	0	0	0	1	0	0	0	0	0	
30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 11b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	0–3 in	4	4	4	5	6	6	4	4	5	5	6	7
		3–6 in	5	5	5	5	5	6	2	2	3	3	4	4
	6–12 in	6	6	5	6	6	6	3	3	3	3	4	4	4
		>12 in	0	0	0	0	0	0	0	0	0	0	0	1
	Litter	2	4	5	5	6	6	8	5	5	5	6	6	7
		Duff	17	17	17	17	17	0	0	1	1	1	1	2
	Flame length (ft)	Moderate	2	2	3	3	3	3	4	2	3	3	3	3
		Severe	3	4	4	4	5	5	4	3	4	4	4	5
	Torching index	Severe	66	63	56	41	36	23	30	76	22	22	29	24
		Crowning index	57	57	62	64	65	50	65	51	52	52	52	52
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Hard snags (stems/ac)	3	4	10	13	12	6	11	15	18	16	13	16	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	1	2	3	4	5	6	1	2	3	5	6	7
		3–6 in	1	1	2	2	3	4	1	1	1	2	3	3
		6–12 in	2	2	2	2	3	3	1	1	1	2	2	3
>12 in	0	0	0	0	0	0	0	0	0	0	0	0	1	
	Litter	2	4	5	5	6	8	6	5	5	6	6	7	
Duff	15	15	15	15	16	16	0	16	0	1	1	1	2	
	Moderate	1	1	2	2	3	2	3	1	3	3	3	3	
Severe	1	2	3	3	4	4	3	4	2	4	4	4	4	
	296	253	141	85	41	41	82	41	194	22	22	29	29	
Crowning index	Severe	57	57	62	64	65	50	66	51	52	52	52	52	
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Type of fire	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	3	4	11	13	12	6	11	15	18	16	13	16	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
30–36 in	Hard snags (stems/ac)	0	0	0	0	0	0	0	0	0	0	0	0	
		0–3 in	1	2	3	4	5	6	1	2	3	5	6	7
		3–6 in	1	1	2	2	3	4	1	1	1	2	3	3
6–12 in	2	2	2	2	3	3	1	1	1	2	2	2	3	
	>12 in	0	0	0	0	0	0	1	0	0	0	0	1	
Litter	2	4	5	5	6	6	8	6	5	5	6	6	7	
	Duff	15	15	15	15	16	0	16	0	1	1	1	2	
Moderate	1	1	2	2	3	3	2	3	1	3	3	3	3	
	Severe	1	2	3	3	4	3	4	2	4	4	4	4	
Torching index	Severe	296	253	141	85	41	82	41	194	22	22	29	29	
	Crowning index	57	57	62	64	65	50	66	51	52	52	52	52	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	3	4	11	13	12	6	11	15	18	16	13	16	
18–29.9 in	Hard snags (stems/ac)	0	0	0	0	0	0	0	0	0	0	0	0	
		0–3 in	1	2	3	4	5	6	1	2	3	5	6	7
		3–6 in	1	1	2	2	3	4	1	1	1	2	3	3
6–12 in	2	2	2	2	3	3	1	1	1	2	2	2	3	
	>12 in	0	0	0	0	0	0	1	0	0	0	0	1	
Litter	2	4	5	5	6	6	8	6	5	5	6	6	7	
	Duff	15	15	15	15	16	0	16	0	1	1	1	2	
Moderate	1	1	2	2	3	3	2	3	1	3	3	3	3	
	Severe	1	2	3	3	4	3	4	2	4	4	4	4	
Torching index	Severe	296	253	141	85	41	82	41	194	22	22	29	29	
	Crowning index	57	57	62	64	65	50	66	51	52	52	52	52	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	3	4	11	13	12	6	11	15	18	16	13	16	
18–29.9 in	Hard snags (stems/ac)	0	0	0	0	0	0	0	0	0	0	0	0	
		0–3 in	1	2	3	4	5	6	1	2	3	5	6	7
		3–6 in	1	1	2	2	3	4	1	1	1	2	3	3
6–12 in	2	2	2	2	3	3	1	1	1	2	2	2	3	
	>12 in	0	0	0	0	0	0	1	0	0	0	0	1	
Litter	2	4	5	5	6	6	8	6	5	5	6	6	7	
	Duff	15	15	15	15	16	0	16	0	1	1	1	2	
Moderate	1	1	2	2	3	3	2	3	1	3	3	3	3	
	Severe	1	2	3	3	4	3	4	2	4	4	4	4	
Torching index	Severe	296	253	141	85	41	82	41	194	22	22	29	29	
	Crowning index	57	57	62	64	65	50	66	51	52	52	52	52	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	3	4	11	13	12	6	11	15	18	16	13	16	
18–29.9 in	Hard snags (stems/ac)	0	0	0	0	0	0	0	0	0	0	0	0	
		0–3 in	1	2	3	4	5	6	1	2	3	5	6	7
		3–6 in	1	1	2	2	3	4	1	1	1	2	3	3
6–12 in	2	2	2	2	3	3	1	1	1	2	2	2	3	
	>12 in	0	0	0	0	0	0	1	0	0	0	0	1	
Litter	2	4	5	5	6	6	8	6	5	5	6	6	7	
	Duff	15	15	15	15	16	0	16	0	1	1	1	2	
Moderate	1	1	2	2	3	3	2	3	1	3	3	3	3	
	Severe	1	2	3	3	4	3	4	2	4	4	4	4	
Torching index	Severe	296	253	141	85	41	82	41	194	22	22	29	29	
	Crowning index	57	57	62	64	65	50	66	51	52	52	52	52	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	3	4	11	13	12	6	11	15	18	16	13	16	
18–29.9 in	Hard snags (stems/ac)	0	0	0	0	0	0	0	0	0	0	0	0	
		0–3 in	1	2	3	4	5	6	1	2	3	5	6	7
		3–6 in	1	1	2	2	3	4	1	1	1	2	3	3
6–12 in	2	2	2	2	3	3	1	1	1	2	2	2	3	
	>12 in	0	0	0	0	0	0	1	0	0	0	0	1	
Litter	2	4	5	5	6	6	8	6	5	5	6	6	7	
	Duff	15	15	15	15	16	0	16	0	1	1	1	2	
Moderate	1	1	2	2	3	3	2	3	1	3	3	3	3	
	Severe	1	2	3	3	4	3	4	2	4	4	4	4	
Torching index	Severe	296	253	141	85	41	82	41	194	22	22	29	29	
	Crowning index	57	57	62	64	65	50	66	51	52	52	52	52	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	3	4	11	13	12	6	11	15	18	16	13	16	
18–29.9 in	Hard snags (stems/ac)	0	0	0	0	0	0	0	0	0	0	0	0	
		0–3 in	1	2	3	4	5	6	1	2	3	5	6	7
		3–6 in	1	1	2	2	3	4	1	1	1	2	3	3
6–12 in	2	2	2	2	3	3	1	1	1	2	2	2	3	
	>12 in	0	0	0	0	0	0	1	0	0	0	0	1	
Litter	2	4	5	5	6	6	8	6	5	5	6	6	7	
	Duff	15	15	15	15	16	0	16	0	1	1	1	2	
Moderate	1	1	2	2	3	3	2	3	1	3	3	3	3	
	Severe	1	2	3	3	4	3	4	2	4	4	4	4	
Torching index	Severe	296	253	141	85	41	82	41	194	22	22	29	29	
	Crowning index	57	57	62	64	65	50	66	51	52	52	52	52	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	3	4	11	13	12	6	11	15	18	16	13	1	

Table 11b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	2	3	3	3	3	0	3	3	3	3	3
	0–3 in												
	3–6 in	0	3	3	3	3	3	0	4	4	4	4	4
	6–12 in	3	6	6	6	6	6	1	7	7	6	6	6
Flame length (ft)	>12 in	0	1	1	1	1	1	0	1	1	2	1	2
	Litter	1	3	3	3	4	4	0	2	2	3	3	3
	Duff	12	12	12	12	12	12	0	0	0	0	1	1
	Moderate	1	2	2	2	3	3	4	4	4	3	3	3
Torching index	Severe	1	6	3	3	5	5	7	6	6	5	6	5
	Severe	239	24	106	97	44	46	27	27	31	60	52	69
Crowning index	Severe	94	97	97	103	103	104	131	123	122	122	122	118
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Type of fire	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	37	9	5	3	3	4	69	9	4	2	2	3
Hard snags (stems/ac)	0–17.9 in	1	0	0	0	0	0	1	0	0	0	0	0
	18–29.9 in												
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 11c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	733	662	562	492	441	401	26	25	25	24	23	23
	Quadratic mean diameter (in)	6.4	7.1	7.9	8.5	9.1	9.7	6.4	15.2	16.2	17.0	17.8	18.5
Total volume (ft ³)	Merchantable volume (ft ³)	1,648	2,223	2,648	3,054	3,435	3,804	432	497	623	747	873	994
	Basal area (ft ²)	1,565	2,072	2,468	2,912	3,327	3,762	421	486	610	733	857	977
Stand density index	Stand density index	162	182	189	195	200	205	30	32	35	38	40	42
	Canopy closure (percent)	356	382	381	382	381	380	47	49	53	56	58	61
Crown competition factor	Canopy closure (percent)	85	87	88	88	88	89	24	26	27	29	30	31
	Crown competition factor	190	209	212	215	217	218	28	30	32	34	35	37
Canopy bulk density (kg/m ³)	Canopy base height (ft)	4	4	4	5	5	5	17	17	19	20	21	22
	Canopy bulk density (kg/m ³)	0.07	0.06	0.06	0.06	0.05	0.05	0.01	0.01	0.01	0.01	0.01	0.01

Table 11c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	733	50	63	62	60	58	57	100	105	103	100	97	95
	Quadratic mean diameter (in)	6.4	15.1	14.1	14.9	15.5	16.1	16.6	12.9	13.3	14.2	15.0	15.8	16.5
	Total volume (ft ³)	1,648	946	1,068	1,305	1,528	1,741	1,948	1,384	1,584	1,973	2,360	2,750	3,149
	Merchantable volume (ft ³)	1,565	946	1,068	1,304	1,527	1,739	1,944	1,370	1,570	1,958	2,345	2,735	3,133
	Basal area (ft ²)	162	62	69	74	79	82	85	90	102	113	123	132	141
	Stand density index	356	97	110	117	122	125	128	150	167	181	193	203	212
	Canopy cover (percent)	85	45	48	50	52	53	54	60	64	67	69	71	73
	Crown competition factor	190	60	66	70	74	76	79	91	101	110	118	125	131
	Canopy base height (ft)	4	12	13	13	14	14	15	10	11	11	12	12	12
	Canopy bulk density (kg/m ³)	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
Pile and burn	Trees per acre	733	50	71	70	68	66	64	100	109	107	104	101	98
	Quadratic mean diameter (in)	6.4	15.1	13.3	14.0	14.6	15.2	15.7	12.9	13.1	14.0	14.8	15.5	16.2
	Total volume (ft ³)	1,648	946	1,067	1,305	1,530	1,746	1,957	1,384	1,584	1,972	2,361	2,753	3,155
	Merchantable volume (ft ³)	1,565	946	1,067	1,304	1,528	1,742	1,950	1,370	1,570	1,958	2,345	2,738	3,139
	Basal area (ft ²)	162	62	69	74	79	83	86	90	102	113	123	132	141
	Stand density index	356	97	113	119	125	129	132	150	169	182	194	204	214
	Canopy cover (percent)	85	45	48	50	52	54	55	60	64	67	69	71	73
	Crown competition factor	190	60	65	70	74	77	79	91	101	110	118	125	131
	Canopy base height (ft)	4	12	13	13	14	14	15	10	11	11	12	12	12
	Canopy bulk density (kg/m ³)	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
Prescribed fire	Trees per acre	733	50	63	61	60	58	57	100	76	74	72	70	68
	Quadratic mean diameter (in)	6.4	15.1	9.8	10.2	10.5	11.0	11.6	12.9	12.2	13.0	13.7	14.4	15.1
	Total volume (ft ³)	1,648	459	515	622	728	839	959	829	957	1,207	1,454	1,703	1,957
	Merchantable volume (ft ³)	1,565	459	515	621	721	820	949	819	946	1,195	1,440	1,686	1,936
	Basal area (ft ²)	162	62	33	34	36	38	42	90	61	68	74	79	85
	Stand density index	356	97	61	63	65	68	72	150	104	112	119	126	132
	Canopy cover (percent)	85	45	26	27	28	29	31	60	44	47	49	52	54
	Crown competition factor	190	60	30	31	33	35	38	91	58	63	68	73	77
	Canopy base height (ft)	4	14	16	16	13	16	16	17	17	19	21	22	24
	Canopy bulk density (kg/m ³)	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 11c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	733	200	199	188	178	169	162	300	287	270	256	245	233
	Quadratic mean diameter (in)	6.4	10.6	11.3	12.2	13.0	13.7	14.4	9.2	10.0	10.8	11.5	12.1	12.7
	Total volume (ft ³)	1,648	1,752	2,025	2,527	3,003	3,470	3,938	1,871	2,136	2,670	3,208	3,748	4,247
	Merchantable volume (ft ³)	1,565	1,736	2,009	2,510	2,986	3,447	3,915	1,849	2,113	2,651	3,191	3,727	4,224
	Basal area (ft ²)	162	122	140	153	164	174	184	138	155	170	184	196	206
	Stand density index	356	219	244	259	271	282	292	261	285	303	319	334	344
	Canopy cover (percent)	85	73	77	79	81	82	83	78	81	83	85	87	88
	Crown competition factor	190	130	146	157	165	172	179	151	167	180	191	201	208
	Canopy base height (ft)	4	7	8	9	9	10	10	6	7	7	7	8	8
	Canopy bulk density (kg/m ³)	0.07	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04
Pile and burn	Trees per acre	733	200	201	190	179	171	163	300	289	271	258	247	234
	Quadratic mean diameter (in)	6.4	10.6	11.3	12.1	12.9	13.7	14.4	9.2	9.9	10.7	11.4	12.1	12.7
	Total volume (ft ³)	1,648	1,752	2,025	2,526	3,003	3,473	3,944	1,871	2,135	2,670	3,208	3,748	4,244
	Merchantable volume (ft ³)	1,565	1,736	2,009	2,509	2,986	3,449	3,920	1,849	2,112	2,650	3,191	3,727	4,221
	Basal area (ft ²)	162	122	140	153	164	174	184	138	155	170	184	196	206
	Stand density index	356	219	244	259	271	282	292	261	286	303	320	334	344
	Canopy cover (percent)	85	73	77	79	81	82	83	78	81	83	85	87	88
	Crown competition factor	190	130	146	156	165	172	179	151	167	180	191	201	208
	Canopy base height (ft)	4	7	8	9	9	10	10	6	7	7	7	8	8
	Canopy bulk density (kg/m ³)	0.07	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04
Prescribed fire	Trees per acre	733	200	94	92	90	87	85	300	60	58	57	55	54
	Quadratic mean diameter (in)	6.4	10.6	12.1	13.0	13.8	14.6	15.3	9.2	12.9	13.7	14.5	15.2	15.8
	Total volume (ft ³)	1,648	983	1,140	1,454	1,772	2,093	2,422	730	842	1,061	1,280	1,498	1,714
	Merchantable volume (ft ³)	1,565	972	1,128	1,440	1,753	2,073	2,400	719	830	1,047	1,264	1,479	1,691
	Basal area (ft ²)	162	122	75	85	93	101	109	138	54	60	65	69	74
	Stand density index	356	219	128	140	150	160	168	261	90	97	103	108	113
	Canopy cover (percent)	85	73	53	56	59	62	64	78	40	43	45	47	49
	Crown competition factor	190	130	75	83	89	96	102	151	52	56	60	64	67
	Canopy base height (ft)	4	9	11	12	12	13	13	17	16	18	21	22	23
	Canopy bulk density (kg/m ³)	0.07	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 11d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	Years	No action						Prescribed fire only								
		Fuel models						Fuel models								
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight			
None	1	10	75	6	25	10	100	10	67	2	33	10	68	10	32	
	10	6	56	10	44	10	67	10	58	2	42	10	63	10	37	
	20	10	66	6	34	10	54	2	54	10	46	2	68	10	32	
	30	10	91	6	9	2	63	2	63	10	37	2	68	10	32	
	40	10	92	12	8	2	63	2	63	10	37	2	68	10	32	
50	10	81	12	19	2	68	10	32	2	68	10	32	2	68	10	32

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Years	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit							
		Fuel models						Fuel models							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight		
None	1	10	72	5	27	6	1	10	58	8	42	10	58	8	42
	10	10	49	5	36	6	16	10	53	8	47	10	53	8	47
	20	10	42	6	31	5	27	10	59	8	41	10	59	8	41
	30	6	43	10	39	5	18	10	66	8	34	10	66	8	34
	40	6	52	10	38	5	10	10	75	8	25	10	75	8	25
50	6	59	10	38	5	3	10	84	8	16	10	84	8	16	
Pile and burn	1	5	97	6	3	8	100	8	100	8	100	8	100	8	100
	10	5	69	6	31	8	100	8	100	8	100	8	100	8	100
	20	6	54	5	46	8	86	10	14	10	14	10	14	10	14
	30	6	69	5	28	10	3	8	72	10	28	8	72	10	28
	40	6	78	5	13	10	8	8	59	10	41	8	59	10	41
50	6	86	10	13	5	2	10	53	8	47	10	53	8	47	
Prescribed fire	1	2	100	5	7	2	100	2	100	10	9	2	100	10	9
	10	2	93	5	16	2	91	2	91	10	19	2	91	10	19
	20	2	84	5	16	2	65	2	65	10	33	2	65	10	33
	30	2	100	5	16	2	42	2	42	8	25	2	42	8	25
	40	2	100	5	16	8	46	8	46	10	2	8	46	10	2
50	2	100	5	16	2	65	2	65	10	35	2	65	10	35	

Table 11d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit										
	Fuel models					Fuel models					Fuel models					Fuel models					
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None	1	8	53	10	47	10	84	8	16	10	84	8	16	10	84	8	16	10	84	8	16
	10	10	59	8	41	8	57	10	43	8	57	10	43	8	57	10	43	8	57	10	43
	20	10	74	8	26	10	100	10	100	10	100	10	100	10	100	10	100	10	100	10	100
	30	10	91	8	9	10	100	10	100	10	100	10	100	10	100	10	100	10	100	10	100
	40	10	95	12	5	10	100	10	100	10	100	10	100	10	100	10	100	10	100	10	100
50	10	85	12	15	10	92	12	8	10	92	12	8	10	92	12	8	10	92	12	8	
Pile and burn	1	8	100			8	67	10	33	8	67	10	33	8	67	10	33	8	67	10	33
	10	8	92	10	8	8	89	10	11	8	89	10	11	8	89	10	11	8	89	10	11
	20	8	70	10	30	10	100	10	100	10	100	10	100	10	100	10	100	10	100	10	100
	30	10	52	8	48	10	100	10	100	10	100	10	100	10	100	10	100	10	100	10	100
	40	10	100			10	100			10	100			10	100			10	100		
50	10	100			10	100			10	100			10	100			10	100			
Prescribed fire	1	8	100			2	100			2	100			2	100			2	100		
	10	5	72	10	28	2	57	10	43	2	57	10	43	2	57	10	43	2	57	10	43
	20	8	62	10	38	2	56	10	44	2	56	10	44	2	56	10	44	2	56	10	44
	30	8	56	10	44	10	100			10	100			10	100			10	100		
	40	10	100			2	46	10	42	2	46	10	42	2	46	10	42	2	46	10	42
50	10	100			10	43	2	36	10	43	2	36	10	43	2	36	10	43	2	36	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 11e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff	Live
Severe—98 th percentile	19	85	3	5	13	16	50	100
Moderate—75 th percentile	10	75	5	7	16	19	125	150

Table 10f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).

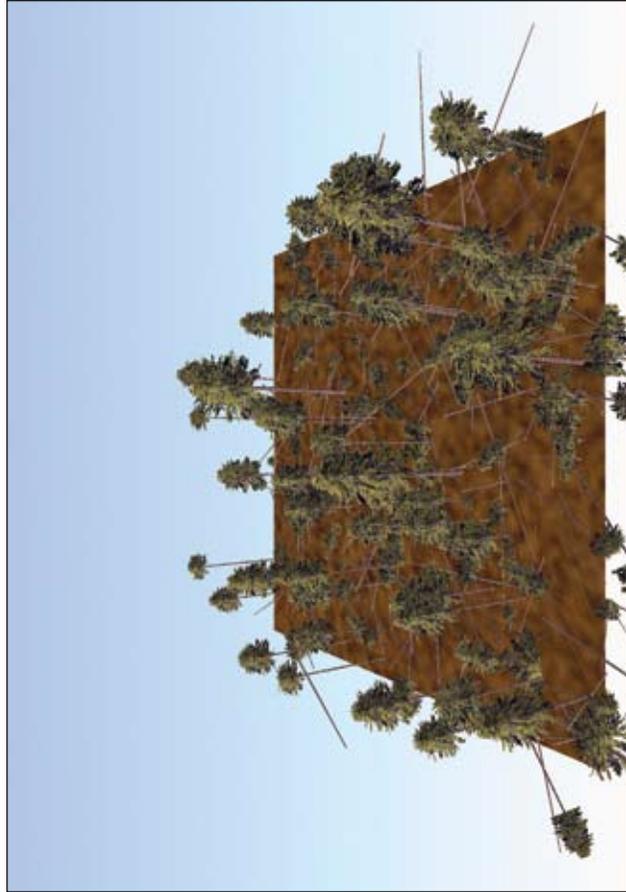


Initial stand conditions

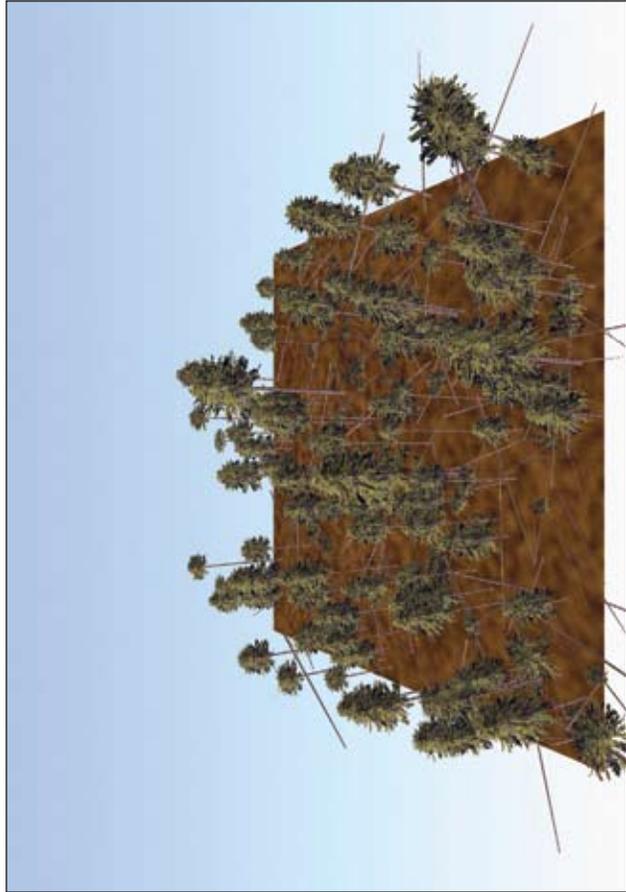
Site: Elevation = 5,400 ft, slope = 15 percent, aspect = 360°.

Species (based on trees per acre): Ponderosa pine (*Pinus ponderosa*) = 77 percent, gambel oak (*Quercus gambelii*) = 21 percent, Douglas-fir (*Pseudotsuga menziesii*) = 2 percent.

Stand attributes: Stem density = 571 tpa, basal area = 79 ft²/ac, top height = 45 ft, stand density index = 190, quadratic mean diameter = 5.0 in, crown competition factor = 67, canopy cover = 49 percent.



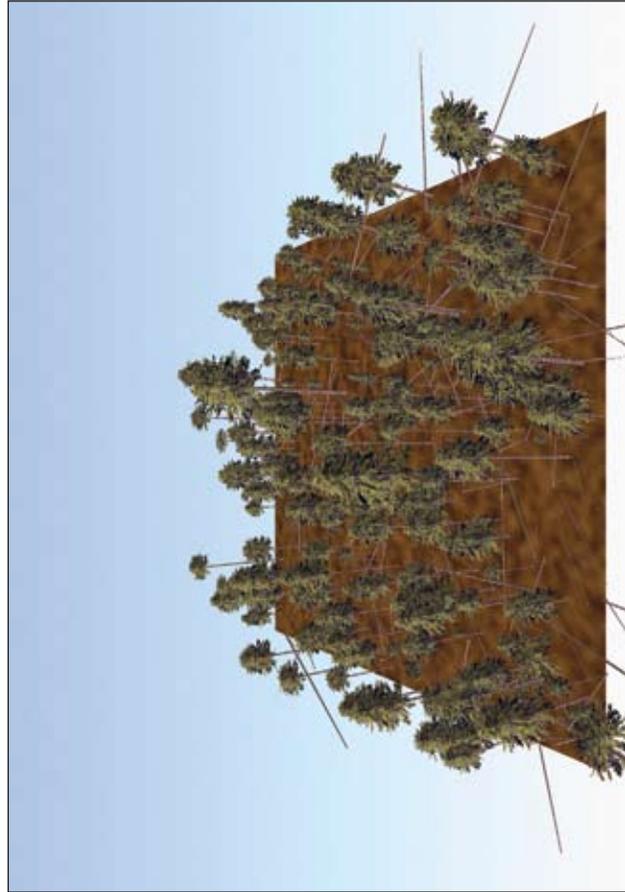
Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has initial tree density of 571 trees per acre (tpa) composed of Douglas-fir, gambel oak, and ponderosa pine in the understory and ponderosa pine in the overstory. Canopy bulk density is 0.04 kg/m³ (0.0025 lb/ft³), and canopy base height is 8 ft, so ladder fuels and canopy fuels are not sufficient to enable crown fire initiation or spread. Woody fuel loading is 6 tons/acre, and litter and duff loading is 6 tons/acre. Although the predicted fire type is surface fire, potential flame lengths are 5 ft and potential basal area mortality is 66 percent for severe fire weather because fire behavior is predicted by using fuel model 5 suggesting the importance of brush fuels. The FFE model does not track brush fuels directly, so these results should be interpreted with caution. Canopy base height decreases and canopy bulk density increases over time as smaller trees grow into the overstory, and in 10 years passive crown fire becomes likely for severe and moderate fire weather. In 30 years, canopy base height begins to increase again as the trees grow and crowns rise causing the predicted fire type to become surface fire again for severe and moderate fire weather. There is little surface fuel accumulation over time, and flame lengths decline as the fuel model shifts from 5 to 9.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment increases canopy base height and reduces canopy bulk density slightly and consumes much of the surface fuels. However, many snags are created that contribute to surface fuel loading in 10 years. Thinning to 50 tpa or less is required to increase canopy base height and decrease canopy bulk density; all other treatments have little effect on stand structure. Potential flame lengths and basal area mortality remain high for severe fire weather in all treatments because fire behavior is predicted by using fuel model 5. Potential flame lengths and basal area mortality are low for moderate fire weather in all treatments. The pile and burn and prescribed fire surface fuel treatments reduce woody surface fuels to below initial levels, but potential flame lengths and basal area mortality remain high for severe fire weather because the predominant fuel model is 5. The prescribed fire surface fuel treatment causes the highest potential flame lengths and basal area mortality.

Silvicultural and surface fuel treatments—long-term effects

Although the treatments have little effect on crown fire potential in the short term, they do reduce crown fire potential in the long term. In all treatments, canopy base height increases over time as the trees grow and the stand self-thins. Flame lengths remain high for severe fire weather, but the increase in canopy base height causes the predicted fire type to become surface fire in 10 years and remain surface fire for the duration of the 50-year projection. Potential flame lengths decrease in 20 years in the higher density treatments (200 tpa and 300 tpa) with a pile and burn or no surface fuel treatment as the fuel model shifts from 5 to 9. However, in the higher density treatments with prescribed fire, the additional tree mortality creates a more open stand with more brush fuels, and flame lengths remain above 5 ft for 40 years.

Table 12a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	0-3 in	1	4	3	3	2
		3-6 in	0	2	2	2	2
		6-12 in	1	1	2	2	2
		>12 in	0	0	0	0	0
		Litter	2	2	2	2	2
		Duff	4	3	4	4	4
		Moderate	1	1	1	1	1
		Severe	5	6	5	5	5
		Torching index	19	20	17	19	19
		Crowning index	52	66	59	52	52
Pile and burn	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Surface	Surface	Passive	Surface	Surface	Surface
		33	25	31	33	33	33
		66	70	71	66	66	66
		0-3 in	1	1	1	1	1
		3-6 in	1	1	1	1	1
Prescribed fire	Surface fuel loadings (tons/ac)	0-3 in	1	1	1	1	1
		3-6 in	0	0	0	0	0
		6-12 in	1	1	1	1	1
		>12 in	0	0	0	0	0
		Litter	2	2	1	1	1
		Duff	2	2	3	4	4
		Moderate	1	1	1	1	1
		Severe	2	2	5	5	5
		Torching index	112	112	17	19	19
		Crowning index	90	90	59	52	52
Prescribed fire	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Surface	Surface	Passive	Surface	Surface	Surface
		5	5	31	33	33	33
		11	11	71	66	66	66
		0-3 in	0	0	0	0	0
		3-6 in	0	0	0	0	0
None	Surface fuel loadings (tons/ac)	0-3 in	0	0	0	0	0
		3-6 in	0	0	0	0	0
		6-12 in	1	1	1	1	1
		>12 in	0	0	0	0	0
		Litter	0	0	0	0	0
		Duff	2	2	3	3	3
		Moderate	1	1	1	1	1
		Severe	1	1	6	6	6
		Torching index	120	120	18	20	20
		Crowning index	96	96	73	66	66
None	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Surface	Surface	Passive	Surface	Surface	Surface
		5	5	23	25	25	25
		8	8	73	70	70	70
		0-3 in	0	0	0	0	0
		3-6 in	0	0	0	0	0

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 12b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	2	2	3	3	4	5	1	4	3	3	3	3
	0–3 in	2	2	2	2	3	3	0	2	2	2	2	2
	3–6 in	2	2	2	2	2	2	1	3	3	3	3	3
	6–12 in	0	0	0	0	0	0	0	0	0	0	0	0
	>12 in	2	3	4	4	5	5	0	1	1	2	2	2
	Litter	4	4	4	5	5	5	3	3	3	3	3	3
	Duff	1	1	2	2	2	2	1	1	1	1	1	1
	Moderate	5	5	3	3	3	3	6	5	5	5	5	4
	Severe	19	0	0	14	35	46	20	60	72	81	90	100
	Torching index	52	43	38	35	32	30	66	71	63	57	54	52
None	Surface fuel loadings (tons/ac)	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	18–29.9 in	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	30–36 in	5	8	10	9	24	26	124	10	6	4	4	
	0–17.9 in	0	0	0	0	0	0	3	2	1	0	0	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	
	Hard snags (stems/ac)	0	0	0	0	0	0	0	0	0	0	0	0
	0–17.9 in	0	0	0	0	0	0	0	0	0	0	0	0
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0
30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
None	Surface fuel loadings (tons/ac)	4	3	2	2	2	3	3	3	3	3	3	
	0–3 in	2	2	2	2	2	2	2	2	2	2	2	
	3–6 in	1	1	1	1	1	1	2	2	2	2	2	
	6–12 in	0	0	0	0	0	0	0	0	0	0	0	
	>12 in	2	1	1	1	1	1	2	1	1	2	2	
	Litter	3	3	3	3	3	3	4	4	4	4	4	
	Duff	1	1	1	1	1	1	1	1	1	1	1	
	Moderate	2	1	1	1	1	1	5	5	5	5	3	
	Severe	112	193	209	220	238	248	17	68	77	90	142	
	Torching index	90	89	80	75	73	71	59	64	59	54	52	
None	Surface fuel loadings (tons/ac)	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–3 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	3–6 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	6–12 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	>12 in	1	1	2	3	3	3	1	2	3	4	5	
	Litter	0	0	0	0	0	0	0	0	0	0	0	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	
	Hard snags (stems/ac)	0	0	0	0	0	0	0	0	0	0	0	
	0–17.9 in	0	0	0	0	0	0	0	0	0	0	0	
18–29.9 in	0	0	0	0	0	0	0	0	0	0	0		
30–36 in	0	0	0	0	0	0	0	0	0	0	0		

Table 12b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	1	1	1	2	2	2	1	1	2	2	3	4
	0–3 in	1	1	1	1	1	1	1	1	1	1	1	1
	3–6 in	0	0	0	0	0	0	0	0	0	0	0	0
	6–12 in	2	2	2	2	2	2	3	3	3	3	4	4
	>12 in	1	1	1	1	1	1	1	1	1	1	2	2
	Litter	2	2	2	2	2	2	3	3	3	3	3	4
	Duff	1	1	1	1	1	1	1	1	1	1	2	2
	Moderate	2	2	2	2	2	2	3	3	3	3	3	4
	Severe	112	193	210	213	224	241	17	68	77	86	170	159
	Torching index	90	84	76	72	68	67	59	64	59	53	51	50
Prescribed fire	Surface fuel loadings (tons/ac)	0	2	2	2	2	2	0	3	3	3	3	3
	0–3 in	0	1	1	1	1	1	1	1	1	1	1	2
	3–6 in	1	1	1	1	1	1	1	2	2	2	2	2
	6–12 in	0	0	0	0	0	0	0	0	0	0	0	0
	>12 in	0	1	1	1	2	2	1	1	1	1	2	2
	Litter	2	2	2	2	2	2	3	3	3	3	3	3
	Duff	1	1	1	1	1	1	1	1	1	1	1	1
	Moderate	2	2	2	2	2	2	5	6	5	5	5	5
	Severe	112	162	166	185	201	206	17	61	68	76	84	87
	Torching index	90	79	69	62	59	58	59	77	67	61	56	55
Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface
	Severe	5	4	4	3	3	3	17	10	6	4	4	4
	0–17.9 in	1	1	0	0	0	0	3	3	2	0	0	0
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

Table 12b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	3	2	3	3	4	4	2	2	3	3	3	3	4
		2	2	2	2	2	2	2	2	2	2	2	2	2
		2	2	2	2	2	2	2	2	2	2	2	2	2
		0	0	0	0	0	0	0	0	0	0	0	0	0
		2	2	2	3	3	3	2	2	3	3	4	4	4
		4	4	4	4	4	5	4	4	4	4	4	5	5
		1	1	2	2	2	2	1	1	2	2	2	2	2
		5	5	3	3	3	3	5	5	3	3	3	3	3
		19	57	115	122	129	125	19	41	94	98	92	61	61
		52	49	45	41	40	39	52	43	38	35	33	32	32
Pile and burn	Surface fuel loadings (tons/ac)	1	1	2	3	3	4	1	1	2	3	3	3	4
		1	1	1	1	1	1	1	1	1	1	1	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1
		0	0	0	0	0	0	0	0	0	0	0	0	0
		1	2	2	3	3	3	1	2	3	3	4	4	4
		4	4	4	4	4	4	4	4	4	4	4	4	4
		1	1	2	1	2	2	1	1	2	2	2	2	2
		5	5	2	2	2	3	5	5	2	2	3	3	3
		19	57	129	152	147	138	19	41	114	120	60	77	77
		52	49	45	41	39	38	52	43	38	35	33	31	31
Flame length (ft)	Surface fuel loadings (tons/ac)	2	3	4	5	5	6	3	4	5	5	6	7	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		1	2	2	3	3	3	1	2	3	3	4	4	
		4	4	4	4	4	4	4	4	4	4	4	4	
		1	1	2	1	2	2	1	1	2	2	2	2	
		5	5	2	2	2	3	5	5	2	2	3	3	
		19	57	129	152	147	138	19	41	114	120	60	77	
		52	49	45	41	39	38	52	43	38	35	33	31	
		2	3	4	5	5	6	3	4	5	5	6	8	
Torching index	Surface fuel loadings (tons/ac)	0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
Crowning index	Surface fuel loadings (tons/ac)	0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
Type of fire	Surface fuel loadings (tons/ac)	0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	0	0	0	0	0	0	0	0	0	0	

Table 12b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	3	3	3	3	3	0	3	3	3	3	3
	0–3 in												
	3–6 in	0	2	2	2	2	2	0	2	2	2	2	2
	6–12 in	1	3	3	3	3	3	1	3	3	3	3	3
	>12 in	0	0	0	0	0	0	0	0	0	0	0	0
	Litter	0	1	1	2	2	2	0	1	1	2	2	2
	Duff	3	3	3	3	3	3	3	3	3	3	3	3
	Moderate	1	1	1	1	1	2	1	1	1	1	1	2
	Severe	6	5	5	5	5	3	6	5	5	5	5	3
	Torching index	20	60	72	81	90	135	20	60	69	81	90	135
	Crowning index	66	67	59	55	52	50	66	67	59	55	52	50
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	33	10	7	4	4	4	50	10	7	4	4	4
Hard snags (stems/ac)	0–17.9 in	3	2	1	0	0	0	3	2	1	0	0	0
	18–29.9 in												
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 12c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	571	561	551	543	517	494	104	103	101	99	97	95
	Quadratic mean diameter (in)	5.0	5.7	6.3	6.8	7.4	7.9	5.0	11.0	12.3	13.5	14.5	15.4
	Total volume (ft ³)	1,188	1,655	2,144	2,618	3,038	3,435	1,067	1,265	1,671	2,071	2,461	2,832
	Merchantable volume (ft ³)	955	1,351	1,786	2,230	2,628	2,999	895	1,058	1,447	1,836	2,198	2,561
	Basal area (ft ²)	79	99	120	138	153	166	60	68	84	98	112	124
	Stand density index	190	227	263	295	316	335	108	120	142	160	177	191
	Canopy closure (percent)	49	56	63	67	71	73	39	43	49	53	57	60
	Crown competition factor	67	82	98	112	122	131	49	55	66	76	84	92
	Canopy base height (ft)	8	1	1	3	7	9	10	24	26	27	28	29
	Canopy bulk density (kg/m ³)	0.04	0.05	0.06	0.07	0.08	0.09	0.03	0.03	0.03	0.04	0.04	0.04

Table 12c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	571	50	64	63	62	60	59	100	106	104	102	100	98
	Quadratic mean diameter (in)	5.0	12.8	12.7	14.1	15.2	16.3	17.2	11.1	12.0	13.2	14.2	15.1	15.9
	Total volume (ft ³)	1,188	890	1,037	1,340	1,651	1,960	2,256	1,262	1,460	1,866	2,272	2,663	3,031
	Merchantable volume (ft ³)	955	765	908	1,206	1,509	1,810	2,098	1,048	1,219	1,615	2,010	2,390	2,747
	Basal area (ft ²)	79	45	57	68	78	87	96	67	83	98	112	124	135
	Stand density index	190	75	95	108	121	132	142	118	142	162	179	194	206
	Canopy cover (percent)	49	30	35	39	43	46	49	42	49	54	57	60	63
	Crown competition factor	67	36	43	50	56	62	67	55	67	77	85	92	99
	Canopy base height (ft)	8	23	31	31	31	32	32	8	25	26	28	29	30
	Canopy bulk density (kg/m ³)	0.04	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04
Pile and burn	Trees per acre	571	50	72	70	69	68	66	100	110	108	106	104	102
	Quadratic mean diameter (in)	5.0	12.8	12.0	13.3	14.4	15.4	16.3	11.1	11.8	12.9	13.9	14.8	15.6
	Total volume (ft ³)	1,188	890	1,035	1,340	1,650	1,957	2,253	1,262	1,459	1,866	2,272	2,664	3,034
	Merchantable volume (ft ³)	955	765	906	1,205	1,507	1,805	2,092	1,048	1,219	1,615	2,010	2,391	2,749
	Basal area (ft ²)	79	45	57	68	78	87	96	67	83	98	112	124	135
	Stand density index	190	75	97	111	124	135	145	118	143	163	180	195	208
	Canopy cover (percent)	49	30	35	39	43	46	49	42	49	54	57	60	63
	Crown competition factor	67	36	43	50	56	62	67	55	67	77	85	92	99
	Canopy base height (ft)	8	23	31	31	30	30	31	8	25	26	27	29	30
	Canopy bulk density (kg/m ³)	0.04	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04
Prescribed fire	Trees per acre	571	50	89	87	85	84	82	100	95	93	91	89	88
	Quadratic mean diameter (in)	5.0	12.8	10.3	11.4	12.4	13.3	14.2	11.1	10.7	12.0	13.2	14.2	15.1
	Total volume (ft ³)	1,188	821	956	1,243	1,540	1,837	2,123	977	1,153	1,521	1,885	2,240	2,575
	Merchantable volume (ft ³)	955	708	841	1,121	1,409	1,695	1,968	821	979	1,338	1,691	2,035	2,360
	Basal area (ft ²)	79	45	51	61	71	81	90	67	60	73	86	98	109
	Stand density index	190	75	92	107	120	133	144	118	106	125	142	157	170
	Canopy cover (percent)	49	30	32	36	40	44	47	42	38	43	48	51	55
	Crown competition factor	67	36	39	45	52	58	63	55	48	57	65	72	79
	Canopy base height (ft)	8	23	28	26	27	28	29	10	26	27	28	29	30
	Canopy bulk density (kg/m ³)	0.04	0.02	0.02	0.03	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.04	0.04

Table 12c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	571	200	200	197	193	189	186	300	299	294	289	284	277
	Quadratic mean diameter (in)	5.0	8.5	9.5	10.4	11.2	12	12.6	7.0	7.8	8.6	9.2	9.8	10.4
	Total volume (ft ³)	1,188	1,428	1,654	2,116	2,577	3,019	3,440	1,429	1,656	2,127	2,596	3,047	3,464
	Merchantable volume (ft ³)	955	1,179	1,355	1,789	2,233	2,660	3,064	1,180	1,357	1,799	2,248	2,681	3,083
	Basal area (ft ²)	79	79	99	117	133	148	161	79	99	117	135	150	163
	Stand density index	190	154	185	210	233	252	269	167	200	229	255	277	295
	Canopy cover (percent)	49	49	56	61	65	68	71	49	56	61	66	69	72
	Crown competition factor	67	67	81	94	105	114	123	67	81	95	107	117	126
	Canopy base height (ft)	8	8	19	21	23	25	25	8	14	18	19	18	14
	Canopy bulk density (kg/m ³)	0.04	0.04	0.05	0.05	0.06	0.06	0.06	0.04	0.06	0.06	0.07	0.08	0.09
Pile and burn	Trees per acre	571	200	202	198	195	191	187	300	301	296	291	286	279
	Quadratic mean diameter (in)	5.0	8.5	9.5	10.4	11.2	11.9	12.5	7.0	7.8	8.5	9.2	9.8	10.4
	Total volume (ft ³)	1,188	1,428	1,654	2,116	2,577	3,020	3,441	1,429	1,656	2,127	2,596	3,047	3,463
	Merchantable volume (ft ³)	955	1,179	1,355	1,789	2,233	2,660	3,065	1,180	1,357	1,799	2,248	2,681	3,082
	Basal area (ft ²)	79	79	99	117	133	148	161	79	99	117	135	150	163
	Stand density index	190	154	185	211	233	253	269	167	201	229	255	277	296
	Canopy cover (percent)	49	49	56	61	65	68	71	49	56	61	66	69	72
	Crown competition factor	67	67	81	94	105	114	123	67	81	95	107	117	126
	Canopy base height (ft)	8	8	19	21	23	25	25	8	14	18	19	10	14
	Canopy bulk density (kg/m ³)	0.04	0.04	0.05	0.05	0.06	0.06	0.06	0.04	0.06	0.06	0.07	0.08	0.09
Prescribed fire	Trees per acre	571	200	115	113	110	108	106	300	115	113	110	108	106
	Quadratic mean diameter (in)	5.0	8.5	10.4	11.7	12.8	13.8	14.6	7.0	10.4	11.7	12.8	13.8	14.6
	Total volume (ft ³)	1,188	1,067	1,264	1,669	2,072	2,465	2,837	1,067	1,264	1,671	2,074	2,467	2,843
	Merchantable volume (ft ³)	955	894	1,058	1,445	1,837	2,201	2,563	895	1,058	1,447	1,838	2,208	2,569
	Basal area (ft ²)	79	79	68	84	99	112	124	79	68	84	99	112	124
	Stand density index	190	154	123	145	164	181	196	167	123	145	164	181	196
	Canopy cover (percent)	49	49	43	49	53	57	60	49	43	49	53	57	60
	Crown competition factor	67	67	55	66	76	84	92	67	55	66	76	84	92
	Canopy base height (ft)	8	10	24	26	27	28	29	10	24	25	27	28	29
	Canopy bulk density (kg/m ³)	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.04	0.04	0.04	0.04

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 12d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None	1	5	100					5	100				
	10	5	92	10	8			5	96	10	4		
	20	9	81	10	19			5	94	10	6		
	30	9	72	10	28			5	94	10	6		
	40	9	61	10	39			5	91	10	9		
50	10	52	9	48			5	87	10	13			

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None	1	8	91	10	9			5	99	10	1		
	10	8	100			5	100	5	100				
	20	8	100			5	100	5	100				
	30	8	100			5	97	10	3				
	40	8	100			9	90	10	10				
50	8	100			9	83	10	17					
Pile and burn	1	8	91	10	9			5	100				
	10	8	100			5	100	5	100				
	20	8	100			5	100	5	100				
	30	8	100			5	100	5	100				
	40	8	100			9	100	9	100				
50	8	100			9	92	10	8					
Prescribed fire	1	8	100			5	100	5	100				
	10	8	100			5	100	5	100				
	20	8	100			5	100	5	100				
	30	8	100			5	100	5	100				
	40	8	100			5	99	10	1				
50	8	100			5	95	10	5					

Table 12d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit										
	Years					Fuel models					Fuel models					Fuel models					
	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	
None		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent	
	1	5	100																		
	10	5	99	10	1																
	20	9	95	10	5																
	30	9	88	10	12																
	40	9	79	10	21																
50	9	70	10	30																	
Pile and burn	1	5	100																		
	10	5	100																		
	20	9	100																		
	30	9	100																		
	40	9	91	10	9																
	50	9	80	10	20																
Prescribed fire	1	5	100																		
	10	5	100	10																	
	20	5	96	10	4																
	30	5	95	10	5																
	40	5	91	10	9																
	50	9	87	10	13																

tpa = trees per acre, d.b.h. = diameter at breast height.

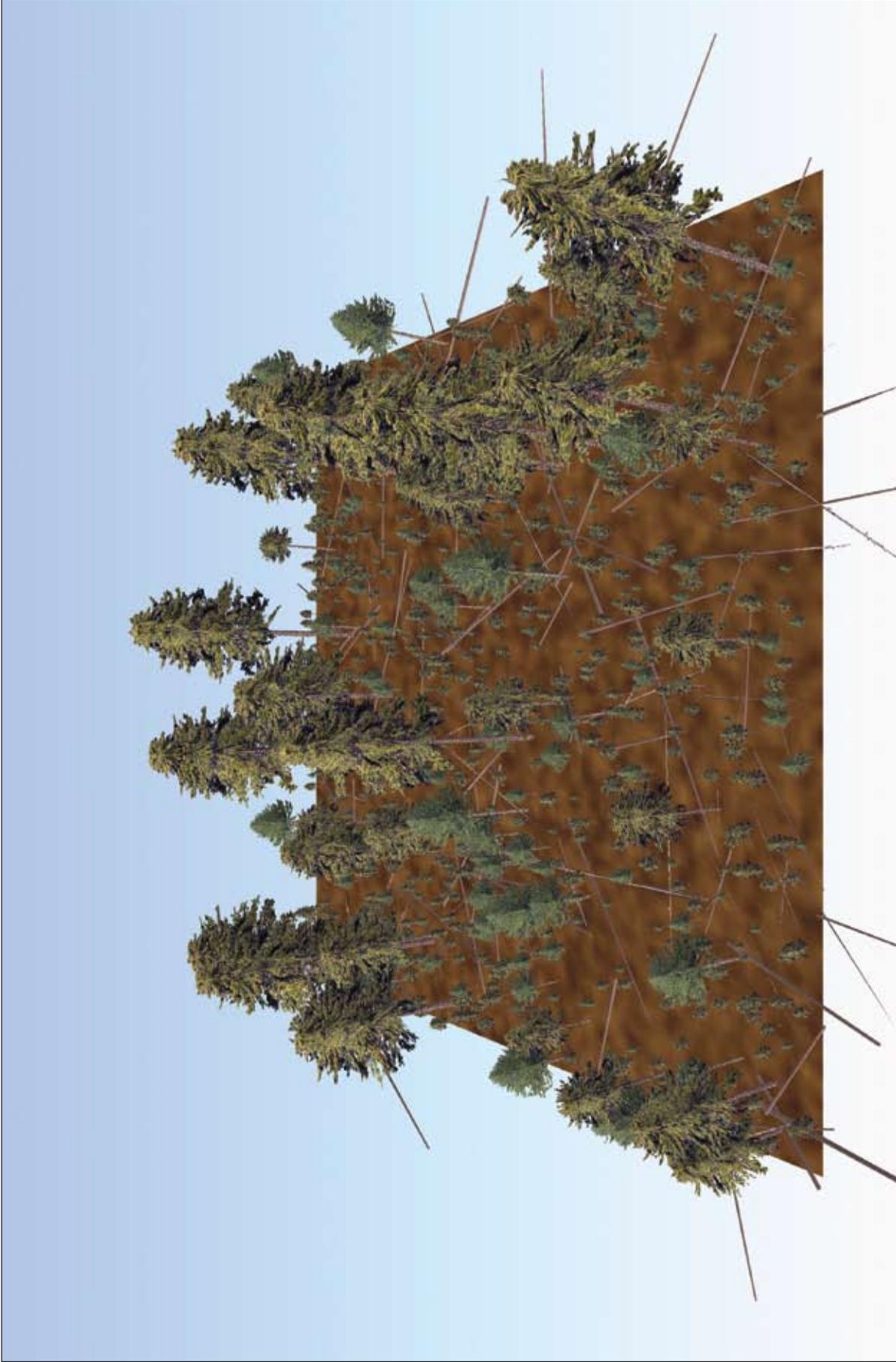
Table 12e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff	Live
Severe—98 th percentile	19	87	3	5	12	16	50	100
Moderate—75 th percentile	8	69	5	7	16	19	125	150

Table 12f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

Site: Elevation = 5,400 ft, slope = 15 percent, aspect = 360°.

Species (based on trees per acre): Ponderosa pine (*Pinus ponderosa*) = 68 percent, gambel oak (*Quercus gambelii*) = 19 percent, mountain juniper (*Juniperus scopulorum*) = 12 percent.

Stand attributes: Stem density = 838 tpa, basal area = 87 ft²/ac, top height = 46 ft, stand density index = 221, quadratic mean diameter = 4.4 in, crown competition factor = 72, canopy cover = 51 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has initial tree density of 838 trees per acre (tpa) composed of gambel oak, juniper, and ponderosa pine in the understory and a ponderosa pine overstory. Canopy base height is only 3 ft, and canopy bulk density is 0.07 kg/m³ (0.0044 lb/ft³), so initial conditions have high potential for passive crown fire but low potential for active crown fire spread under severe fire weather. Potential tree mortality is 61 percent for severe fire but only 10 percent for moderate fire weather. Woody fuel loading is 6 tons/ac, and litter and duff loading is 7 tons/ac. With no action, canopy base height will increase as the trees grow and the stand self-thins, making passive crown fire unlikely in 20 yrs, but flame lengths increase as surface fuels accumulate.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment initially reduces surface fuels but has little effect on canopy base height and canopy bulk density. Passive crown fire remains likely after treatment, but potential flame lengths and basal area mortality are lower than initial conditions. Thinning to 100 tpa or less is needed to increase canopy base height and decrease canopy bulk density. The low-density treatments decrease crown fire potential (predicted fire type changes to surface fire) and basal area mortality, but activity fuels generated from the thinning prevent potential flame lengths from decreasing with treatment. The pile and burn surface fuel treatment and, to a greater extent, the prescribed fire treatment reduce surface fuels to below initial conditions. These surface fuel treatments further decrease crown fire potential, flame lengths, and basal area mortality for severe and moderate fire weather in the low-density treatments. Surface fuel treatments also decrease potential flame lengths and basal area mortality in the higher density treatments, but canopy base height is still low enough that passive crown fire remains likely for severe fire weather.

Silvicultural and surface fuel treatments—long-term effects

The prescribed fire only treatment increases canopy base height over time as the trees grow and the stand self-thins. In 10 years, the predicted fire type changes to surface fire for severe and moderate fire weather and remains surface fire for the 50-year projection. Surface fuels accumulate slowly, and potential flame lengths increase slightly over time. Regeneration in the low-density treatments causes a decrease in canopy base height in 20 years, and passive crown fire becomes likely. In reality, the decrease in canopy base height may not be as extreme or sudden as the model predicts, but generally regeneration in the more open stands can be expected to increase crown fire potential and another treatment may be necessary. Canopy base height continues to increase in the high-density treatments, and the predicted fire type changes from passive to surface fire in 10 years. In the high-density treatments with pile and burn or no surface fuel treatment, surface fuels accumulate and flame lengths increase, and passive crown fire is predicted again in 20 to 30 years. At this time, a second treatment would be necessary to reduce surface fuels. The high-density treatments with prescribed fire have a long-term effect on crown fire potential, because both surface fuels and regeneration are low.

Table 13a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit	
None	Surface fuel loadings (tons/ac)	0–3 in	1	4	4	3	3	
		3–6 in	0	3	3	2	2	
	>12 in	6–12 in	1	3	2	2	2	
		>12 in	0	0	0	0	0	
	Litter	Litter	1	3	3	3	3	
		Duff	4	3	4	4	4	
	Flame length (ft)	Moderate	1	2	1	1	1	
		Severe	2	2	2	2	2	
	Torching index	Severe	17	18	47	52	10	11
		Severe	35	44	59	58	58	50
Crowning index	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Passive	Surface	Surface	Passive	Passive	
Potential basal area mortality (%)	Moderate	10	6	8	9	10	11	
	Severe	61	11	12	14	17	20	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	1	1	1	1	1	
		3–6 in	1	1	1	1	1	
	>12 in	6–12 in	1	1	1	1	1	
		>12 in	0	0	0	0	0	
	Litter	Litter	3	3	3	3	3	
		Duff	3	3	3	3	3	
	Flame length (ft)	Moderate	2	2	1	1	1	
		Severe	2	2	2	2	2	
	Torching index	Severe	47	47	52	52	10	11
		Severe	59	59	58	58	58	50
Crowning index	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Surface	Surface	Passive	Passive	Passive	
Potential basal area mortality (%)	Moderate	3	3	4	4	5	6	
	Severe	6	6	7	7	9	10	
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	0	0	0	0	
		3–6 in	0	0	0	0	0	
	>12 in	6–12 in	1	1	1	1	1	
		>12 in	0	0	0	0	0	
	Litter	Litter	1	1	1	1	1	
		Duff	3	3	3	3	3	
	Flame length (ft)	Moderate	1	1	1	1	1	
		Severe	1	1	1	1	1	
	Torching index	Severe	88	88	86	86	17	17
		Severe	63	63	62	62	61	61
Crowning index	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Passive	Passive	
Potential basal area mortality (%)	Moderate	3	3	4	4	5	5	
	Severe	5	5	7	7	9	9	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 13b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	2	3	4	5	6	7	1	2	3	4	5	6
	0–3 in	2	3	4	5	6	7	1	2	3	4	5	6
	3–6 in	2	2	3	3	3	4	0	1	1	1	2	2
	6–12 in	2	2	2	2	2	2	1	2	1	1	2	2
	>12 in	0	0	0	0	0	1	0	0	0	0	1	1
	Litter	3	4	4	5	5	5	1	3	4	5	5	5
	Duff	4	4	4	4	5	5	3	3	3	3	3	4
	Flame length (ft)	1	2	2	2	2	2	1	1	2	2	2	2
	Moderate	2	3	3	3	3	3	1	1	3	3	3	3
	Severe	17	12	21	38	52	62	18	30	19	29	41	54
Torching index	35	29	30	31	34	35	44	37	33	35	35	36	
Crowning index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Type of fire	Passive	Passive	Passive	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	
Hard snags (stems/ac)	14	16	38	47	39	31	61	7	12	31	37	31	
0–17.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
None	Surface fuel loadings (tons/ac)	4	3	3	4	4	4	4	3	3	4	4	5
	0–3 in	4	3	3	4	4	4	4	3	3	4	4	5
	3–6 in	3	3	3	3	4	4	3	3	3	3	3	4
	6–12 in	3	3	3	3	3	2	2	3	2	2	2	2
	>12 in	0	0	0	0	0	0	0	0	0	0	0	0
	Litter	3	2	3	4	4	4	3	3	4	4	4	5
	Duff	4	4	4	4	4	5	4	4	4	4	4	5
	Flame length (ft)	2	2	2	2	2	2	1	2	2	2	2	2
	Moderate	2	3	3	3	3	3	2	3	3	3	3	3
	Severe	47	82	0	18	15	32	52	18	0	8	20	32
Torching index	59	53	51	49	43	36	58	53	51	45	36	34	
Crowning index	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	
Type of fire	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface	Passive	Surface	Surface	Surface	
Hard snags (stems/ac)	6	4	2	3	3	3	7	5	3	4	4	4	
0–17.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 13b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	1	2	2	3	4	4	1	2	2	3	4	5
	0–3 in	1	1	1	2	2	2	1	1	1	2	2	2
	3–6 in	1	1	1	1	1	1	1	1	1	1	1	1
	6–12 in	0	0	0	0	0	0	0	0	0	0	0	0
	>12 in	3	2	3	4	4	4	3	3	4	4	4	5
	Litter	3	4	4	4	4	4	3	4	4	4	4	4
	Duff	2	1	1	1	2	2	1	1	1	2	2	2
	Moderate	2	1	1	2	3	3	2	1	1	3	3	3
	Severe	47	111	0	25	15	31	52	26	0	8	20	31
	Severe	59	53	51	49	43	36	58	53	51	45	36	34
Prescribed fire	Surface fuel loadings (tons/ac)	0	1	2	3	3	3	0	1	2	3	4	4
	0–3 in	0	1	1	1	2	2	0	1	1	1	2	2
	3–6 in	1	2	2	2	2	2	1	2	2	2	2	2
	6–12 in	0	0	0	1	1	1	0	0	0	0	1	1
	>12 in	1	2	3	3	4	4	3	2	3	4	4	4
	Litter	3	3	3	3	3	3	3	3	3	3	3	3
	Duff	1	1	1	1	2	2	1	1	1	1	2	2
	Moderate	2	1	1	2	3	3	2	1	1	2	3	3
	Severe	50	115	0	25	18	22	56	106	0	24	19	24
	Severe	59	55	52	51	44	40	58	55	53	47	38	37
Type of fire	Surface fuel loadings (tons/ac)	6	2	3	3	3	2	10	2	3	3	3	3
	0–17.9 in	1	1	0	0	0	0	0	0	0	0	0	0
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive
Hard snags (stems/ac)	Surface fuel loadings (tons/ac)	0	1	1	1	1	1	0	1	1	1	1	1
	0–3 in	0	1	1	1	1	1	0	1	1	1	1	1
	3–6 in	1	2	2	2	2	2	1	2	2	2	2	2
	6–12 in	0	0	0	1	1	1	0	0	0	0	1	1
	>12 in	1	2	3	3	4	4	3	2	3	4	4	4
	Litter	3	3	3	3	3	3	3	3	3	3	3	3
	Duff	1	1	1	1	2	2	1	1	1	1	2	2
	Moderate	2	1	1	2	3	3	2	1	1	2	3	3
	Severe	50	115	0	25	18	22	56	106	0	24	19	24
	Severe	59	55	52	51	44	40	58	55	53	47	38	37

Table 13b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	0–3 in	3	3	3	4	5	5	3	3	3	4	5	6
		3–6 in	2	3	3	3	3	4	2	3	3	3	3	4
	6–12 in	2	3	2	2	2	2	2	2	2	2	2	2	2
		>12 in	0	0	0	0	0	0	0	0	0	0	0	0
	Litter	3	3	4	4	4	5	3	3	4	4	4	5	5
		Duff	4	4	4	4	4	5	4	4	4	4	4	5
	Flame length (ft)	Moderate	1	1	2	2	2	2	1	1	2	2	2	2
		Severe	2	2	3	3	3	3	2	2	3	3	3	3
	Torching index	Severe	10	19	33	15	21	30	11	21	14	16	23	34
		Crowning index	58	54	51	49	41	39	50	54	49	43	37	37
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Surface	Surface	Passive	Surface	Surface	Passive	Surface	Passive	Surface	Surface	Surface	
Hard snags (stems/ac)	0–17.9 in	8	6	5	5	5	5	9	8	8	8	13	22	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	1	2	2	3	4	5	1	2	3	4	5	5
		3–6 in	1	1	1	2	2	2	1	1	1	2	2	2
	6–12 in	1	1	1	1	1	1	1	1	1	1	1	1	
		>12 in	0	0	0	0	0	0	0	0	0	0	0	0
	Litter	3	3	4	4	4	5	3	3	4	4	4	5	5
		Duff	3	4	4	4	4	4	3	4	4	4	4	4
	Flame length (ft)	Moderate	1	1	1	2	2	2	1	1	2	2	2	2
		Severe	2	1	2	3	3	3	2	1	3	3	3	3
	Torching index	Severe	10	28	44	15	20	34	11	30	16	16	22	37
		Crowning index	58	54	51	49	41	39	50	54	49	43	37	37
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Surface	Surface	Passive	Surface	Surface	Passive	Surface	Passive	Surface	Surface	Surface	
Hard snags (stems/ac)	0–17.9 in	8	6	5	5	5	5	9	8	8	8	13	22	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 13b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	2	2	3	4	4	0	2	2	3	4	5
	0–3 in												
	3–6 in	0	1	1	1	2	2	0	1	1	1	2	2
	6–12 in	1	2	2	2	2	2	1	2	2	2	2	2
	>12 in	0	0	0	0	1	1	0	0	0	0	1	1
	Litter	1	3	3	4	4	4	1	3	3	4	4	5
	Duff	3	3	3	3	3	3	3	3	3	3	3	3
	Moderate	1	1	1	1	2	2	1	1	1	2	2	2
	Severe	1	1	2	2	3	3	1	1	2	3	3	3
	Torching index	17	26	35	31	18	31	17	28	44	15	20	34
Crowning index	Severe	61	55	53	52	46	61	55	53	48	41	38	
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Type of fire	Severe	Passive	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Passive	Surface	Surface	
	Severe	Passive	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Passive	Surface	Surface	
Hard snags (stems/ac)	0–17.9 in	17	3	4	4	4	24	4	6	6	6	5	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 13c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	838	822	782	738	703	676	613	607	595	563	530	504
	Quadratic mean diameter (in)	4.4	5.0	5.7	6.3	6.9	7.4	4.4	5.5	6.2	6.9	7.6	8.2
	Total volume (ft ³)	1,493	1,928	2,378	2,858	3,377	3,924	1,601	1,815	2,257	2,709	3,189	3,670
	Merchantable volume (ft ³)	1,315	1,662	2,007	2,474	2,930	3,589	1,427	1,601	1,957	2,392	2,903	3,447
	Basal area (ft ²)	87	114	139	162	183	203	90	102	126	147	166	184
	Stand density index	221	274	318	355	389	419	213	235	278	312	340	365
	Canopy closure (percent)	51	62	69	74	78	81	52	57	65	70	74	77
	Crown competition factor	72	96	118	136	153	169	73	83	104	121	135	149
	Canopy base height (ft)	3	5	7	10	12	13	3	4	7	9	11	13
	Canopy bulk density (kg/m ³)	0.07	0.09	0.09	0.08	0.08	0.07	0.05	0.07	0.08	0.07	0.07	0.07

Table 13c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	838	50	274	272	271	269	267	100	323	320	318	315	312
	Quadratic mean diameter (in)	4.4	15.6	7.1	7.8	8.4	9.0	9.7	11.5	6.9	7.5	8.1	8.8	9.4
	Total volume (ft ³)	1,493	1,547	1,714	2,148	2,521	2,930	3,376	1,594	1,773	2,221	2,617	3,049	3,520
	Merchantable volume (ft ³)	1,315	1,459	1,636	2,001	2,354	2,695	3,027	1,489	1,676	2,054	2,433	2,802	3,159
	Basal area (ft ²)	87	66	76	90	103	119	136	72	84	99	115	132	151
	Stand density index	221	102	160	181	204	227	253	125	179	203	229	256	283
	Canopy cover (percent)	51	38	42	50	57	63	69	42	46	54	61	67	73
	Crown competition factor	72	48	54	69	84	99	117	54	62	78	94	111	129
	Canopy base height (ft)	3	13	16	1	4	6	10	13	4	1	4	7	9
	Canopy bulk density (kg/m ³)	0.07	0.03	0.04	0.04	0.05	0.05	0.07	0.04	0.04	0.04	0.05	0.07	0.08
Pile and burn	Trees per acre	838	50	274	272	271	269	267	100	323	320	318	315	312
	Quadratic mean diameter (in)	4.4	15.6	7.1	7.8	8.4	9.0	9.7	11.5	6.9	7.5	8.1	8.8	9.4
	Total volume (ft ³)	1,493	1,547	1,714	2,148	2,521	2,930	3,376	1,594	1,773	2,221	2,617	3,049	3,520
	Merchantable volume (ft ³)	1,315	1,459	1,636	2,001	2,354	2,695	3,027	1,489	1,676	2,054	2,433	2,802	3,159
	Basal area (ft ²)	87	66	76	90	103	119	136	72	84	99	115	132	151
	Stand density index	221	102	160	181	204	227	253	125	179	203	229	256	283
	Canopy cover (percent)	51	38	42	50	57	63	69	42	46	54	61	67	73
	Crown competition factor	72	48	54	69	84	99	117	54	62	78	94	111	129
	Canopy base height (ft)	3	13	16	1	4	6	10	13	4	1	4	7	9
	Canopy bulk density (kg/m ³)	0.07	0.03	0.04	0.04	0.05	0.05	0.07	0.04	0.04	0.04	0.05	0.07	0.08
Prescribed fire	Trees per acre	838	50	269	267	266	264	262	100	303	301	299	296	294
	Quadratic mean diameter (in)	4.4	15.6	7.0	7.6	8.2	8.9	9.6	11.5	6.9	7.5	8.1	8.8	9.4
	Total volume (ft ³)	1,493	1,466	1,634	2,054	2,415	2,819	3,263	1,509	1,680	2,108	2,490	2,906	3,367
	Merchantable volume (ft ³)	1,315	1,384	1,562	1,915	2,255	2,589	2,932	1,415	1,594	1,955	2,317	2,666	3,013
	Basal area (ft ²)	87	66	71	84	98	114	131	72	78	92	107	124	142
	Stand density index	221	102	151	172	194	218	244	125	166	189	214	239	267
	Canopy cover (percent)	51	38	40	48	55	61	68	42	43	52	58	65	71
	Crown competition factor	72	48	51	65	79	95	113	54	57	72	88	104	123
	Canopy base height (ft)	3	14	17	1	4	7	9	13	15	1	4	7	9
	Canopy bulk density (kg/m ³)	0.07	0.03	0.04	0.04	0.04	0.05	0.07	0.03	0.04	0.04	0.05	0.06	0.07

Table 13c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	838	200	271	267	263	259	255	300	369	362	356	345	326
	Quadratic mean diameter (in)	4.4	8.4	7.9	8.6	9.4	10.0	10.7	7.0	7.0	7.7	8.4	9.0	9.7
	Total volume (ft ³)	1,493	1,623	1,812	2,239	2,662	3,102	3,558	1,635	1,840	2,287	2,730	3,178	3,596
	Merchantable volume (ft ³)	1,315	1,487	1,669	2,060	2,521	2,945	3,369	1,486	1,664	2,046	2,540	2,978	3,402
	Basal area (ft ²)	87	76	92	109	126	143	160	80	98	117	136	154	168
	Stand density index	221	150	185	211	237	261	285	169	207	238	268	293	311
	Canopy cover (percent)	51	44	50	57	63	67	71	47	54	61	67	71	74
	Crown competition factor	72	58	70	84	98	112	125	63	77	94	110	124	135
	Canopy base height (ft)	3	3	4	6	6	7	10	3	4	6	6	7	10
	Canopy bulk density (kg/m ³)	0.07	0.04	0.04	0.04	0.05	0.06	0.06	0.04	0.04	0.05	0.05	0.07	0.07
Pile and burn	Trees per acre	838	200	271	267	263	259	255	300	369	362	356	345	326
	Quadratic mean diameter (in)	4.4	8.4	7.9	8.6	9.4	10.0	10.7	7.0	7.0	7.7	8.4	9.0	9.7
	Total volume (ft ³)	1,493	1,623	1,812	2,239	2,662	3,102	3,558	1,635	1,840	2,287	2,730	3,178	3,596
	Merchantable volume (ft ³)	1,315	1,487	1,669	2,060	2,521	2,945	3,369	1,486	1,664	2,046	2,540	2,978	3,402
	Basal area (ft ²)	87	76	92	109	126	143	160	80	98	117	136	154	168
	Stand density index	221	150	185	211	237	261	285	169	207	238	268	293	311
	Canopy cover (percent)	51	44	50	57	63	67	71	47	54	61	67	71	74
	Crown competition factor	72	58	70	84	98	112	125	63	77	94	110	124	135
	Canopy base height (ft)	3	3	4	6	6	7	10	3	4	6	6	7	10
	Canopy bulk density (kg/m ³)	0.07	0.04	0.04	0.04	0.05	0.06	0.06	0.04	0.04	0.05	0.05	0.07	0.07
Prescribed fire	Trees per acre	838	200	225	221	218	215	212	300	296	291	286	281	278
	Quadratic mean diameter (in)	4.4	8.4	8.3	9.1	9.8	10.5	11.2	7.0	7.4	8.2	8.9	9.6	10.2
	Total volume (ft ³)	1,493	1,536	1,715	2,118	2,519	2,935	3,366	1,551	1,740	2,161	2,578	3,016	3,477
	Merchantable volume (ft ³)	1,315	1,420	1,595	1,989	2,400	2,799	3,196	1,423	1,596	1,968	2,421	2,858	3,293
	Basal area (ft ²)	87	76	84	99	115	130	146	80	89	106	123	141	158
	Stand density index	221	150	166	189	212	234	255	169	183	210	237	263	288
	Canopy cover (percent)	51	44	47	53	59	64	68	47	50	57	62	67	72
	Crown competition factor	72	58	63	76	88	101	113	63	68	83	98	112	126
	Canopy base height (ft)	3	3	4	5	5	7	10	3	4	6	6	7	10
	Canopy bulk density (kg/m ³)	0.07	0.03	0.04	0.04	0.04	0.05	0.05	0.03	0.04	0.04	0.05	0.06	0.06

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 13d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None			Percent			Percent			Percent				
	1	8	94	10	6	8	100						
	10	9	77	10	23	8	99	10	1				
	20	9	60	10	40	9	81	10	19				
	30	10	60	9	40	9	63	10	37				
40	10	75	9	25	10	54	9	46					
50	10	88	9	12	10	69	9	31					

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None			Percent			Percent			Percent				
	1	8	63	11	37	8	73	11	27				
	10	8	78	10	22	8	78	10	22				
	20	8	74	10	26	8	72	10	28				
	30	8	65	10	35	9	62	10	38				
40	9	56	10	44	9	50	10	50					
50	10	53	9	47	10	60	9	40					
Pile and burn	1	8	63	11	37	8	73	11	27				
	10	8	100			8	100						
	20	8	100			8	96	10	4				
	30	8	87	10	13	9	81	10	19				
	40	9	74	10	26	9	67	10	33				
50	9	63	10	37	9	55	10	45					
Prescribed fire	1	8	100			8	100						
	10	8	100			8	100						
	20	8	100			8	98	10	2				
	30	8	89	10	11	8	84	10	16				
	40	9	76	10	24	9	69	10	31				
50	9	65	10	35	9	58	10	42					

Table 13d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit										
	Fuel models					Fuel models					Fuel models					Fuel models					
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None	1	8	79	11	21	8	82	11	18	8	82	11	18	8	82	11	18	8	82	11	18
	10	8	78	10	22	8	78	10	22	8	78	10	22	8	78	10	22	8	78	10	22
	20	8	70	10	30	9	69	10	31	9	69	10	31	9	69	10	31	9	69	10	31
	30	9	59	10	41	9	56	10	44	9	56	10	44	9	56	10	44	9	56	10	44
	40	10	52	9	48	10	55	9	45	10	55	9	45	10	55	9	45	10	55	9	45
50	10	62	9	38	10	69	9	31	10	69	9	31	10	69	9	31	10	69	9	31	
Pile and burn	1	8	79	11	21	8	82	11	18	8	82	11	18	8	82	11	18	8	82	11	18
	10	8	100			8	100			8	100			8	100			8	100		
	20	8	93	10	7	9	91	10	9	9	91	10	9	9	91	10	9	9	91	10	9
	30	9	77	10	23	9	74	10	26	9	74	10	26	9	74	10	26	9	74	10	26
	40	9	64	10	36	9	60	10	40	9	60	10	40	9	60	10	40	9	60	10	40
50	9	52	10	48	10	55	9	45	10	55	9	45	10	55	9	45	10	55	9	45	
Prescribed fire	1	8	100			8	100			8	100			8	100			8	100		
	10	8	100			8	100			8	100			8	100			8	100		
	20	8	94	10	6	8	94	10	6	8	94	10	6	8	94	10	6	8	94	10	6
	30	8	80	10	20	9	78	10	22	9	78	10	22	9	78	10	22	9	78	10	22
	40	9	68	10	32	9	64	10	36	9	64	10	36	9	64	10	36	9	64	10	36
50	9	56	10	44	9	53	10	47	9	53	10	47	9	53	10	47	9	53	10	47	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 13e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff	Live
Severe—98 th percentile	19	87	3	5	12	16	50	100
Moderate—75 th percentile	8	69	5	7	16	19	125	150

Table 13f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).

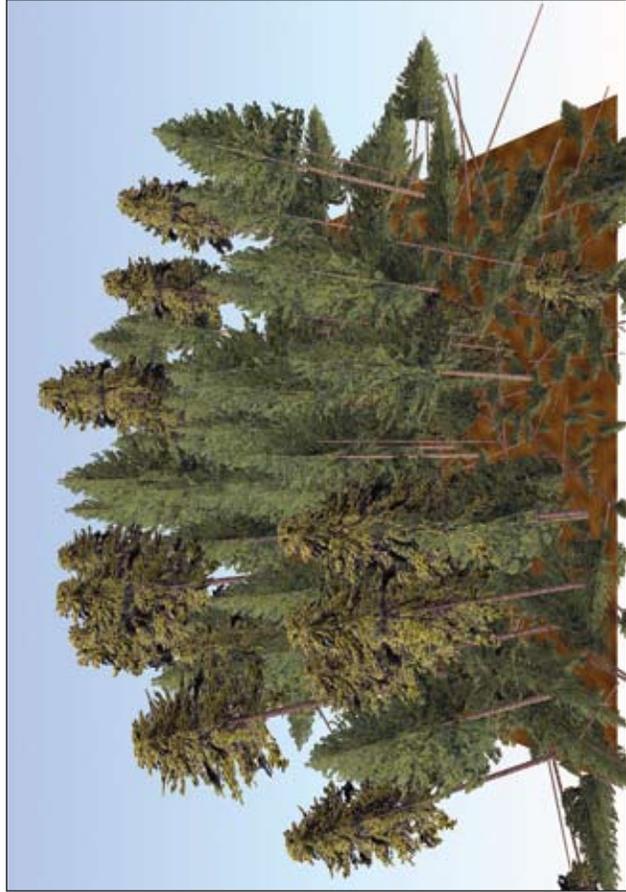


Initial stand conditions

Site: Elevation = 5,000 ft, slope = 23 percent, aspect = 225°.

Species (based on trees per acre): Ponderosa pine (*Pinus ponderosa*) = 2 percent, Engelmann spruce (*Picea engelmannii*) = 38 percent, grand fir (*Abies grandis*) = 56 percent, Douglas-fir (*Pseudotsuga menziesii*) = 4 percent, western larch (*Larix occidentalis*) = <1 percent.

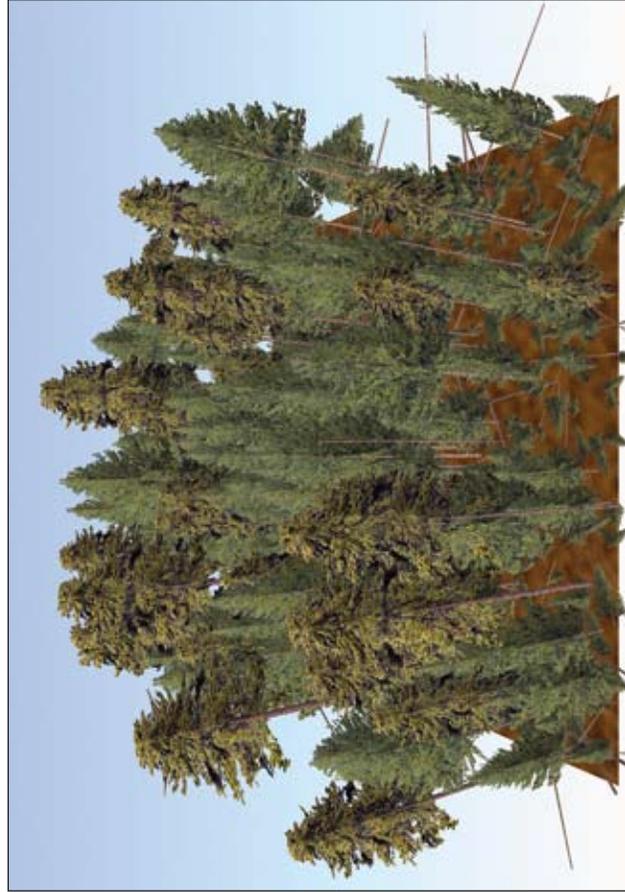
Stand attributes: Stem density = 2,079 tpa, basal area = 240 ft²/ac, top height = 103 ft, stand density index = 598, quadratic mean diameter = 4.6 in, crown competition factor = 74, canopy cover = 52 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand is composed of Ponderosa pine, Engelmann spruce, grand fir, Douglas-fir, and western larch with 2,079 trees per acre (tpa). Canopy bulk density is 0.27 kg/m³ (0.0169 lb/ft³), and canopy base height is 2 ft, so ladder fuels are not sufficient to enable crown fire initiation, but canopy fuels are sufficient to enable active crown fire spread for severe fire weather. Woody fuel loading is 18 tons/ac, and litter and duff loading is 27 tons/ac. Predicted flame lengths are 3 ft, and potential basal area mortality is 100 percent for severe fire weather and 25 percent for moderate fire weather. With no action, canopy base height increases slightly and canopy bulk density decreases as trees grow and the stand self-thins. However surface fuels accumulate causing higher flame lengths, so crown fire potential increases over time. In 20 years, passive crown fire is likely for moderate fire weather, and active crown fire remains likely for severe fire weather for the 50-year projection.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment increases canopy base height and decreases canopy bulk density and surface fuel loading, which reduces crown fire potential and flame lengths, but many snags are created that contribute to high surface fuel loading and increase crown fire potential in 10 years. All thinning treatments reduce canopy bulk density and increase canopy base height, but the higher density treatments (200 and 300 tpa) increase canopy base height by only 1 ft. Activity fuels from thinning increase potential flame lengths in all treatments; the greater the thinning, the greater is the increase in surface fuel loading. In the 200 tpa treatment the increase in canopy base height is not enough to compensate for greater potential flame lengths, so passive crown fire remains likely for severe fire weather, and potential basal area mortality is 82 percent. The pile and burn surface fuel treatment and, to a greater extent, the prescribed fire treatment reduce surface fuel loading, so potential flame lengths and basal area mortality are lower. The reduction in potential flame lengths is sufficient to change the predicted fire type to surface fire in the 200 tpa treatment.

Silvicultural and surface fuel treatments—long-term effects

In the prescribed fire only treatment, fallen snags contribute to higher surface fuel loading in 10 years and potential flame lengths increase, but canopy base height continues to increase, so crown fire potential remains low for the 50-year trajectory. Regeneration in the 50 tpa treatment causes canopy base height to decrease in 20 years, but potential flame lengths are low, so crown fire remains unlikely for the 50-year projection regardless of surface fuel treatment. In the 100 tpa, 200 tpa, and 300 tpa treatments, regeneration causes canopy base height to decrease in 30 years, and potential flame lengths are high enough that passive crown fire is predicted for severe fire weather. At this time, another treatment would be necessary to decrease crown fire potential. However canopy base height increases over time as regeneration grows, and in 50 years the predicted fire type becomes surface fire again, but potential flame lengths are at least 4 ft for severe fire weather.

Table 14a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	0–3 in	1	13	9	7	6
		3–6 in	1	4	4	4	3
	>12 in	6–12 in	3	3	3	3	3
		>12 in	0	0	0	0	0
	Litter	Litter	1	5	4	4	4
		Duff	17	5	5	5	5
	Flame length (ft)	Moderate	2	4	3	2	2
		Severe	3	6	4	4	3
	Torching index	Severe	2	109	99	16	23
		Severe	12	34	32	30	26
Crowning index	Moderate	Surface	Surface	Surface	Surface	Surface	
	Type of fire	Active	Surface	Surface	Passive	Surface	
Potential basal area mortality (%)	Moderate	25	14	8	11	16	
	Severe	100	14	15	13	82	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in		3	2	2	2
		3–6 in		1	1	1	1
	>12 in	6–12 in		1	1	1	1
		>12 in		0	0	0	0
	Litter	Litter		5	4	4	3
		Duff		5	5	5	5
	Flame length (ft)	Moderate		2	1	1	1
		Severe		3	2	2	2
	Torching index	Severe		245	291	75	77
		Severe		41	32	30	26
Crowning index	Moderate	Surface	Surface	Surface	Surface	Surface	
	Type of fire	Severe	Surface	Surface	Surface	Surface	
Potential basal area mortality (%)	Moderate		8	11	15	17	
	Severe		8	11	15	18	
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in		0	0	0	0
		3–6 in		1	1	1	1
	>12 in	6–12 in		2	2	2	2
		>12 in		0	0	0	0
	Litter	Litter		1	1	1	1
		Duff		4	4	4	4
	Flame length (ft)	Moderate		1	1	1	1
		Severe		2	2	2	2
	Torching index	Severe		368	365	176	125
		Severe		44	35	34	34
Crowning index	Moderate	Surface	Surface	Surface	Surface	Surface	
	Type of fire	Severe	Surface	Surface	Surface	Surface	
Potential basal area mortality (%)	Moderate		7	11	12	13	
	Severe		7	11	12	13	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 14b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	4	7	10	10	10	10	1	6	6	6	6	6
	0–3 in												
	3–6 in	7	7	8	8	9	9	1	3	4	4	5	5
	6–12 in	7	7	8	9	10	11	3	7	8	8	8	9
	>12 in	0	1	3	6	10	14	0	2	4	6	9	11
	Litter	2	4	4	4	4	4	1	2	3	3	3	3
	Duff	25	25	25	25	26	26	17	17	18	18	18	18
	Moderate	2	3	4	4	4	5	1	2	2	3	3	4
	Severe	3	4	5	6	6	7	2	4	4	4	5	5
	Torching index	2	0	0	0	0	0	109	60	90	109	120	125
	Crowning index	12	13	16	17	19	20	34	30	28	28	28	29
	Type of fire	Surface Active	Surface Active	Surface Active	Passive Active	Passive Active	Passive Active	Surface Surface					
Hard snags (stems/ac)	0–17.9 in	339	448	394	317	238	177	548	41	35	31	31	
18–29.9 in	4	6	11	14	16	17	6	7	9	11	12	13	
30–36 in	1	1	2	2	2	3	1	1	1	2	2	2	
None	Surface fuel loadings (tons/ac)	13	6	4	3	4	4	9	6	5	5	6	6
	0–3 in												
	3–6 in	4	4	4	4	4	5	4	4	5	5	5	6
	6–12 in	3	3	4	4	4	3	3	3	4	5	5	6
	>12 in	0	1	1	2	3	5	0	1	2	4	7	9
	Litter	5	2	2	2	2	2	4	2	2	3	3	2
	Duff	5	5	6	6	6	6	5	5	6	6	6	7
	Moderate	4	2	2	2	2	2	3	2	2	2	2	3
	Severe	6	3	3	3	3	3	4	3	3	4	4	5
	Torching index	80	272	22	36	42	44	99	227	238	16	17	21
	Crowning index	41	40	40	41	41	42	32	29	28	29	29	31
	Type of fire	Surface Surface	Surface Surface	Surface Surface	Surface Surface	Surface Surface	Surface Surface	Surface Surface					
Hard snags (stems/ac)	0–17.9 in	22	28	17	75	74	52	26	32	26	63	64	
18–29.9 in	3	3	4	6	7	7	3	4	7	10	12	13	
30–36 in	1	1	1	1	1	1	1	1	1	1	2	2	

Table 14b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	3	3	3	3	3	4	2	3	5	5	6	6
	0–3 in												
	3–6 in	1	2	2	2	3	3	1	2	2	3	4	4
	6–12 in	1	2	3	3	3	3	1	2	3	4	4	5
	>12 in	0	1	1	2	3	5	0	1	2	4	7	9
	Litter	5	2	2	2	2	2	4	2	2	3	3	3
	Duff	5	5	5	5	5	5	5	5	5	5	6	6
	Moderate	2	1	1	1	2	2	1	1	2	2	2	3
	Severe	3	2	2	2	2	3	2	2	3	3	4	4
	Severe	245	554	45	53	55	55	291	427	309	23	22	25
Torching index	Surface												
	Severe	41	40	40	41	41	42	32	29	28	29	31	
	Crowning index												
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Hard snags (stems/ac)	22	28	18	82	81	57	26	33	27	68	67	51
	0–17.9 in												
	18–29.9 in	3	3	4	5	7	7	3	4	7	10	12	13
	30–36 in	1	1	1	1	1	1	1	1	1	1	2	2
	Prescribed fire	Surface fuel loadings (tons/ac)	0	2	2	3	3	4	0	3	4	4	5
0–3 in													
3–6 in		1	2	2	2	3	3	1	2	3	3	4	4
6–12 in		2	3	4	4	4	3	2	4	6	6	6	6
>12 in		0	1	3	4	5	6	0	2	4	6	8	10
Litter		1	1	2	2	2	2	4	2	2	2	2	2
Duff		4	4	4	4	4	4	5	4	4	4	5	5
Moderate		1	1	1	2	2	2	1	1	2	2	2	3
Severe		2	2	2	2	3	3	2	2	3	3	4	4
Severe		368	510	37	42	47	49	365	376	17	18	19	14
Torching index	Surface												
	Severe	44	43	43	43	44	44	35	33	32	32	32	32
	Crowning index												
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Hard snags (stems/ac)	25	33	22	91	87	61	41	43	30	79	76	55
	0–17.9 in												
	18–29.9 in	5	5	6	6	6	6	5	6	7	9	10	11
	30–36 in	1	1	1	1	1	1	1	1	1	1	2	2

Table 14b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	0–3 in	7	6	7	7	7	7	6	6	7	8	8	8
		3–6 in	4	4	5	5	6	6	3	3	4	5	6	7
		6–12 in	3	3	5	6	7	8	3	3	5	6	7	8
	Flame length (ft)	>12 in	0	1	3	5	8	12	0	1	3	5	9	13
		Litter	4	3	3	3	3	3	4	3	3	3	3	3
		Duff	5	5	6	6	7	7	5	5	6	6	7	7
	Torching index	Moderate	2	2	2	3	3	4	2	2	2	3	4	4
		Severe	4	3	4	4	5	6	3	3	4	5	5	6
		Severe	16	71	90	7	9	13	23	72	83	11	71	69
	Crowning index	Severe	30	27	25	25	26	26	26	25	25	25	25	24
		Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Passive	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Passive	Passive	Surface	Surface
	Type of fire	Severe	33	42	39	74	76	59	40	54	53	81	80	65
		0–17.9 in	3	5	9	12	14	15	4	6	9	13	16	16
		18–29.9 in	1	1	1	2	2	2	1	1	1	2	2	3
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	2	4	6	7	7	7	2	4	7	8	8	8
		3–6 in	1	2	3	3	4	5	1	2	3	4	5	6
		6–12 in	1	2	3	5	6	7	1	2	4	5	6	7
	Flame length (ft)	>12 in	0	1	2	5	8	12	0	1	3	5	9	13
		Litter	4	3	3	3	3	3	3	3	3	3	3	3
		Duff	5	5	5	6	6	6	5	5	5	6	6	7
	Torching index	Moderate	1	1	2	2	3	4	1	1	2	3	3	4
		Severe	2	2	3	4	5	5	2	2	3	4	5	6
		Severe	75	129	114	12	11	87	77	122	101	7	8	75
	Crowning index	Severe	30	27	25	25	26	27	26	25	25	25	25	24
		Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Passive	Passive	Surface
	Type of fire	Severe	33	43	40	78	80	61	40	55	53	83	84	67
		0–17.9 in	3	5	8	12	14	15	4	6	9	13	15	16
		18–29.9 in	1	1	1	2	2	2	1	1	1	2	2	2

Table 14b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	4	5	5	5	6	0	4	5	5	6	6
	0–3 in												
	3–6 in	1	3	3	4	4	5	1	3	4	4	5	5
	6–12 in	2	5	7	7	7	7	2	5	7	7	7	7
	>12 in	0	2	4	6	8	11	0	2	4	6	8	11
	Litter	1	2	3	3	3	3	1	2	3	3	3	3
	Duff	4	4	4	4	5	5	4	4	4	4	5	5
	Moderate	1	2	2	2	3	3	1	2	2	2	3	3
	Severe	2	3	3	4	4	5	2	3	3	4	4	5
	Torching index	176	193	208	12	13	18	125	94	102	10	12	12
Crowning index	34	30	29	28	29	30	34	31	29	29	29	30	
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Passive	Passive	Passive	
Hard snags (stems/ac)	0–17.9 in	60	44	33	84	80	59	81	46	35	87	84	
	18–29.9 in	5	6	8	10	11	12	5	6	8	10	12	
	30–36 in	1	1	1	1	2	2	1	1	1	1	2	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 14c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,079	1,544	1,176	888	680	533	171	163	148	135	123	112
	Quadratic mean diameter (in)	4.6	5.6	6.6	7.7	8.9	10.1	4.6	15.3	16.7	17.9	19.2	20.4
	Total volume (ft ³)	7,514	8,635	9,521	10,280	10,953	11,568	7,088	7,652	8,655	9,517	10,281	10,959
	Merchantable volume (ft ³)	6,777	7,716	8,375	8,924	9,392	10,321	6,620	7,184	8,124	8,924	9,640	10,404
	Basal area (ft ²)	240	265	279	288	293	297	197	208	224	236	246	253
	Stand density index	598	611	604	585	563	543	312	322	336	344	348	350
	Canopy closure (percent)	91	93	93	94	94	93	81	83	84	85	86	87
	Crown competition factor	236	260	271	274	274	272	167	174	186	193	198	201
	Canopy base height (ft)	2	3	3	4	5	5	6	10	17	24	30	34
	Canopy bulk density (kg/m ³)	0.27	0.25	0.19	0.17	0.15	0.14	0.07	0.08	0.09	0.09	0.09	0.09

Table 14c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,079	50	332	321	240	176	134	100	264	251	197	151	121
	Quadratic mean diameter (in)	4.6	22.5	9.2	9.9	11.8	14.3	16.8	18.6	12.1	12.8	14.9	17.4	19.7
	Total volume (ft ³)	7,514	5,664	6,133	7,015	7,846	8,613	9,315	7,431	8,003	9,023	9,934	10,746	11,459
	Merchantable volume (ft ³)	6,777	5,419	5,886	6,733	7,532	8,267	8,922	7,062	7,634	8,632	9,527	10,291	10,996
	Basal area (ft ²)	240	138	154	170	184	196	206	189	209	226	239	249	257
	Stand density index	598	183	292	313	315	312	307	271	357	375	374	367	361
	Canopy cover (percent)	91	65	69	72	75	76	78	79	81	83	84	85	86
	Crown competition factor	236	106	117	128	138	145	150	154	167	178	185	191	195
	Canopy base height (ft)	2	29	38	3	4	5	6	20	28	33	4	5	7
	Canopy bulk density (kg/m ³)	0.27	0.05	0.06	0.05	0.05	0.05	0.05	0.08	0.09	0.09	0.09	0.08	0.08
Pile and burn	Trees per acre	2,079	50	361	349	260	189	141	100	282	268	207	158	126
	Quadratic mean diameter (in)	4.6	22.5	8.8	9.4	11.4	13.8	16.3	18.6	11.7	12.4	14.5	17.0	19.4
	Total volume (ft ³)	7,514	5,664	6,134	7,020	7,854	8,623	9,328	7,431	8,005	9,030	9,950	10,767	11,491
	Merchantable volume (ft ³)	6,777	5,419	5,887	6,741	7,540	8,284	8,959	7,062	7,635	8,634	9,530	10,336	11,033
	Basal area (ft ²)	240	138	154	170	183	195	205	189	210	226	239	250	258
	Stand density index	598	183	296	318	320	315	309	271	361	380	378	371	364
	Canopy cover (percent)	91	65	69	72	75	76	78	79	81	83	84	85	86
	Crown competition factor	236	106	117	128	137	144	150	154	167	178	185	191	195
	Canopy base height (ft)	2	29	38	3	4	5	6	20	28	33	4	5	7
	Canopy bulk density (kg/m ³)	0.27	0.05	0.06	0.06	0.05	0.05	0.05	0.08	0.09	0.09	0.09	0.09	0.08
Prescribed fire	Trees per acre	2,079	50	391	377	277	202	151	100	325	310	233	173	134
	Quadratic mean diameter (in)	4.6	22.5	8.2	8.8	10.8	13.1	15.5	18.6	10.4	11.1	13.2	15.8	18.3
	Total volume (ft ³)	7,514	5,311	5,769	6,630	7,448	8,211	8,917	6,782	7,345	8,376	9,303	10,134	10,869
	Merchantable volume (ft ³)	6,777	5,083	5,537	6,358	7,144	7,854	8,494	6,448	7,015	8,025	8,913	9,715	10,414
	Basal area (ft ²)	240	138	145	161	175	188	198	189	191	209	223	234	243
	Stand density index	598	183	287	310	312	310	306	271	345	367	366	359	352
	Canopy cover (percent)	91	65	66	70	73	75	77	79	78	80	82	83	84
	Crown competition factor	236	106	109	122	131	139	145	154	150	162	171	177	182
	Canopy base height (ft)	2	29	38	3	4	5	6	23	31	3	4	5	7
	Canopy bulk density (kg/m ³)	0.27	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.07	0.08	0.08	0.08	0.07

Table 14c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,079	200	333	312	253	202	168	300	392	359	296	243	206
	Quadratic mean diameter (in)	4.6	13.9	11.3	12.2	13.8	15.8	17.6	11.6	10.7	11.6	13.0	14.6	16.1
	Total volume (ft ³)	7,514	7,904	8,503	9,555	10,480	11,301	12,036	7,988	8,577	9,609	10,496	11,293	12,010
	Merchantable volume (ft ³)	6,777	7,388	7,969	8,935	9,766	10,643	11,457	7,346	7,878	8,750	9,465	10,296	11,301
	Basal area (ft ²)	240	210	234	251	265	275	283	219	244	262	274	283	291
	Stand density index	598	339	408	426	427	421	415	379	436	453	453	447	442
	Canopy cover (percent)	91	84	86	88	89	89	90	86	88	90	91	91	91
	Crown competition factor	236	182	197	209	217	222	226	197	216	229	237	241	244
	Canopy base height (ft)	2	4	9	15	4	5	25	4	9	15	5	21	24
	Canopy bulk density (kg/m ³)	0.27	0.08	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.11	0.11	0.11	0.11
Pile and burn	Trees per acre	2,079	200	348	326	263	207	171	300	404	371	306	249	210
	Quadratic mean diameter (in)	4.6	13.9	11.1	11.9	13.6	15.6	17.4	11.6	10.5	11.4	12.8	14.4	15.9
	Total volume (ft ³)	7,514	7,904	8,504	9,547	10,469	11,292	12,030	7,988	8,578	9,606	10,503	11,302	12,018
	Merchantable volume (ft ³)	6,777	7,388	7,970	8,940	9,755	10,655	11,485	7,346	7,879	8,745	9,480	10,276	11,272
	Basal area (ft ²)	240	210	234	251	264	275	283	219	244	262	274	284	291
	Stand density index	598	339	411	430	429	423	417	379	438	456	456	450	444
	Canopy cover (percent)	91	84	86	88	89	89	90	86	88	90	91	91	91
	Crown competition factor	236	182	197	209	217	222	226	197	216	229	237	242	245
	Canopy base height (ft)	2	4	9	15	4	5	25	4	9	15	4	5	24
	Canopy bulk density (kg/m ³)	0.27	0.08	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.11	0.11	0.11	0.11
Prescribed fire	Trees per acre	2,079	200	346	329	250	188	147	300	368	349	268	204	161
	Quadratic mean diameter (in)	4.6	13.9	10.4	11.1	13.2	15.5	17.9	11.6	10.1	10.9	12.8	15.0	17.2
	Total volume (ft ³)	7,514	7,056	7,647	8,713	9,676	10,531	11,299	7,078	7,669	8,736	9,697	10,562	11,333
	Merchantable volume (ft ³)	6,777	6,671	7,263	8,301	9,208	10,062	10,821	6,657	7,247	8,256	9,151	10,019	10,819
	Basal area (ft ²)	240	210	203	221	236	247	257	219	206	224	239	251	261
	Stand density index	598	339	366	389	388	381	374	379	375	398	398	392	386
	Canopy cover (percent)	91	84	81	83	84	85	86	86	82	84	85	86	87
	Crown competition factor	236	182	164	177	186	192	197	197	169	183	192	199	204
	Canopy base height (ft)	2	10	20	30	4	5	7	7	11	16	4	5	6
	Canopy bulk density (kg/m ³)	0.27	0.07	0.08	0.09	0.09	0.09	0.08	0.07	0.08	0.09	0.09	0.09	0.08

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 14d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action										Prescribed fire only												
	Fuel models					Fuel models					Fuel models					Fuel models							
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent		
None	1	10	53	8	32	9	15										8	61	9	39			
	10	10	100														10	71	8	17		9	11
	20	10	67	12	33												10	95	8	3		9	2
	30	12	54	10	46												10	92	12	8			
	40	12	70	10	30												10	81	12	19			
50	12	86	10	14												10	69	12	31				

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit										Thin from below to 100 tpa, 18-in. d.b.h. limit												
	Fuel models					Fuel models					Fuel models					Fuel models							
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent		
None	1	10	65	12	35												10	98	12	2			
	10	10	45	8	34	9	22										10	45	8	32		9	23
	20	8	42	10	30	9	28										10	57	8	25		9	18
	30	8	43	10	29	9	28										10	72	8	16		9	12
	40	8	39	10	36	9	26										10	95	8	3		9	2
50	10	46	8	32	9	22										10	88	12	12				
Pile and burn	1	8	46	9	28	10	26										8	56	9	37		10	7
	10	8	61	9	39												8	57	9	40		10	3
	20	8	59	9	38	10	3										8	40	10	32		9	28
	30	8	54	9	35	10	11										10	52	8	27		9	20
	40	8	48	9	31	10	21										10	78	8	13		9	9
50	8	41	10	33	9	27										10	96	12	4				
Prescribed fire	1	8	61	9	39												8	58	9	42			
	10	8	60	9	40												8	49	9	38		10	13
	20	8	55	9	38	10	7										10	44	8	31		9	25
	30	8	48	9	34	10	18										10	65	8	20		9	16
	40	8	42	9	30	10	28										10	85	8	8		9	7
50	10	39	8	35	9	26										10	96	12	4				

Table 14d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit										
	Fuel models					Fuel models					Fuel models					Fuel models					
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent
None	1	10	74	8	16	9	9	9	10	55	8	29	9	16	18	4	9	9	9	9	16
	10	10	47	8	33	19	9	19	10	47	8	35	9	18	18	4	9	9	9	18	
	20	10	78	8	14	8	9	8	10	88	8	8	8	4	4		9	9	9	4	
	30	10	97	12	3		10	3	10	88	12	12	12	12	12		10	12	12	12	
	40	10	80	12	20		10	20	10	69	12	31	12	31	31		10	12	12	31	
50	10	62	12	38		12	38	12	52	10	48	10	48	48		12	10	10	48		
Pile and burn	1	8	64	9	36		9	36	8	65	9	35	9	35		8	29	9	16		
	10	8	56	9	32	10	11	11	8	55	9	29	9	29	16	10	10	10	16		
	20	10	53	8	30	9	17	17	10	66	8	22	8	22	12	9	9	9	12		
	30	10	85	8	10	9	5	5	10	97	12	3	12	3	12		10	12	12	3	
	40	10	89	12	11		10	11	10	77	12	23	12	23	23		10	12	12	23	
50	10	70	12	30		12	30	10	55	12	45	12	45	45		10	12	12	45		
Prescribed fire	1	8	60	9	40		9	40	8	61	9	39	9	39		8	36	9	24		
	10	8	41	10	31	9	28	28	10	40	8	36	8	36	24	9	9	9	24		
	20	10	63	8	22	9	15	15	10	69	8	18	8	18	12	9	9	9	12		
	30	10	86	8	8	9	6	6	10	93	8	4	8	4	3	9	9	9	3		
	40	10	95	12	5		10	5	10	91	12	9	12	9	9		10	12	12	9	
50	10	81	12	19		12	19	10	77	12	23	12	23	23		10	12	12	23		

tpa = trees per acre, d.b.h. = diameter at breast height.

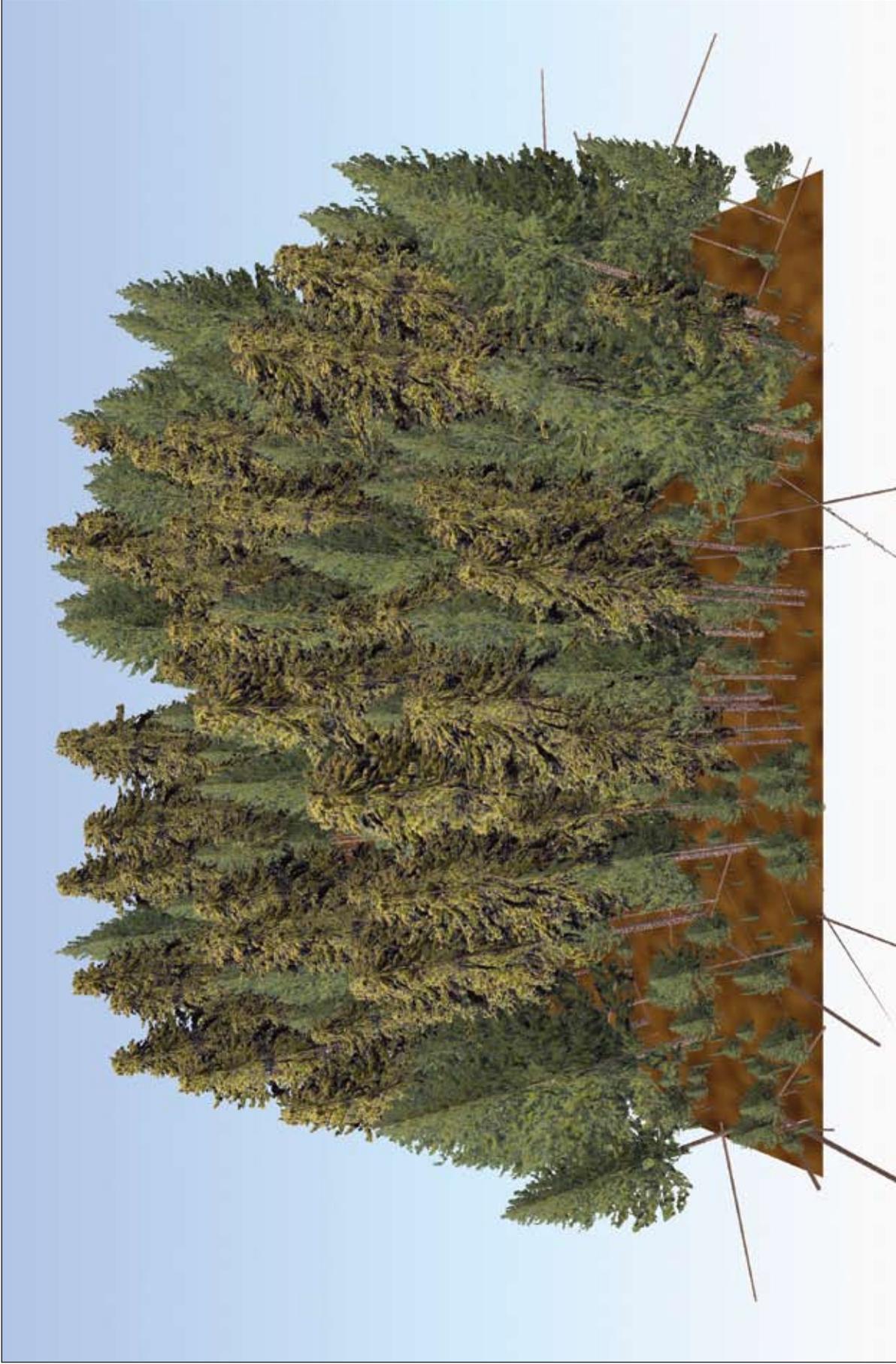
Table 14e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0-0.25 in)	10-hr (0.25-1 in)	100-hr (1-3 in)	1,000-hr (3+ in)	Duff	Live
	Miles/hour	°F	Percent					
Severe—98 th percentile	20	85	3	5	8	15	50	100
Moderate—75 th percentile	11	69	6	7	10	18	125	150

Table 14f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

Site: Elevation = 4,800 ft, slope = 20 percent, aspect = 315°

Species (based on trees per acre): Grand fir (*Abies grandis*) = 85 percent, ponderosa pine (*Pinus ponderosa*) = 6 percent, Douglas-fir (*Pseudotsuga menziesii*) = 8 percent.

Stand attributes: Stem density = 3,158 tpa, basal area = 289 ft²/ac, top height = 96 ft, stand density index = 754, quadratic mean diameter = 4.2 in, crown competition factor = 277, canopy cover = 94 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This is a dense stand with 3,158 trees per acre (tpa) composed of Douglas-fir and grand fir understory with a low-density ponderosa pine overstory. Canopy bulk density is 0.17 kg/m³ (0.0106 lb/ft³), and canopy base height is 3 ft, so ladder fuels are not sufficient to enable crown fire initiation, but canopy fuels are sufficient to enable active crown fire spread for severe fire weather. Woody fuel loading is 9 tons/ac, and litter and duff loading is 8 tons/ac. Predicted flame lengths and potential basal area mortality are low for severe and moderate fire weather. With no action, canopy base height increases slightly and canopy bulk density decreases as trees grow and the stand self-thins, but surface fuels accumulate rapidly causing higher flame lengths and crown fire potential. In 10 years, the predicted fire type is active crown fire for severe fire weather and passive crown fire for moderate fire weather. In 40 years, canopy base height increases enough that the predicted fire type becomes passive crown fire for both moderate and severe fire weather.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment increases canopy base height and reduces canopy bulk density and surface fuel loading, which decreases crown fire potential. Thinning to 200 tpa or less is required to increase canopy base height and reduce canopy bulk density sufficiently to affect crown fire potential. Activity fuels from thinning treatments increase surface fuel loading, which causes higher potential flame lengths and basal area mortality; the greater the thinning, the greater are activity fuels. The pile and burn, and to a greater extent, the prescribed fire treatments reduce surface fuels, which decreases potential flame lengths and basal area mortality. The prescribed fire treatment also causes tree mortality, which increases canopy base height. This additional increase in canopy base height is sufficient to change the predicted fire type to surface fire in the 300 tpa treatment.

Silvicultural and surface fuel treatments—long-term effects

In the prescribed fire only treatment, surface fuel loading increases from fallen snags in 10 years, and potential flame lengths increase. Passive crown fire is likely again because the treatment does not increase canopy base height sufficiently to compensate for higher flame lengths associated with surface fuel accumulation. In 20 years, canopy base height increases and the predicted fire type is surface fire, but surface fuels continue to accumulate and potential flame lengths increase. In 50 years, potential flame lengths are 5 ft and 8 ft for moderate and severe fire weather respectively, so an additional treatment may be necessary to reduce surface fuels. In the 50 tpa treatment, regeneration causes canopy base height to decrease in 20 years and passive crown fire is likely again, but the effect is short lived and the predicted fire type changes to surface fire again in 30 years. In all other treatments, regeneration causes a decrease in canopy base height in 20 or 30 years, and passive crown fire remains likely for the duration of the 50-year projection. A second treatment would be necessary to decrease crown fire potential. Surface fuels accumulate over time, and flame lengths exceed 5 ft in 50 years for severe fire weather, so an additional surface fuel treatment may also be necessary to reduce tree mortality.

Table 15a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit	
None	Surface fuel loadings (tons/ac)	0–3 in	1	17	12	8	6	
		3–6 in	0	4	4	4	4	
	>12 in	6–12 in	1	3	3	3	3	
		>12 in	0	0	0	0	0	
	Litter	Litter	3	2	7	6	5	
		Duff	5	4	5	5	5	
	Flame length (ft)	Moderate	1	1	5	2	2	
		Severe	2	2	7	4	3	
	Torching index	Severe	38	55	69	111	125	53
		Crowning index	18	21	43	29	21	18
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Conditional	Surface	Surface	Surface	Surface	Conditional	
Potential basal area mortality (%)	Moderate	18	14	6	8	12	14	
	Severe	19	14	45	11	12	15	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in		4	3	2	2	
		3–6 in		1	1	1	1	
	>12 in	6–12 in		1	1	1	1	
		>12 in		0	0	0	0	
	Litter	Litter		7	6	5	5	
		Duff		5	5	5	5	
	Flame length (ft)	Moderate		2	2	1	1	
		Severe		4	3	2	2	
	Torching index	Severe		140	233	249	127	
		Crowning index		43	29	21	18	
Type of fire	Moderate		Surface	Surface	Surface	Surface		
	Severe		Surface	Surface	Surface	Conditional		
Potential basal area mortality (%)	Moderate		6	8	12	14		
	Severe		6	8	12	14		
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in		0	0	0	0	
		3–6 in		1	1	1	1	
	>12 in	6–12 in		2	2	2	2	
		>12 in		0	0	0	0	
	Litter	Litter		1	1	1	2	
		Duff		4	4	4	4	
	Flame length (ft)	Moderate		2	1	1	1	
		Severe		3	2	2	2	
	Torching index	Severe		201	350	282	283	
		Crowning index		45	31	24	21	
Type of fire	Moderate		Surface	Surface	Surface	Surface		
	Severe		Surface	Surface	Surface	Surface		
Potential basal area mortality (%)	Moderate		6	8	11	13		
	Severe		6	8	11	13		

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 15b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	3	9	15	16	16	15	1	8	11	11	12	12
	3–6 in	3	4	6	8	10	12	0	4	6	7	9	10
	6–12 in	3	4	7	11	14	17	1	6	9	12	14	16
	>12 in	0	1	4	8	13	18	0	2	5	8	12	16
	Litter	3	8	7	7	7	6	2	5	5	5	5	4
	Duff	5	6	7	8	9	10	4	4	5	6	6	7
	Moderate	1	3	4	5	6	6	1	3	4	5	5	5
	Severe	2	4	6	7	8	9	2	4	6	7	7	8
	Torching index	38	0	0	0	0	0	55	12	36	52	54	59
	Crowning index	18	13	14	20	22	23	21	23	23	24	26	27
Type of fire	Moderate	Surface	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Conditional	Active	Active	Active	Passive	Surface	Passive	Surface	Surface	Surface	Surface	
Hard snags (stems/ac)	0–17.9 in	601	773	733	524	366	250	812	77	80	67	59	
	18–29.9 in	3	7	11	14	14	14	4	6	9	11	12	
	30–36 in	0	0	1	1	1	2	0	0	0	1	1	
None	Surface fuel loadings (tons/ac)	17	9	6	6	6	7	12	8	7	8	8	
	3–6 in	4	5	5	5	6	7	4	4	5	6	7	
	6–12 in	3	3	4	4	4	4	3	4	5	5	6	
	>12 in	0	1	2	2	3	5	0	1	2	4	6	
	Litter	7	3	3	3	4	4	7	4	4	5	5	
	Duff	5	6	6	7	7	7	5	6	6	7	7	
	Moderate	5	3	2	2	2	3	4	2	3	3	4	
	Severe	7	4	4	4	4	4	5	4	4	5	5	
	Torching index	69	138	5	19	24	22	111	188	0	5	7	
	Crowning index	43	43	35	32	41	46	29	30	30	31	32	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Passive	Passive	Passive	Passive	
Hard snags (stems/ac)	0–17.9 in	24	30	16	129	121	89	28	39	28	147	147	
	18–29.9 in	1	1	3	4	5	7	1	3	5	8	9	
	30–36 in	0	0	0	0	1	1	0	0	0	1	1	

Thin from below to 50 tpa, 18-in d.b.h. limit

Thin from below to 100 tpa, 18-in d.b.h. limit

Table 15b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	4	3	4	4	6	7	3	4	5	7	8	9
	0–3 in												
	3–6 in	1	2	2	3	4	5	1	2	3	4	5	6
	6–12 in	1	2	3	3	3	3	1	2	3	4	5	6
	>12 in	0	1	1	2	3	5	0	1	2	4	6	9
	Litter	7	3	3	3	4	4	6	4	4	5	5	5
	Duff	5	5	5	6	6	7	5	5	6	6	7	7
	Moderate	2	2	2	2	2	2	2	2	2	2	3	4
	Severe	4	3	3	3	3	4	3	3	3	4	5	6
	Severe	140	225	17	28	29	29	233	263	10	10	10	5
Prescribed fire	Surface fuel loadings (tons/ac)	43	43	33	30	39	46	29	30	30	31	32	33
	0–3 in												
	3–6 in	1	2	2	3	4	5	1	2	3	4	5	6
	6–12 in	2	3	4	4	4	4	2	3	5	6	6	7
	>12 in	0	1	3	4	4	6	0	2	4	6	8	10
	Litter	1	2	3	3	4	4	6	4	4	4	5	4
	Duff	4	4	4	4	5	5	5	4	4	5	5	6
	Moderate	2	1	2	2	2	3	1	2	2	3	3	4
	Severe	3	2	3	3	4	4	2	3	3	4	5	6
	Severe	201	266	17	26	27	27	350	271	9	8	4	5
Surface fuel treatment	Surface fuel loadings (tons/ac)	45	44	32	29	38	43	31	31	32	32	33	34
	0–3 in												
	3–6 in	1	2	2	3	4	5	1	2	3	4	5	6
	6–12 in	2	3	4	4	4	4	2	3	5	6	6	7
	>12 in	0	1	3	4	4	6	0	2	4	6	8	10
	Litter	1	2	3	3	4	4	6	4	4	4	5	4
	Duff	4	4	4	4	5	5	5	4	4	5	5	6
	Moderate	2	1	2	2	2	3	1	2	2	3	3	4
	Severe	3	2	3	3	4	4	2	3	3	4	5	6
	Severe	201	266	17	26	27	27	350	271	9	8	4	5
Type of fire	Surface	28	35	18	143	134	99	40	49	30	165	163	114
	Surface	3	3	4	4	5	7	3	4	6	7	9	10
	Passive	0	0	0	0	1	1	0	0	0	1	1	1
	Surface	0	0	0	0	1	1	0	0	0	1	1	1
	Surface	0	0	0	0	1	1	0	0	0	1	1	1
	Passive	0	0	0	0	1	1	0	0	0	1	1	1
	Surface	0	0	0	0	1	1	0	0	0	1	1	1
	Surface	0	0	0	0	1	1	0	0	0	1	1	1
	Passive	0	0	0	0	1	1	0	0	0	1	1	1
	Surface	0	0	0	0	1	1	0	0	0	1	1	1

Table 15b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	8	8	10	11	11	11	6	8	11	12	12	13
	0–3 in												
	3–6 in	4	5	6	7	8	10	4	4	6	8	10	11
	6–12 in	3	4	6	8	11	12	3	4	7	10	13	15
	>12 in	0	1	3	6	10	15	0	1	3	7	11	16
	Litter	6	5	5	5	5	5	5	6	6	6	6	5
	Duff	5	6	6	7	8	9	5	6	6	7	8	9
	Moderate	2	3	3	4	5	5	2	3	4	4	5	5
	Severe	4	4	5	6	7	7	3	4	6	7	7	8
	Torching index	125	161	125	0	0	0	53	47	108	0	0	0
Pile and burn	Crowning index	21	21	22	23	24	25	18	19	20	21	23	23
	Type of fire	Surface	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface	Passive	Passive	Passive
	Severe	Surface	Surface	Surface	Passive	Passive	Passive	Cond.	Cond.	Surface	Passive	Passive	Passive
	Hard snags (stems/ac)	39	53	53	131	135	99	50	68	73	120	117	90
	0–17.9 in												
	18–29.9 in	2	4	8	11	12	13	3	5	9	12	13	13
	30–36 in	0	0	0	1	1	2	0	0	0	1	1	2
	Surface fuel loadings (tons/ac)	2	5	8	10	11	11	2	6	10	11	12	12
	0–3 in												
	3–6 in	1	2	4	5	7	8	1	2	4	6	8	10
None	6–12 in	1	2	5	7	9	11	1	2	5	8	11	14
	>12 in	0	1	3	6	10	15	0	1	3	7	11	16
	Litter	5	5	5	5	5	5	5	6	6	6	5	5
	Duff	5	5	6	6	7	8	5	5	6	7	7	8
	Moderate	1	2	3	4	4	5	1	2	3	4	5	5
	Severe	2	3	4	6	6	7	2	3	5	6	7	8
	Torching index	249	204	154	0	0	0	127	67	122	0	0	0
	Crowning index	21	21	22	23	24	26	18	19	20	21	23	24
	Type of fire	Surface	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface	Passive	Passive	Passive
	Severe	Surface	Surface	Surface	Passive	Passive	Passive	Cond.	Cond.	Cond.	Passive	Passive	Passive
Hard snags (stems/ac)	39	54	54	138	144	105	50	68	73	125	123	93	
0–17.9 in													
18–29.9 in	2	4	8	11	12	13	3	5	9	12	13	13	
30–36 in	0	0	0	1	1	2	0	0	0	1	1	1	

Table 15b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	5	7	9	10	11	0	6	8	10	11	11
	0–3 in												
	3–6 in	1	3	4	6	7	8	1	4	6	7	9	10
	6–12 in	2	5	8	10	12	13	2	6	9	12	13	15
	>12 in	0	2	4	8	11	14	0	2	5	8	11	15
	Litter	1	5	5	5	5	5	2	5	5	6	5	5
	Duff	4	4	5	5	6	7	4	4	5	5	6	7
	Moderate	1	2	3	4	5	5	1	2	4	4	5	5
	Severe	2	3	5	6	7	7	2	4	5	6	7	8
	Torching index	282	183	0	0	0	0	283	167	0	0	0	0
Crowning index	Severe	24	23	23	24	25	27	21	21	22	22	24	25
	Moderate	Surface	Surface	Passive	Passive	Passive	Passive	Surface	Surface	Passive	Passive	Passive	Passive
Type of fire	Severe	Surface	Surface	Passive	Passive	Passive	Passive	Surface	Surface	Passive	Passive	Passive	Passive
	Severe	Surface	Surface	Passive	Passive	Passive	Passive	Surface	Surface	Passive	Passive	Passive	Passive
Hard snags (stems/ac)	0–17.9 in	60	66	51	163	167	116	73	70	60	161	163	116
	18–29.9 in	3	5	8	10	11	12	3	5	8	11	12	12
	30–36 in	0	0	0	1	1	1	0	0	0	1	1	1

tpa = trees per acre; d.b.h. = diameter at breast height; Cond. = conditional.

Table 15c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	3,158	2,221	1,512	1,053	742	537	321	292	248	213	185	163
	Quadratic mean diameter (in)	4.1	5.0	6.1	7.3	8.8	10.3	4.1	12.7	14.0	15.3	16.5	17.7
	Total volume (ft ³)	8,386	9,128	9,715	10,264	10,791	11,282	7,963	8,400	9,169	9,835	10,441	10,970
	Merchantable volume (ft ³)	7,266	8,131	8,628	9,152	9,636	10,349	7,169	7,726	8,470	9,126	9,739	10,336
	Basal area (ft ²)	289	303	308	309	310	310	252	258	267	272	276	278
	Stand density index	754	731	685	641	599	562	430	430	428	422	415	407
	Canopy closure (percent)	94	95	95	95	94	94	89	89	89	89	89	89
	Crown competition factor	277	296	296	292	289	282	219	221	224	224	225	222
	Canopy base height (ft)	3	3	4	4	5	5	4	5	14	21	24	28
	Canopy bulk density (kg/m ³)	0.17	0.25	0.22	0.14	0.12	0.12	0.13	0.12	0.12	0.11	0.10	0.10

Table 15c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	3,158	50	623	613	464	361	288	100	621	606	451	330	250
	Quadratic mean diameter (in)	4.1	21.1	6.3	6.8	8.3	9.9	11.5	18.3	7.7	8.1	9.7	11.6	13.5
	Total volume (ft ³)	8,386	4,602	5,026	5,863	6,680	7,473	8,249	6,595	7,103	8,033	8,898	9,688	10,403
	Merchantable volume (ft ³)	7,266	4,405	4,812	5,567	6,338	7,017	7,587	6,290	6,757	7,637	8,473	9,214	9,885
	Basal area (ft ²)	289	122	137	156	174	191	207	183	199	217	230	241	250
	Stand density index	754	166	300	333	343	353	360	264	406	433	428	417	406
	Canopy cover (percent)	94	59	63	69	73	76	78	76	78	81	82	83	84
	Crown competition factor	277	90	100	117	130	143	153	143	152	166	173	178	182
	Canopy base height (ft)	3	33	34	3	5	6	7	32	34	3	4	5	6
	Canopy bulk density (kg/m ³)	3.00	0.05	0.05	0.07	0.08	0.05	0.05	0.09	0.08	0.08	0.08	0.08	0.07
Pile and burn	Trees per acre	3,158	50	659	648	490	380	302	100	668	652	486	353	266
	Quadratic mean diameter (in)	4.1	21.1	6.2	6.7	8.1	9.6	11.3	18.3	7.4	7.8	9.3	11.2	13.2
	Total volume (ft ³)	8,386	4,602	5,027	5,864	6,681	7,489	8,277	6,595	7,105	8,061	8,935	9,735	10,463
	Merchantable volume (ft ³)	7,266	4,405	4,813	5,570	6,318	6,989	7,553	6,290	6,759	7,693	8,516	9,269	9,985
	Basal area (ft ²)	289	122	137	157	174	192	209	183	199	218	231	242	251
	Stand density index	754	166	303	337	348	358	365	264	411	440	435	424	413
	Canopy cover (percent)	94	59	63	69	73	76	79	76	78	81	82	83	84
	Crown competition factor	277	90	100	118	131	144	154	143	152	166	174	179	183
	Canopy base height (ft)	3	33	34	3	5	6	7	32	34	3	4	5	5
	Canopy bulk density (kg/m ³)	3.00	0.05	0.05	0.07	0.08	0.06	0.05	0.09	0.08	0.08	0.08	0.08	0.07
Prescribed fire	Trees per acre	3,158	50	695	684	519	403	319	100	704	689	510	373	282
	Quadratic mean diameter (in)	4.1	21.1	5.9	6.4	7.7	9.3	10.9	18.3	7.0	7.4	8.9	10.7	12.6
	Total volume (ft ³)	8,386	4,374	4,788	5,611	6,431	7,227	8,022	6,134	6,719	7,680	8,568	9,376	10,115
	Merchantable volume (ft ³)	7,266	4,374	4,591	5,327	6,080	6,715	7,286	5,812	6,405	7,325	8,164	8,904	9,602
	Basal area (ft ²)	289	122	130	151	169	188	206	183	188	208	222	234	244
	Stand density index	754	166	295	330	344	356	365	264	397	428	425	417	408
	Canopy cover (percent)	94	59	61	68	72	76	78	76	76	80	81	82	83
	Crown competition factor	277	90	95	114	128	142	153	143	143	159	167	173	178
	Canopy base height (ft)	3	34	34	3	5	6	7	32	33	3	4	4	5
	Canopy bulk density (kg/m ³)	0.17	0.05	0.05	0.08	0.09	0.06	0.04	0.08	0.08	0.08	0.07	0.07	0.07

Table 15c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	3,158	200	514	489	375	274	210	300	477	441	349	271	219
	Quadratic mean diameter (in)	4.1	15.1	9.7	10.1	11.8	13.9	16.0	12.9	10.4	11.0	12.5	14.2	15.9
	Total volume (ft ³)	8,386	8,237	8,716	9,558	10,347	11,077	11,732	8,709	9,153	9,938	10,676	11,338	11,915
	Merchantable volume (ft ³)	7,266	7,717	8,192	9,015	9,774	10,524	11,157	7,711	8,392	9,199	9,975	10,618	11,209
	Basal area (ft ²)	289	250	262	274	282	288	293	270	281	289	296	300	302
	Stand density index	754	389	488	500	485	464	446	449	507	511	497	478	461
	Canopy cover (percent)	94	88	88	89	89	89	89	91	91	91	91	91	91
	Crown competition factor	277	210	214	220	223	223	222	239	241	243	243	245	241
	Canopy base height (ft)	3	23	31	34	4	5	5	9	11	32	4	5	7
	Canopy bulk density (kg/m ³)	3.00	0.14	0.13	0.13	0.12	0.11	0.10	0.17	0.15	0.14	0.13	0.12	0.11
Pile and burn	Trees per acre	3,158	200	547	522	399	290	220	300	498	461	364	280	225
	Quadratic mean diameter (in)	4.1	15.1	9.4	9.8	11.4	13.5	15.6	12.9	10.2	10.7	12.2	14.0	15.7
	Total volume (ft ³)	8,386	8,237	8,718	9,565	10,358	11,096	11,761	8,709	9,155	9,941	10,680	11,328	11,912
	Merchantable volume (ft ³)	7,266	7,717	8,194	9,059	9,827	10,570	11,227	7,711	8,393	9,195	9,957	10,623	11,232
	Basal area (ft ²)	289	250	263	274	283	289	294	270	281	289	296	299	302
	Stand density index	754	389	494	507	492	470	451	449	512	516	501	481	463
	Canopy cover (percent)	94	88	88	89	89	89	89	91	91	91	91	91	91
	Crown competition factor	277	210	215	220	223	224	223	239	241	243	243	244	241
	Canopy base height (ft)	3	23	31	34	4	5	5	9	11	32	4	5	6
	Canopy bulk density (kg/m ³)	3.00	0.14	0.13	0.13	0.12	0.11	0.10	0.17	0.15	0.14	0.13	0.12	0.11
Prescribed fire	Trees per acre	3,158	200	642	619	462	328	244	300	640	611	461	334	252
	Quadratic mean diameter (in)	4.1	15.1	8.3	8.7	10.3	12.4	14.6	12.9	8.5	9.0	10.5	12.5	14.5
	Total volume (ft ³)	8,386	7,632	8,137	9,041	9,890	10,663	11,351	7,945	8,439	9,327	10,159	10,895	11,551
	Merchantable volume (ft ³)	7,266	7,632	7,655	8,564	9,378	10,157	10,847	7,945	7,840	8,726	9,536	10,287	10,948
	Basal area (ft ²)	289	250	243	258	268	276	282	270	255	268	278	284	289
	Stand density index	754	389	478	498	486	464	446	449	497	513	499	477	458
	Canopy cover (percent)	94	88	86	87	88	88	88	91	88	89	89	90	90
	Crown competition factor	277	210	196	206	211	212	213	239	212	220	225	227	226
	Canopy base height (ft)	3	23	30	3	4	5	5	22	30	3	4	5	5
	Canopy bulk density (kg/m ³)	3.00	0.11	0.12	0.11	0.11	0.11	0.10	0.13	0.13	0.13	0.12	0.11	0.10

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 15d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only									
	Fuel models			Fuel models			Fuel models			Fuel models						
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent
None	1	9	48	8	47	10	5	9	56	8	44	10	90	12	10	49
	10	10	87	12	13			10	90	12	10	10	51	10	49	
	20	12	76	10	24			12	80	10	20	12	96	13	4	
	30	12	85	13	15			12	75	13	25	12	80	10	20	
	40	12	58	13	42			12	75	13	25	12	96	13	4	
50	13	65	12	35			12	75	13	25	12	96	13	4		

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit									
	Fuel models			Fuel models			Fuel models			Fuel models						
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent
None	1	12	80	10	20			10	61	12	39	10	97	9	2	1
	10	10	99	12	1			10	96	12	4	10	96	12	4	
	20	10	81	9	13	8	6	10	83	12	17	10	66	12	34	
	30	10	81	9	13	8	6	10	66	12	34	10	54	10	46	
	40	10	96	9	3	8	1	10	42	10	35	10	46	10	27	8
50	10	88	12	12			10	46	10	27	8	25	8	14		
Pile and burn	1	10	58	9	27	8	13	9	79	12	21	9	79	12	21	8
	10	9	59	8	28	10	13	9	56	12	44	9	56	12	44	
	20	9	50	10	27	8	23	10	62	9	25	10	62	9	25	
	30	10	46	9	38	8	17	10	98	9	1	10	98	9	1	
	40	10	70	9	21	8	9	10	79	12	21	10	79	12	21	
50	10	100					10	56	12	44	10	56	12	44		
Prescribed fire	1	9	57	8	28	2	16	9	64	8	36	9	64	8	36	
	10	9	68	8	32			9	50	8	28	9	50	8	28	
	20	9	52	10	24	8	24	10	68	9	21	10	68	9	21	
	30	10	49	9	35	8	15	10	93	12	7	10	93	12	7	
	40	10	77	9	16	8	6	10	74	12	26	10	74	12	26	
50	10	95	12	5			10	53	12	47	10	53	12	47		

Table 15d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit						Thin from below to 300 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent
None	1	10	94	9	4	8	2	10	65	9	19	8	16
	10	10	98	12	2			10	96	12	4		
	20	10	68	12	32			10	56	12	44		
	30	12	61	10	39			12	78	10	22		
	40	12	87	10	13			12	90	13	10		
50	12	88	13	12			12	65	13	35			
Pile and burn	1	9	54	8	38	10	8	9	54	8	46		
	10	10	54	9	27	8	19	10	65	9	19	8	16
	20	10	89	12	11			10	75	12	25		
	30	10	54	12	46			12	64	10	36		
	40	12	76	10	24			12	100				
50	12	96	13	4			12	73	13	27			
Prescribed fire	1	9	60	8	40			9	57	8	43		
	10	10	66	9	20	8	14	10	94	9	4	8	2
	20	10	80	12	20			10	62	12	38		
	30	12	54	10	46			12	71	10	29		
	40	12	79	10	21			12	100				
50	12	95	13	5			12	78	13	22			

tpa = trees per acre, d.b.h. = diameter at breast height.

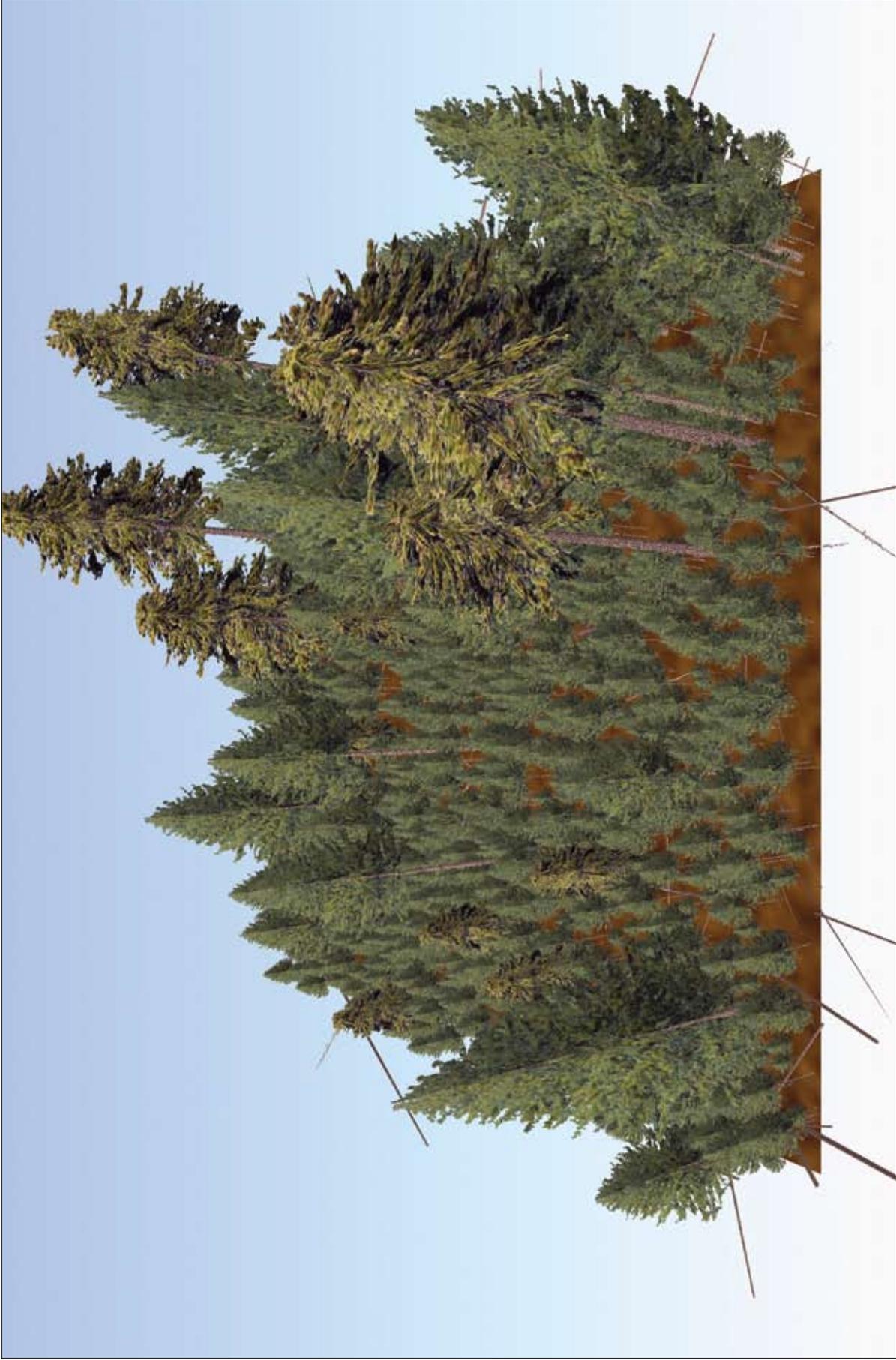
Table 15e—FVS fuel model selection

Fire weather conditions	Windspeed Miles/hour	Temperature °F	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff Live	
Severe—98 th percentile	20	85	3	5	8	15	50	100
Moderate—75 th percentile	11	69	6	8	11	18	125	150

Table 15f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

Site: Elevation = 5,800 ft, slope = 25 percent, aspect = 135°.

Species (based on trees per acre): Douglas-fir (*Pseudotsuga menziesii*) = 62 percent, grand fir (*Abies grandis*) = 33 percent, ponderosa pine (*Pinus ponderosa*) = 5 percent.

Stand attributes: Stem density = 2,144 tpa, basal area = 181 ft²/ac, top height = 67 ft, stand density index = 479, quadratic mean diameter = 3.9 in, crown competition factor = 242, canopy cover = 91 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This is a dense stand with 2,144 trees per acre (tpa) composed of Douglas-fir and grand fir understory with a low-density ponderosa pine overstory. Canopy bulk density is 0.42 kg/m³ (0.0262 lb/ft³), and canopy base height is 3 ft, so ladder fuels are not sufficient to enable crown fire initiation. Canopy fuels are sufficient to enable crown fire spread for severe fire weather. Woody fuel loading is 11 tons/ac, and litter and duff loading is 12 tons/ac. Predicted flame lengths are low, and potential basal area mortality is about 40 percent for severe and moderate fire weather. With no action, canopy base height increases and canopy bulk density decreases slightly as trees grow and the stand self-thins, but surface fuels accumulate rapidly causing higher flame lengths, so crown fire potential increases. In 10 years, predicted fire type is active crown fire for severe fire weather and remains so for the duration of the 50-year projection.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment creates many snags and has little effect on crown fire potential because canopy base height does not increase and canopy bulk density is not reduced enough to prevent conditional crown fire for severe fire weather. All thinning treatments increase canopy base height to a similar height, but the greater the thinning, the greater is the reduction in canopy bulk density. The 300 tpa treatment does not reduce canopy bulk density sufficiently enough to prevent conditional crown fire for severe fire weather. In all treatments, extensive activity fuels increase potential flame lengths to at least 5 ft for moderate and severe fire weather, so passive crown fire remains likely and potential basal area mortality is higher than initial conditions. Surface fuel treatments are necessary to further decrease crown fire potential and flame lengths. The pile and burn, and to a greater extent, the prescribed fire treatments, reduce surface fuels, which decreases potential flame lengths and basal area mortality. However, even after surface fuel treatments are applied, flame lengths and potential basal area mortality remain greater than initial conditions, because fire behavior is predicted by using primarily fuel model 2, suggesting grass fuels greatly influence fire behavior following surface fuel treatments. These results should be interpreted cautiously because grass fuels are not tracked in FFE.

Silvicultural and surface fuel treatments—long-term effects

In the prescribed fire only treatment, surface fuel loading increases from fallen snags in 10 years and then declines again as fuels decompose, but flame lengths remain higher than initial conditions for the 50-year projection. Canopy base height increases as trees grow and the stand self-thins, but canopy bulk density remains high enough that conditional crown fire is predicted for the entire 50-year projection. In the thinned stands without surface fuel treatment, surface fuels decompose rapidly and passive crown fire becomes unlikely in 10 years. Regeneration causes a decrease in canopy base height in all thinned stands in 20 years; this increases the potential for passive crown fire in stands without surface fuel treatment or with prescribed fire, but crown fire potential declines again in 30 years. The thinned stands with a pile and burn surface fuel treatment can sustain only a surface fire and have the lowest flame lengths for the 50-year projection.

Table 16a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	0–3 in	1	17	16	15	13
		3–6 in	0	10	10	9	8
	>12 in	6–12 in	2	3	3	3	4
		>12 in	0	0	0	0	0
	Litter	Litter	1	6	6	6	5
		Duff	10	9	9	10	10
	Flame length (ft)	Moderate	1	6	5	5	5
		Severe	2	8	8	7	7
	Torching index	Severe	51	49	14	18	23
		Crowning index	8	18	42	25	18
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Conditional	Conditional	Passive	Passive	Passive	Conditional
Potential basal area mortality (%)	Moderate	39	24	27	30	33	
	Severe	43	25	92	85	49	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	4	4	4	4	3
		3–6 in	3	3	3	3	2
	>12 in	6–12 in	1	1	1	1	1
		>12 in	0	0	0	0	0
	Litter	Litter	6	6	5	5	5
		Duff	8	8	8	9	9
	Flame length (ft)	Moderate	3	3	3	2	2
		Severe	5	5	4	4	3
	Torching index	Severe	40	40	46	73	96
		Crowning index	51	51	42	25	18
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	
	Severe	Conditional	Conditional	Surface	Surface	Surface	
Potential basal area mortality (%)	Moderate	9	9	11	16	19	
	Severe	23	23	24	23	24	
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	0	0	0	0
		3–6 in	3	3	3	2	2
	>12 in	6–12 in	2	2	2	2	2
		>12 in	0	0	0	0	0
	Litter	Litter	0	0	0	0	0
		Duff	6	6	7	7	7
	Flame length (ft)	Moderate	4	4	3	3	3
		Severe	6	6	6	6	6
	Torching index	Severe	48	48	48	49	52
		Crowning index	72	72	69	63	58
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	
	Severe	Conditional	Conditional	Surface	Surface	Surface	
Potential basal area mortality (%)	Moderate	5	5	6	6	7	
	Severe	18	18	18	19	21	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 16b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	3	7	12	14	14	14	1	9	8	8	8	8	
	0–3 in	4	4	5	7	9	12	0	5	5	6	6	7	
	3–6 in	4	3	3	3	4	5	2	2	2	2	3	3	
	6–12 in	0	0	1	1	3	4	0	0	1	1	2	3	
	>12 in	2	6	7	7	7	7	1	3	3	4	4	4	
	Litter	10	11	11	12	13	14	7	7	8	8	9	9	
	Duff	1	2	3	4	5	5	1	2	2	2	3	3	
	Moderate	2	4	5	6	7	7	2	4	4	4	4	4	
	Severe	51	2	6	6	13	12	49	19	48	71	81	87	
	Severe	8	8	8	8	9	10	18	18	16	16	16	17	
Flame length (ft)	Moderate	Surface Cond.	Surface Active	Surface Active	Surface Active	Surface Active	Surface Cond.	Surface Active	Surface Cond.	Surface Cond.	Surface Cond.	Surface Cond.		
	Severe	246	369	460	358	263	447	51	78	68	59	51		
	0–17.9 in	1	2	4	5	6	1	2	2	3	3	4		
	18–29.9 in	0	0	1	1	2	0	0	1	1	1	1		
	30–36 in													
	Torching index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
		Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	
		Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	
		199	199	199	199	199	199	199	199	199	199	199	199	
		Crowning index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Active			Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	
Cond.			Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	
447			447	447	447	447	447	447	447	447	447	447	447	
Type of fire			Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
			Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active
	Cond.		Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	
	447		447	447	447	447	447	447	447	447	447	447	447	
	Hard snags (stems/ac)		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
			Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active
		Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	Cond.	
		447	447	447	447	447	447	447	447	447	447	447	447	
		None	Surface fuel loadings (tons/ac)	17	9	6	4	4	5	16	9	6	5	5
			0–3 in	10	9	9	8	8	8	10	9	8	8	8
3–6 in			3	3	3	2	2	2	3	3	3	3	3	
6–12 in			0	0	0	0	1	2	0	0	0	0	2	
>12 in			6	2	2	2	3	3	6	2	2	3	3	
Litter			9	10	10	10	10	11	9	10	10	10	11	
Duff	6		3	2	2	2	2	5	3	2	2	2		
Moderate	8		5	4	4	4	4	8	5	4	4	4		
Severe	14		55	4	22	37	42	14	45	5	23	38		
Severe	51		47	46	45	45	40	42	41	39	37	36		
Flame length (ft)	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface		
	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive		
	5	6	5	54	51	39	5	10	10	59	58	46		
	2	6	5	54	51	39	5	10	10	59	58	46		
	Torching index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
		Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	
		0	1	1	1	2	3	0	1	1	2	2	4	
		0	1	1	1	2	3	0	1	1	2	2	4	
		Crowning index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
			Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive
0			0	0	0	1	1	0	0	0	0	1	1	
0			0	0	0	1	1	0	0	0	0	1	1	
Type of fire			Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
			Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive
	2		6	5	54	51	39	5	10	10	59	58	46	
	0		1	1	1	2	3	0	1	1	2	2	4	
	Hard snags (stems/ac)		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
			Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive
		0	0	0	0	1	1	0	0	0	0	1	1	
		0	0	0	0	1	1	0	0	0	0	1	1	

Table 16b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
Pile and burn	Surface fuel loadings (tons/ac)	4	3	3	3	4	5	4	3	3	3	4	5	
	0–3 in													
	3–6 in	3	3	3	3	3	4	3	3	3	3	3	4	
	6–12 in	1	1	1	1	1	1	1	1	1	1	1	1	
	>12 in	0	0	0	0	1	2	0	0	0	0	1	2	
	Litter	6	2	2	2	3	3	5	2	2	3	3	3	
	Duff	8	8	9	9	9	9	8	9	9	9	9	10	
	Moderate	3	2	1	1	2	2	3	2	1	2	2	2	
	Severe	5	4	2	2	3	3	4	3	2	2	3	3	
	Severe	40	108	30	51	61	59	46	131	33	52	62	59	
Torching index	Crowning index	51	47	46	45	45	39	42	41	39	37	36	35	
	Moderate													
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Hard snags (stems/ac)	2	6	6	59	56	43	5	10	10	64	63	49	
	0–17.9 in													
	18–29.9 in	0	1	1	1	2	3	0	1	1	2	2	4	
	30–36 in	0	0	0	0	1	1	0	0	0	1	1	1	
	Prescribed fire	Surface fuel loadings (tons/ac)	0	2	2	2	3	3	0	2	2	2	3	3
		0–3 in												
3–6 in		3	3	3	3	3	3	3	3	3	3	3	4	
6–12 in		2	3	3	3	3	3	2	3	3	3	3	3	
>12 in		0	0	1	1	1	1	0	0	1	1	1	1	
Litter		0	1	1	2	2	2	5	1	1	2	2	2	
Duff		6	6	7	7	7	7	8	7	7	7	7	7	
Moderate		4	3	3	2	2	2	3	3	3	2	2	2	
Severe		6	6	5	3	3	3	6	5	4	3	3	3	
Severe		48	71	11	34	59	58	48	72	12	35	58	57	
Crowning index	Severe	72	65	49	48	50	44	69	63	48	48	48	44	
	Moderate													
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Hard snags (stems/ac)	19	16	7	55	53	41	31	14	6	56	53	41	
	0–17.9 in													
	18–29.9 in	1	1	1	1	1	2	1	1	1	1	2	2	
	30–36 in	0	0	0	0	1	1	0	0	0	0	1	1	

Table 16b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	0–3 in	15	9	6	5	6	6	13	8	6	6	6	7
		3–6 in	9	8	8	8	8	8	8	8	8	8	8	9
	Flame length (ft)	6–12 in	3	3	3	3	3	3	4	3	3	3	3	4
		>12 in	0	0	0	1	1	2	0	0	0	1	1	2
	Torching index	Litter	6	2	3	3	3	3	5	3	3	4	4	4
		Duff	10	11	11	11	11	12	10	11	11	11	12	12
	Crowning index	Moderate	5	3	2	2	2	3	5	3	2	2	3	3
		Severe	7	5	4	4	4	4	7	4	4	4	4	4
	Type of fire	Severe	18	49	4	16	28	29	23	66	4	21	23	23
		Moderate	25	27	28	27	27	27	18	22	23	22	22	22
Hard snags (stems/ac)	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Conditional	Conditional	Passive	Passive	Surface	Surface	
	11	20	21	70	69	56	19	32	34	81	79	65		
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	4	3	3	4	5	6	3	3	4	5	6	7
		3–6 in	3	3	3	3	4	5	2	2	3	3	4	5
	Flame length (ft)	6–12 in	1	1	1	1	1	2	1	1	1	1	1	2
		>12 in	0	0	0	1	1	2	0	0	0	1	1	2
	Torching index	Litter	5	2	3	3	3	4	5	3	3	4	4	4
		Duff	9	9	10	10	10	10	9	9	10	10	10	11
	Crowning index	Moderate	2	1	1	2	2	2	2	1	2	2	2	2
		Severe	4	2	2	3	3	3	3	2	2	3	3	4
	Type of fire	Severe	73	167	34	40	47	50	96	202	33	45	39	42
		Moderate	25	27	28	27	27	27	18	22	23	22	23	23
Hard snags (stems/ac)	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Conditional	Conditional	Surface	Surface	Surface	Surface	
	11	20	21	74	74	59	19	32	35	86	83	69		
None	18–29.9 in	0	1	1	2	3	4	0	1	2	2	3	4	
	30–36 in	0	0	0	1	1	1	0	0	0	1	1	2	

Table 16b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	3	2	2	3	4	0	4	3	3	3	4
	0–3 in												
	3–6 in	2	4	4	4	4	4	2	4	4	4	4	5
	6–12 in	2	3	3	3	3	2	2	3	3	3	2	2
	>12 in	0	0	1	1	1	2	0	0	1	1	1	2
Flame length (ft)	Litter	0	1	2	2	2	3	0	1	2	2	2	3
	Duff	7	7	7	7	8	8	7	7	7	8	8	8
	Moderate	3	3	2	2	2	2	3	3	2	2	2	2
	Severe	6	5	4	3	3	3	6	5	4	3	3	3
Torching index	Severe	49	68	13	38	56	56	52	66	14	40	52	53
	Severe	63	59	49	48	47	41	58	57	49	49	44	39
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface
	Hard snags (stems/ac)	49	9	6	57	55	42	76	11	7	59	57	44
tpa = trees per acre; d.b.h. = diameter at breast height; cond. = conditional.	18–29.9 in	1	1	1	1	2	3	1	1	1	1	2	3
	30–36 in	0	0	0	0	1	1	0	0	0	0	1	1

Table 16c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,144	1,705	1,299	1,010	802	650	506	461	397	345	302	267
	Quadratic mean diameter (in)	3.9	4.7	5.6	6.5	7.5	8.4	3.9	7.2	8.3	9.3	10.3	11.3
	Total volume (ft ³)	3,633	4,316	4,910	5,489	6,056	6,601	3,120	3,415	4,014	4,584	5,142	5,691
	Merchantable volume (ft ³)	2,559	2,751	2,886	2,978	3,659	4,090	2,564	2,712	2,987	3,249	3,640	4,718
	Basal area (ft ²)	181	209	223	234	244	250	122	132	150	164	176	187
	Stand density index	479	515	514	509	501	492	262	274	295	309	319	326
	Canopy closure (percent)	91	93	94	94	94	94	73	75	79	81	83	84
	Crown competition factor	242	272	280	285	287	286	130	139	156	168	177	185
	Canopy base height (ft)	3	3	5	6	9	10	3	5	9	13	16	20
	Canopy bulk density (kg/m ³)	0.42	0.42	0.40	0.39	0.35	0.32	0.16	0.16	0.18	0.19	0.18	0.18

Table 16c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,144	50	310	305	244	201	169	100	353	346	281	234	199
	Quadratic mean diameter (in)	3.9	17.9	7.7	8.3	9.9	11.6	13.3	13.0	7.4	8.1	9.6	11.1	12.6
	Total volume (ft ³)	3,633	2,923	3,179	3,706	4,287	4,919	5,577	2,990	3,260	3,838	4,460	5,115	5,780
	Merchantable volume (ft ³)	2,559	2,769	3,011	3,509	4,023	4,560	5,052	2,768	3,004	3,475	3,966	4,696	5,225
	Basal area (ft ²)	181	87	100	115	131	148	163	92	106	123	140	157	173
	Stand density index	479	127	203	227	241	255	267	151	219	246	262	277	289
	Canopy cover (percent)	91	49	54	59	64	68	71	53	58	64	68	72	75
	Crown competition factor	242	68	77	90	102	114	125	76	87	102	115	128	139
	Canopy base height (ft)	3	14	19	3	5	7	8	13	15	3	5	7	8
	Canopy bulk density (kg/m ³)	0.42	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.07
Pile and burn	Trees per acre	2,144	50	336	331	264	217	183	100	379	372	302	250	211
	Quadratic mean diameter (in)	3.9	17.9	7.4	8.0	9.6	11.2	12.9	13.0	7.2	7.8	9.3	10.8	12.3
	Total volume (ft ³)	3,633	2,923	3,180	3,715	4,295	4,920	5,586	2,990	3,261	3,844	4,474	5,138	5,826
	Merchantable volume (ft ³)	2,559	2,769	3,012	3,512	4,034	4,534	5,027	2,768	3,004	3,488	3,991	4,703	5,267
	Basal area (ft ²)	181	87	100	116	132	149	165	92	106	124	141	159	175
	Stand density index	479	127	207	232	246	261	274	151	222	250	267	283	296
	Canopy cover (percent)	91	49	54	60	64	69	72	53	58	64	69	73	76
	Crown competition factor	242	68	77	91	103	116	127	76	87	103	117	130	142
	Canopy base height (ft)	3	14	19	3	5	7	8	13	15	3	5	7	8
	Canopy bulk density (kg/m ³)	0.42	0.04	0.04	0.05	0.05	0.05	0.06	0.05	0.05	0.06	0.06	0.06	0.07
Prescribed fire	Trees per acre	2,144	50	335	331	267	222	188	100	338	334	268	223	188
	Quadratic mean diameter (in)	3.9	17.9	6.6	7.1	8.5	10.1	11.7	13.0	6.7	7.2	8.6	10.2	11.8
	Total volume (ft ³)	3,633	2,574	2,753	3,120	3,548	4,075	4,697	2,601	2,786	3,166	3,602	4,146	4,774
	Merchantable volume (ft ³)	2,559	2,463	2,643	2,984	3,331	3,656	4,278	2,486	2,671	3,023	3,378	3,730	4,337
	Basal area (ft ²)	181	87	81	92	106	124	141	92	82	94	109	126	143
	Stand density index	479	127	174	193	208	226	243	151	177	197	211	229	246
	Canopy cover (percent)	91	49	45	50	56	61	66	53	46	51	57	62	66
	Crown competition factor	242	68	59	70	81	95	107	76	61	72	83	97	109
	Canopy base height (ft)	3	27	29	3	5	7	9	25	27	3	5	7	9
	Canopy bulk density (kg/m ³)	0.42	0.02	0.03	0.04	0.04	0.04	0.05	0.03	0.03	0.04	0.04	0.04	0.05

Table 16c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,144	200	433	418	345	289	246	300	504	479	397	334	285
	Quadratic mean diameter (in)	3.9	9.6	7.0	7.7	9.1	10.5	11.9	8.2	6.8	7.5	8.8	10.1	11.3
	Total volume (ft ³)	3,633	3,112	3,405	4,053	4,732	5,456	6,152	3,227	3,535	4,203	4,933	5,643	6,344
	Merchantable volume (ft ³)	2,559	2,760	2,984	3,429	3,826	4,786	5,528	2,753	2,960	3,353	3,732	4,494	5,655
	Basal area (ft ²)	181	100	117	137	155	174	189	109	127	148	168	185	200
	Stand density index	479	187	246	278	296	313	323	217	272	304	324	339	349
	Canopy cover (percent)	91	60	65	71	75	78	80	65	70	76	79	82	84
	Crown competition factor	242	91	104	123	138	152	163	106	121	141	158	171	181
	Canopy base height (ft)	3	13	14	3	4	6	8	13	15	3	5	6	8
	Canopy bulk density (kg/m ³)	0.42	0.10	0.09	0.09	0.09	0.09	0.09	0.15	0.12	0.12	0.12	0.12	0.12
Pile and burn	Trees per acre	2,144	200	459	443	365	304	258	300	528	502	415	348	294
	Quadratic mean diameter (in)	3.9	9.6	6.8	7.5	8.9	10.2	11.6	8.2	6.7	7.4	8.6	9.9	11.2
	Total volume (ft ³)	3,633	3,112	3,406	4,040	4,731	5,446	6,153	3,227	3,536	4,211	4,935	5,655	6,340
	Merchantable volume (ft ³)	2,559	2,760	2,984	3,415	3,836	4,786	5,585	2,753	2,960	3,359	3,716	4,716	5,636
	Basal area (ft ²)	181	100	117	137	156	174	190	109	127	149	169	186	200
	Stand density index	479	187	249	281	300	316	328	217	275	308	328	343	352
	Canopy cover (percent)	91	60	65	71	75	78	80	65	70	76	80	82	84
	Crown competition factor	242	91	105	123	139	152	163	106	122	142	159	172	181
	Canopy base height (ft)	3	13	14	3	4	6	8	13	15	3	5	6	8
	Canopy bulk density (kg/m ³)	0.42	0.10	0.09	0.09	0.09	0.09	0.09	0.15	0.12	0.12	0.12	0.12	0.12
Prescribed fire	Trees per acre	2,144	200	343	339	273	225	190	300	355	350	282	234	197
	Quadratic mean diameter (in)	3.9	9.6	6.8	7.3	8.7	10.3	11.9	8.2	6.8	7.3	8.8	10.3	12.0
	Total volume (ft ³)	3,633	2,650	2,847	3,255	3,724	4,296	4,934	2,702	2,913	3,353	3,858	4,435	5,094
	Merchantable volume (ft ³)	2,559	2,527	2,719	3,099	3,491	3,873	4,426	2,562	2,761	3,172	3,589	3,984	4,581
	Basal area (ft ²)	181	100	85	98	113	131	148	109	89	103	118	136	154
	Stand density index	479	187	183	203	218	237	253	217	190	213	229	247	263
	Canopy cover (percent)	91	60	47	53	58	63	68	65	49	55	60	65	69
	Crown competition factor	242	91	64	75	87	101	113	106	68	80	93	106	119
	Canopy base height (ft)	3	22	24	3	5	7	8	20	21	3	5	7	8
	Canopy bulk density (kg/m ³)	0.42	0.03	0.03	0.04	0.04	0.04	0.05	0.03	0.03	0.04	0.04	0.05	0.06

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 16d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	Years	No action						Prescribed fire only							
		Fuel models			Fuel models			Fuel models			Fuel models				
		Model	Weight	Percent	Model	Weight	Percent	Model	Weight	Percent	Model	Weight	Percent		
None	1	8	70	9	20	10	10	8	66	9	34	8	66	9	34
	10	10	84	8	12	9	4	10	85	8	10	9	85	8	10
	20	10	73	12	27			10	83	8	12	9	83	8	12
	30	12	52	10	48			10	88	8	9	9	88	8	9
	40	12	70	10	30			10	99	8	1	1	99	8	1
50	12	87	10	13			10	91	12	9	9	91	12	9	

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Years	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit							
		Fuel models			Fuel models			Fuel models			Fuel models				
		Model	Weight	Percent	Model	Weight	Percent	Model	Weight	Percent	Model	Weight	Percent		
None	1	12	89	10	11			12	84	10	16	12	84	10	16
	10	10	94	12	6			10	94	12	6	10	94	12	6
	20	10	69	8	16	9	14	2	72	8	16	9	72	8	16
	30	10	54	8	24	9	22	10	60	8	23	9	60	8	23
	40	10	55	8	23	9	22	10	64	8	20	9	64	8	20
50	10	65	9	18	8	17	10	76	8	13	9	76	8	13	
Pile and burn	1	10	55	2	24	8	12	10	51	8	18	10	51	8	18
	10	8	37	9	31	2	30	8	49	9	38	8	49	9	38
	20	8	52	9	46	2	2	8	54	9	41	10	54	9	41
	30	8	48	9	45	10	7	8	49	9	38	10	49	9	38
	40	9	40	8	40	10	19	8	40	9	32	10	40	9	32
50	10	35	9	34	8	31	10	46	8	30	9	46	8	30	
Prescribed fire	1	2	96	8	2	9	2	2	92	8	5	2	92	8	5
	10	2	77	8	13	9	11	2	72	8	15	2	72	8	15
	20	2	49	8	27	9	24	2	44	8	30	2	44	8	30
	30	8	39	9	37	2	21	8	41	9	38	2	41	9	38
	40	9	46	8	43	10	12	9	44	8	42	10	44	8	42
50	9	42	8	35	10	24	9	40	8	34	10	40	8	34	

Table 16d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit											
	Fuel models					Fuel models					Fuel models					Fuel models						
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	
None	1	12	72	10	28							12	58	10	42							
	10	10	96	12	4							10	99	12	1							
	20	10	77	8	14	9	9					10	78	8	14	9	7					
	30	10	71	8	18	9	11					10	79	8	14	9	7					
	40	10	80	8	12	9	7					10	93	8	5	9	2					
50	10	97	8	2	9	1					10	92	12	8								
Pile and burn	1	10	44	8	33	9	22	2	1			8	40	10	36	9	23					
	10	8	57	9	36	10	7					8	59	9	32	10	9					
	20	8	54	9	33	10	12					8	53	9	28	10	19					
	30	8	47	9	28	10	25					8	43	10	35	9	21					
	40	10	43	8	36	9	21					10	57	8	29	9	14					
50	10	64	8	23	9	13					10	81	8	13	6							
Prescribed fire	1	2	84	8	8	9	7					2	76	8	13	9	11					
	10	2	57	8	18	9	15	10	10			2	42	10	21	8	20					
	20	2	34	8	32	9	27	10	7			8	35	9	30	2	21					
	30	8	43	9	39	10	9	2	8			8	44	9	40	10	15					
	40	9	42	8	41	10	18					9	38	8	38	10	24					
50	9	37	8	32	10	31					10	39	9	33	8	29						

tpa = trees per acre, d.b.h. = diameter at breast height.

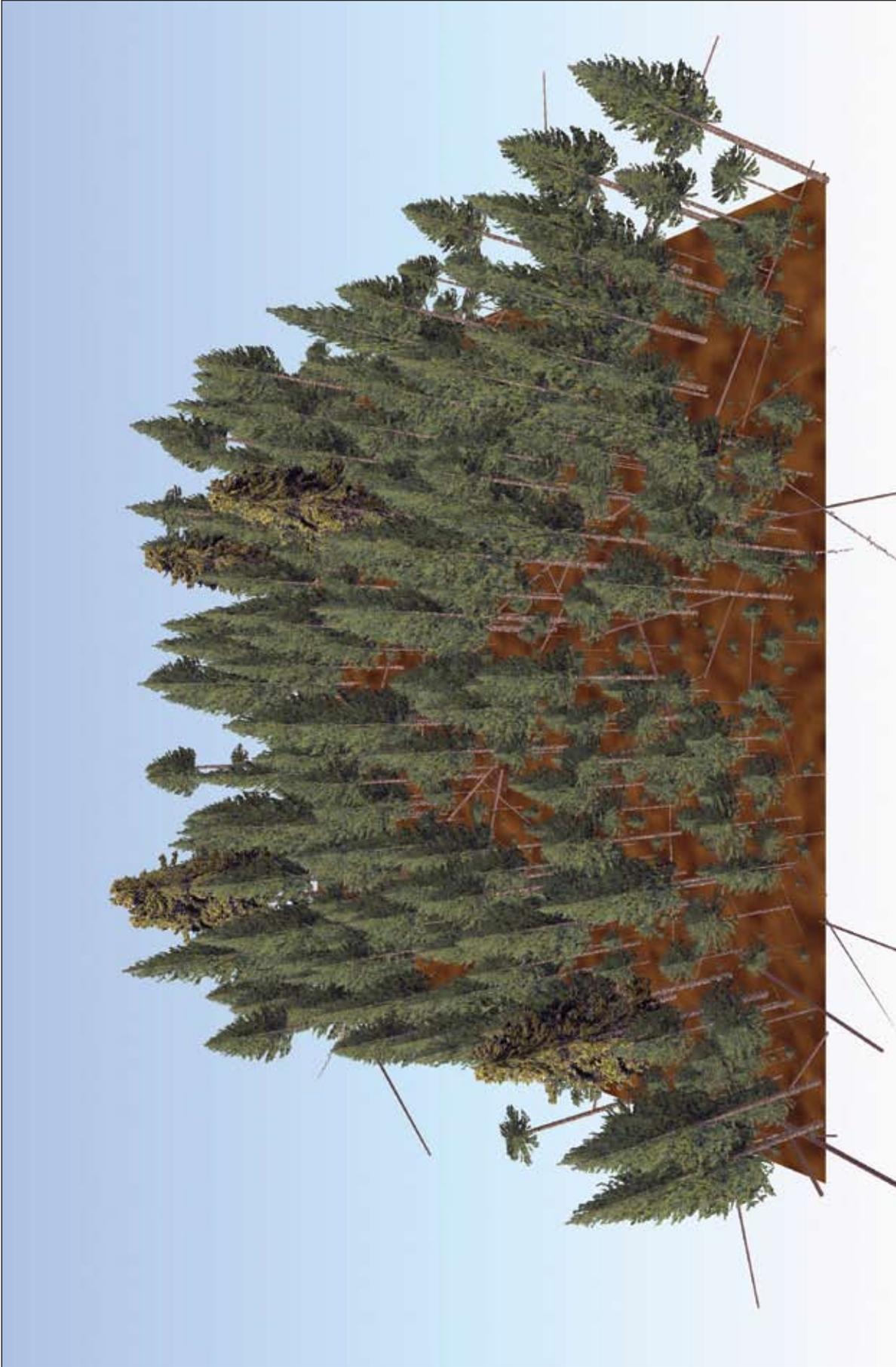
Table 16e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					Live
			1-hr (0-0.25 in)	10-hr (0.25-1 in)	100-hr (1-3 in)	1,000-hr (3+ in)	Duff	
Severe—98 th percentile	20	85	3	5	10	15	50	100
Moderate—75 th percentile	11	69	6	8	15	18	125	150

Table 16f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

Site: Elevation = 5,100 ft, slope = 10 percent, aspect = 180°.

Species (based on trees per acre): Hardwoods = 56 percent, white fir (*Abies concolor*) = 43 percent, ponderosa pine (*Pinus ponderosa*) = 1 percent.

Stand attributes: Stem density = 1,427 tpa, basal area = 272 ft²/ac, top height = 85 ft, stand density index = 614, quadratic mean diameter = 5.9 in, crown competition factor = 169, canopy cover = 82 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has 1,427 trees per acre (tpa) composed primarily of white fir and hardwoods with a low-density ponderosa pine overstory. Canopy bulk density is 0.23 kg/m³ (0.0144 lb/ft³), and canopy base height is 6 ft, so ladder fuels and canopy fuels are not sufficient to enable crown fire initiation or spread. Woody fuel loading is 14 tons/ac and litter and duff loading is 20 tons/ac. Potential flame lengths are less than 2 ft and potential basal area mortality is about 35 percent for moderate and severe fire weather. For the 50-year projection, canopy base height increases as the trees grow, and canopy bulk density declines as the stand self-thins, but surface fuels accumulate rapidly contributing to higher flame lengths. In 20 years, predicted flame lengths are 7 ft and fire type is passive crown fire for severe fire weather. Surface fire is predicted again at 40 years owing to higher canopy base height, but predicted flame lengths are 6 and 8 ft for moderate and severe fire weather, respectively.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment increases canopy base height and decreases canopy bulk density and surface fuel loading, which reduces crown fire potential and flame lengths, but many snags are created, contributing to high surface fuel loading and increased crown fire potential in 10 years. The low density (50 and 100 tpa) thinning treatments create similar stand structures; both raise canopy base height and reduce canopy bulk density. The high-density treatments (200 and 300 tpa) also raise canopy base height but have little effect on canopy bulk density. All thinning treatments increase surface fuel loading; the greater the thinning the greater the surface fuel loading, so thinning without surface fuel treatment increases potential flame lengths and basal area mortality despite the changes in canopy base height. Surface fuel treatments are critical to reducing flame lengths and crown fire potential in this stand. The pile and burn treatment reduces surface fuels, but the lower density treatments still have higher surface fuel loadings and potential flame lengths than the initial conditions. In the higher density treatments, the pile and burn treatment decreases surface fuels and potential flame lengths to below that of the initial conditions. Prescribed fire reduces all size classes of surface fuels more than the pile and burn, but fuel model selection is not sensitive to this difference in surface fuel loading, so flame lengths and potential mortality are similar for the surface fuel treatment options.

Silvicultural and surface fuel treatments—long-term effects

Regeneration in the more open stands (50 and 100 tpa) causes canopy base height to decrease and crown fire potential to increase in 30 or 40 years, but passive crown fire is predicted only in the 50 tpa treatment with no surface fuel treatment because of higher flame lengths from residual activity fuels. Surface fire is the predicted fire type for the 50-year trajectory in all other treatments, but without further treatment, surface fuels accumulate and potential flame lengths increase over time.

Table 17a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	0-3 in	1	23	18	12	9
		3-6 in	1	8	9	9	8
	>12 in	6-12 in	2	5	6	6	5
		>12 in	0	0	0	0	0
	Flame length (ft)	Litter	4	1	1	2	3
		Duff	16	11	15	19	18
	Torching index	Moderate	1	1	6	3	2
		Severe	2	1	8	5	3
	Crowning index	Severe	125	456	24	36	51
		Severe	14	18	30	18	15
Potential basal area mortality (%)	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface
Pile and burn	Surface fuel loadings (tons/ac)	0-3 in	6	6	4	3	2
		3-6 in	2	2	3	3	2
	>12 in	6-12 in	1	1	2	2	2
		>12 in	0	0	0	0	0
	Flame length (ft)	Litter	1	1	1	2	3
		Duff	13	13	17	17	16
	Torching index	Moderate	2	2	1	1	1
		Severe	2	2	2	2	1
	Crowning index	Severe	218	218	410	410	687
		Severe	30	30	18	15	14
Potential basal area mortality (%)	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface
Prescribed fire	Surface fuel loadings (tons/ac)	0-3 in	0	0	0	0	0
		3-6 in	2	2	2	2	2
	>12 in	6-12 in	3	3	4	3	3
		>12 in	0	0	0	0	0
	Flame length (ft)	Litter	1	1	1	2	2
		Duff	10	10	13	13	12
	Torching index	Moderate	1	1	1	2	1
		Severe	1	1	1	2	1
	Crowning index	Severe	494	494	521	358	651
		Severe	32	32	21	18	18
Potential basal area mortality (%)	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 17b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	4	15	31	42	46	45	1	16	19	21	24	27
	0–3 in	5	5	7	10	12	14	1	8	7	7	8	8
	3–6 in	5	5	8	12	17	21	2	11	12	12	13	14
	6–12 in	0	1	2	4	6	9	0	2	4	6	6	8
	>12 in	4	4	4	4	3	3	2	2	3	3	3	3
	Litter	16	16	16	17	17	17	11	11	11	11	12	12
	Duff	1	3	5	6	6	6	1	4	5	5	5	6
	Moderate	2	4	7	8	8	8	1	6	6	7	7	8
	Severe	125	13	5	5	13	27	456	5	10	19	28	29
	Severe	14	14	14	14	15	16	18	18	20	20	19	20
None	Surface fuel loadings (tons/ac)	196	301	265	183	182	120	367	52	45	39	34	56
	0–17.9 in	1	1	3	4	8	13	3	3	3	3	5	10
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface
	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe
	Flame length (ft)	15	15	14	14	14	14	19	19	19	18	18	18
	Moderate	6	5	4	3	3	3	5	4	4	4	4	4
	Severe	8	7	5	5	4	4	6	6	5	5	5	6
	Severe	24	37	53	7	25	66	36	52	70	85	96	100
None	Surface fuel loadings (tons/ac)	30	34	35	35	35	34	18	21	23	22	22	22
	0–3 in	37	29	12	6	5	6	39	32	15	9	14	23
	3–6 in	1	2	2	2	2	3	1	1	1	2	6	11
	6–12 in	0	0	0	0	0	0	0	0	0	0	0	0
	>12 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Litter	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Duff	15	15	14	14	14	14	19	19	19	18	18	18
	Moderate	6	5	4	3	3	3	5	4	4	4	4	4
	Severe	8	7	5	5	4	4	6	6	5	5	5	6
	Severe	24	37	53	7	25	66	36	52	70	85	96	100
None	Surface fuel loadings (tons/ac)	30	34	35	35	35	34	18	21	23	22	22	22
	0–17.9 in	37	29	12	6	5	6	39	32	15	9	14	23
	18–29.9 in	1	2	2	2	2	3	1	1	1	2	6	11
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe
	Flame length (ft)	15	15	14	14	14	14	19	19	19	18	18	18
	Moderate	6	5	4	3	3	3	5	4	4	4	4	4
	Severe	8	7	5	5	4	4	6	6	5	5	5	6
	Severe	24	37	53	7	25	66	36	52	70	85	96	100

Table 17b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
Pile and burn	Surface fuel loadings (tons/ac)	6	6	6	6	7	8	4	6	8	10	13	17	
	0–3 in													
	3–6 in	2	2	2	2	2	2	3	2	2	2	2	3	
	6–12 in	1	2	2	2	2	2	2	2	2	3	3	4	
	>12 in	0	1	1	2	2	2	0	1	1	2	3	4	
	Litter	1	1	1	1	1	1	1	1	2	2	2	2	
	Duff	13	13	13	13	12	12	17	17	17	16	16	16	
	Moderate	2	1	2	2	2	2	1	1	2	2	3	4	
	Severe	2	2	2	2	3	3	2	2	3	3	4	5	
	Severe	218	269	286	38	69	128	410	285	219	172	36	112	
Crowning index	Surface	30	34	35	35	34	34	18	21	22	22	22	22	
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface		
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface		
	Severe	37	29	13	7	6	6	39	32	16	10	17	24	
	0–17.9 in	1	2	2	3	2	3	1	1	1	2	6	10	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in													
	Prescribed fire	Surface fuel loadings (tons/ac)	0	3	4	4	5	7	0	5	7	8	10	12
		0–3 in												
		3–6 in	2	2	2	2	2	2	3	3	3	3	3	2
6–12 in		3	3	4	3	3	3	4	5	6	6	6	5	
>12 in		0	1	2	3	3	3	0	2	4	5	5	5	
Litter		1	1	1	1	1	1	1	1	1	1	2	2	
Duff		10	10	10	10	10	10	17	13	13	13	13	13	
Moderate		6	1	1	2	2	2	5	2	2	2	3	3	
Severe		8	1	2	2	2	3	6	2	3	4	4	4	
Severe		24	599	377	43	78	90	36	237	135	20	34	41	
Crowning index	Surface	30	37	39	38	38	37	18	25	26	26	25	25	
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface		
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface		
	Severe	38	27	19	9	7	7	61	44	26	10	8	14	
	0–17.9 in	3	3	3	2	2	2	3	3	2	3	2	6	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in													

Table 17b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	12	14	19	24	30	34	9	15	23	30	35	38
	0–3 in												
	3–6 in	9	8	7	7	8	10	8	7	7	8	11	14
	6–12 in	6	5	6	9	13	20	5	5	7	10	16	25
	>12 in	0	1	1	3	6	11	0	1	1	3	6	10
	Litter	2	3	3	3	3	2	3	3	3	3	3	2
	Duff	19	19	19	19	19	19	18	18	18	18	18	18
	Flame length (ft)	3	3	4	5	6	6	2	3	4	4	5	6
	Moderate												
	Severe	5	5	5	6	8	9	3	4	6	7	8	9
	Torching index	51	91	108	116	87	69	89	124	137	109	89	81
	Crowning index	15	17	17	17	19	19	14	15	15	15	17	18
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	40	33	33	43	59	73	46	52	45	57	78	83
0–17.9 in													
18–29.9 in	1	1	2	4	14	15	1	1	2	2	11	13	
30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
Pile and burn	Surface fuel loadings (tons/ac)	3	8	15	22	27	31	2	10	20	28	34	37
	0–3 in												
	3–6 in	3	2	3	4	5	7	2	2	3	5	8	11
	6–12 in	2	2	3	6	11	18	2	2	4	8	15	23
	>12 in	0	1	1	3	6	11	0	1	1	3	6	10
	Litter	2	3	3	3	3	2	3	3	3	3	3	2
	Duff	17	17	17	17	17	17	16	16	16	16	16	16
	Flame length (ft)	1	2	3	4	5	6	1	2	4	5	6	6
	Moderate												
	Severe	1	2	4	6	7	9	1	2	5	7	8	9
	Torching index	687	319	157	133	100	66	827	315	154	131	89	79
	Crowning index	15	17	17	17	19	21	14	15	15	15	18	19
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Hard snags (stems/ac)	40	33	33	41	62	72	46	52	45	59	77	83	
0–17.9 in													
18–29.9 in	1	1	2	4	15	16	1	1	2	2	11	13	
30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 17b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	9	12	14	17	21	0	12	15	17	20	24
	0–3 in	2	5	5	5	5	5	2	7	6	6	6	7
	3–6 in	3	11	11	11	11	12	3	12	12	12	13	14
	6–12 in	0	2	4	5	6	8	0	2	4	5	6	8
	>12 in	2	2	2	2	2	2	2	2	2	2	2	2
Flame length (ft)	Litter	13	13	13	13	13	13	12	12	12	12	12	12
	Duff	2	3	4	4	4	5	1	4	4	4	5	5
	Moderate	2	4	5	5	6	7	1	5	6	6	7	7
Torching index	Severe	358	83	76	90	18	99	651	72	80	90	101	96
	Severe	18	20	22	21	21	21	18	19	20	20	20	20
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Hard snags (stems/ac)	0–17.9 in	79	50	27	18	27	40	97	50	24	27	28	29
	18–29.9 in	3	3	2	3	5	12	3	3	2	3	5	7
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 17c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	1,427	1,095	840	676	507	427	286	281	261	235	214	176
	Quadratic mean diameter (in)	5.9	7.1	8.3	9.5	11.0	12.0	5.9	12.0	13.5	15.2	16.7	18.7
	Total volume (ft ³)	6,334	8,840	10,724	12,336	13,387	14,296	5,555	6,836	9,303	11,577	13,819	14,896
	Merchantable volume (ft ³)	4,801	7,090	8,891	10,446	11,641	12,562	4,647	5,822	8,077	10,206	12,348	13,517
	Basal area (ft ²)	272	301	318	332	334	334	198	220	260	294	327	334
	Stand density index	614	631	626	621	590	571	347	376	423	458	489	479
	Canopy closure (percent)	82	81	80	78	75	73	59	61	64	65	66	63
	Crown competition factor	169	168	160	151	139	129	89	94	102	105	108	99
	Canopy base height (ft)	6	5	9	11	15	23	15	6	10	15	21	25
	Canopy bulk density (kg/m ³)	0.23	0.22	0.23	0.24	0.22	0.19	0.17	0.17	0.15	0.15	0.15	0.15

Table 17c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	1,427	50	98	96	94	92	89	100	122	118	114	108	98
	Quadratic mean diameter (in)	5.9	19	15.3	17.3	19.2	21.1	22.7	16.8	17.1	19.2	21.1	23.0	25.0
	Total volume (ft ³)	6,334	3,478	4,246	5,820	7,538	9,409	11,130	5,214	6,381	8,771	11,173	13,284	14,968
	Merchantable volume (ft ³)	4,801	3,151	3,869	5,352	6,961	8,698	10,271	4,637	5,731	8,006	10,280	12,260	13,871
	Basal area (ft ²)	272	98	126	156	188	222	251	155	194	237	279	311	333
	Stand density index	614	140	196	231	267	303	333	231	288	336	380	410	426
	Canopy cover (percent)	82	25	28	33	37	41	45	41	45	49	52	55	55
	Crown competition factor	169	28	33	40	46	53	60	53	60	67	74	79	80
	Canopy base height (ft)	6	26	29	32	5	10	22	25	29	34	38	42	46
Canopy bulk density (kg/m ³)	0.23	0.09	0.07	0.07	0.07	0.07	0.07	0.17	0.13	0.12	0.12	0.13	0.12	
Pile and burn	Trees per acre	1,427	50	124	121	117	114	110	100	135	131	127	118	107
	Quadratic mean diameter (in)	5.9	19.0	13.6	15.4	17.2	18.9	20.4	16.8	16.2	18.2	20.1	22.0	23.9
	Total volume (ft ³)	6,334	3,478	4,246	5,818	7,539	9,395	11,109	5,214	6,381	8,776	11,169	13,245	14,944
	Merchantable volume (ft ³)	4,801	3,151	3,869	5,332	6,962	8,684	10,270	4,637	5,731	8,010	10,279	12,238	13,816
	Basal area (ft ²)	272	98	126	156	188	222	250	155	194	237	279	310	333
	Stand density index	614	140	205	242	279	316	346	231	294	343	388	417	433
	Canopy cover (percent)	82	25	28	33	37	41	44	41	45	49	52	55	55
	Crown competition factor	169	28	33	39	46	53	58	53	60	67	74	79	80
	Canopy base height (ft)	6	26	29	32	5	10	22	25	29	35	38	13	47
Canopy bulk density (kg/m ³)	0.23	0.09	0.07	0.07	0.07	0.07	0.07	0.17	0.13	0.12	0.12	0.13	0.13	
Prescribed fire	Trees per acre	1,427	50	192	186	181	176	170	100	144	139	135	131	122
	Quadratic mean diameter (in)	5.9	19.0	10.3	11.6	13.1	14.4	15.7	16.8	14.4	16.2	18.0	19.8	21.5
	Total volume (ft ³)	6,334	3,035	3,697	5,064	6,702	8,245	9,970	4,320	5,328	7,373	9,514	11,860	13,711
	Merchantable volume (ft ³)	4,801	2,750	3,371	4,645	6,206	7,582	9,121	3,863	4,825	6,724	8,754	10,955	12,678
	Basal area (ft ²)	272	98	110	136	168	198	228	155	162	200	238	279	307
	Stand density index	614	140	200	236	277	314	350	231	257	302	346	391	416
	Canopy cover (percent)	82	25	25	30	35	40	44	41	38	42	46	50	52
	Crown competition factor	169	28	29	36	44	51	58	53	47	54	62	70	74
	Canopy base height (ft)	6	30	34	34	5	10	21	25	29	33	7	12	24
Canopy bulk density (kg/m ³)	0.23	0.08	0.06	0.06	0.06	0.06	0.06	0.14	0.11	0.10	0.10	0.11	0.11	

Table 17c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	1,427	200	207	190	168	139	106	300	289	258	216	168	121
	Quadratic mean diameter (in)	5.9	14.1	15.3	17.1	19.1	21.0	24.0	12.2	13.5	15.1	17.0	19.1	22.5
	Total volume (ft ³)	6,334	6,964	8,531	11,267	13,418	14,416	15,019	7,501	8,952	11,627	13,623	14,244	14,912
	Merchantable volume (ft ³)	4,801	5,986	7,465	10,034	12,139	13,130	13,845	6,193	7,580	10,162	12,195	12,939	13,738
	Basal area (ft ²)	272	217	266	305	332	333	334	245	286	321	342	333	333
	Stand density index	614	348	412	452	472	456	433	414	466	500	509	474	444
	Canopy cover (percent)	82	63	66	68	67	65	58	71	73	73	70	66	59
	Crown competition factor	169	98	109	113	110	106	87	124	129	131	122	109	89
	Canopy base height (ft)	6	20	32	40	49	51	51	20	36	46	53	56	57
	Canopy bulk density (kg/m ³)	0.23	0.21	0.18	0.18	0.18	0.16	0.15	0.23	0.21	0.20	0.21	0.17	0.16
Pile and burn	Trees per acre	1,427	200	214	196	173	141	109	300	296	265	221	172	125
	Quadratic mean diameter (in)	5.9	14.1	15.1	16.9	18.8	20.8	23.6	12.2	13.3	14.9	16.8	18.8	22.1
	Total volume (ft ³)	6,334	6,964	8,531	11,262	13,421	14,367	14,974	7,501	8,952	11,617	13,564	14,242	14,920
	Merchantable volume (ft ³)	4,801	5,986	7,465	10,031	12,134	13,089	13,794	6,193	7,580	10,151	12,189	12,932	13,712
	Basal area (ft ²)	272	217	266	305	333	332	332	245	286	320	341	333	334
	Stand density index	614	348	415	455	476	456	434	414	468	502	509	476	447
	Canopy cover (percent)	82	63	66	68	67	65	58	71	73	73	70	67	60
	Crown competition factor	169	98	109	113	111	106	88	124	129	131	121	110	90
	Canopy base height (ft)	6	20	32	41	49	51	51	20	36	47	54	56	57
	Canopy bulk density (kg/m ³)	0.23	0.21	0.18	0.18	0.18	0.15	0.14	0.23	0.21	0.21	0.21	0.17	0.15
Prescribed fire	Trees per acre	1,427	200	169	164	154	139	119	300	199	196	175	159	143
	Quadratic mean diameter (in)	5.9	14.1	14.8	16.6	18.5	20.5	22.6	12.2	14.0	15.6	17.6	19.4	21.2
	Total volume (ft ³)	6,334	5,287	6,550	9,142	11,651	13,740	15,029	5,495	6,798	9,516	11,798	13,966	15,857
	Merchantable volume (ft ³)	4,801	4,621	5,800	8,224	10,603	12,603	13,864	4,720	5,943	8,482	10,698	12,762	14,585
	Basal area (ft ²)	272	217	202	247	289	320	333	245	213	259	294	325	351
	Stand density index	614	348	318	370	415	442	442	414	342	399	431	459	478
	Canopy cover (percent)	82	63	51	56	58	59	58	71	56	60	61	62	63
	Crown competition factor	169	98	72	81	88	90	87	124	82	93	95	98	98
	Canopy base height (ft)	6	23	31	34	39	13	50	23	32	36	40	47	52
	Canopy bulk density (kg/m ³)	0.23	0.16	0.14	0.13	0.13	0.14	0.13	0.17	0.16	0.14	0.14	0.15	0.15

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 17d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only								
	Fuel models			Fuel models			Fuel models			Fuel models					
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight
None	1	8	80	10	20	Percent	8	100			Percent				
	10	10	83	12	17		12	71	10	29					
	20	12	51	13	49		12	99	10	1					
	30	13	100				12	85	13	15					
	40	13	100				12	63	13	37					
50	13	100				13	67	12	33						

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit								
	Fuel models			Fuel models			Fuel models			Fuel models					
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight
None	1	12	97	10	3	Percent	12	71	10	29	Percent				
	10	12	54	10	46		10	53	12	47					
	20	10	73	12	27		10	62	12	38					
	30	10	90	12	10		10	63	12	37					
	40	10	99	12	1		10	57	12	43					
50	10	99	8	1		12	65	10	35						
Pile and burn	1	8	81	10	19		8	91	10	9					
	10	8	82	10	18		8	73	10	27					
	20	8	77	10	23		10	53	8	47					
	30	8	70	10	30		10	78	8	22					
	40	8	61	10	39		10	93	12	7					
50	10	51	8	49		10	59	12	41						
Prescribed fire	1	8	100				8	100							
	10	8	100				8	69	10	31					
	20	8	86	10	14		10	73	8	27					
	30	8	76	10	24		10	93	8	7					
	40	8	67	10	33		10	98	12	2					
50	8	51	10	49		10	83	12	17						

Table 17d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit						Thin from below to 300 tpa, 18-in. d.b.h. limit									
	Fuel models			Fuel models			Fuel models			Fuel models						
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent
None	1	10	70	12	30		10	97	12	3		10	97	12	3	
	10	10	64	12	36		10	69	12	31		10	69	12	31	
	20	12	63	10	37		12	93	10	7		12	93	10	7	
	30	12	87	13	13		13	57	12	43		13	57	12	43	
	40	13	69	12	31		13	100				13	100			
50	13	100				13	100				13	100				
Pile and burn	1	8	100				8	100				8	100			
	10	8	56	10	44		10	60	8	40		10	60	8	40	
	20	10	89	12	11		12	53	10	47		12	53	10	47	
	30	12	77	10	23		12	74	13	26		12	74	13	26	
	40	12	60	13	40		13	100				13	100			
50	13	100				13	100				13	100				
Prescribed fire	1	8	81	6	19		8	100				8	100			
	10	10	87	12	13		10	58	12	42		10	58	12	42	
	20	10	57	12	43		12	70	10	30		12	70	10	30	
	30	12	53	10	47		12	83	10	17		12	83	10	17	
	40	12	80	10	20		12	89	13	11		12	89	13	11	
50	12	86	13	14		12	58	13	42		12	58	13	42		

tpa = trees per acre, d.b.h. = diameter at breast height.

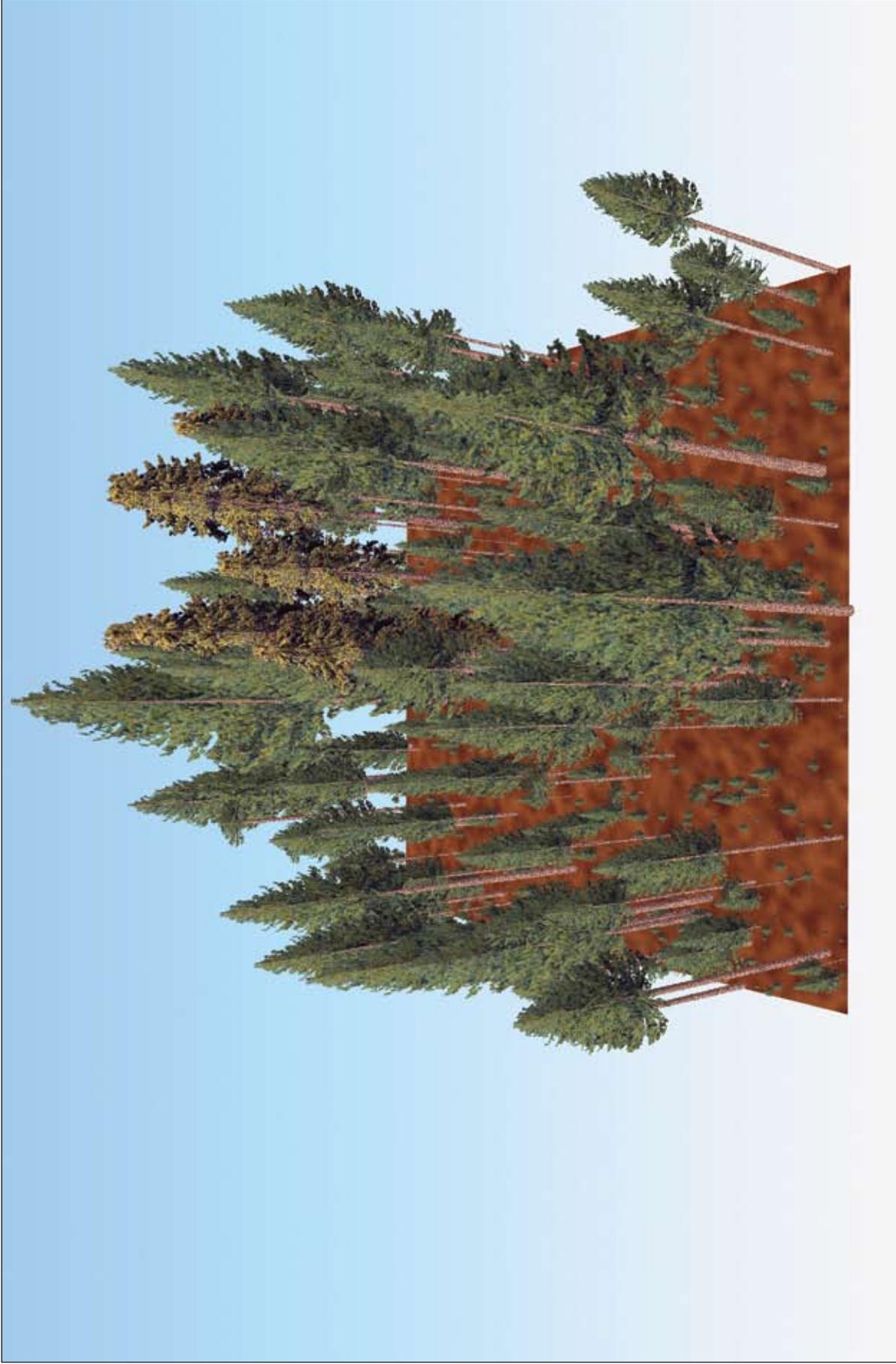
Table 17e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Live	
Severe—98 th percentile	12	97	3	4	7	15	125	100
Moderate—75 th percentile	8	72	5	7	10	23	125	150

Table 17f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

Site: Elevation = 5,000 ft, slope = 30 percent, aspect = 225°.

Species (based on trees per acre): White fir (*Abies concolor*) = 77 percent, hardwoods = 13 percent, sugar pine (*Pinus lambertiana*) = 8 percent, ponderosa pine (*Pinus ponderosa*) = 1 percent.

Stand attributes: Stem density = 776 tpa, basal area = 291 ft²/ac, top height = 119 ft, stand density index = 575, quadratic mean diameter = 8.3 in, crown competition factor = 85, canopy cover = 60 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has 776 trees per acre (tpa) composed primarily of white fir and hardwood understory with ponderosa pine and sugar pine overstory. Canopy bulk density is 0.07 kg/m³ (0.0044 lb/ft³), and canopy base height is 2 ft, so ladder fuels are sufficient to enable passive crown fire, but crown fire spread is unlikely. Woody fuel loading is 18 tons/ac, and litter and duff loading is 16 tons/ac. Potential flame lengths are 5 ft, and potential basal area mortality is 95 percent for severe fire. With no action, canopy base height increases and canopy bulk density decreases rapidly as trees grow. In 30 years, passive crown fire is unlikely for moderate and severe fire weather. Surface fuels also accumulate rapidly, and in 50 years, flame lengths are 8 ft and 12 ft for moderate and severe fire weather respectively.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment raises canopy base height and reduces crown fire potential and flame lengths, but creates many snags that contribute to higher surface fuel loading in 10 years. In the short term, the lower density thinning treatments (50 and 100 tpa) effectively raise canopy base height, reducing crown fire potential, but potential flame lengths are higher than initial conditions because of activity fuels from the treatment. The 200 tpa treatment does not reduce canopy bulk density and only slightly increases canopy base height; the predicted fire type remains passive crown fire, and potential basal area mortality is 95 percent for severe fire weather. The 300 tpa treatment is not sufficient to affect canopy base height or canopy bulk density, so crown fire potential remains similar to initial conditions. The low-density treatments increase surface fuels slightly, but flame lengths remain similar to initial conditions, and the higher density treatments have little effect on surface fuels. The pile and burn treatment and, to a greater extent the prescribed fire treatment, reduce surface fuels and flame lengths to below initial conditions. The prescribed fire treatment reduces crown fire potential more than thinning alone because fire-caused mortality of small trees further increase canopy base height.

Silvicultural and surface fuel treatments—long-term effects

In the prescribed fire only treatment, crown fire potential increases slightly over time as surface fuels accumulate, but the predicted fire type is surface fire for 50 years, and potential flame lengths remain lower than the no-action trajectory. Surface fuels accumulate rapidly in the low-density treatments without surface fuel treatment, and flame lengths exceed 10 ft in 20 years, but canopy base height also increases as the trees grow and the stand continues to self-thin. Canopy base height remains high in relation to flame lengths in the 50 tpa treatment with a pile and burn, and in the 100 tpa treatment with no surface fuel treatment and pile and burn. The predicted fire type is surface fire for the 50-year projection. In the 50 tpa treatment without surface fuel treatment, the combination of regeneration and high activity fuels creates conditions conducive to passive crown fire in 20 years. Regeneration causes a decrease in canopy base height in the 50 tpa and 100 tpa treatments with prescribed fire in 20 years, and passive crown fire is the predicted fire type for severe and moderate fire weather. In the higher density treatments, canopy base height increases in 10 years and the predicted fire type becomes surface fire and remains surface fire for the 50-year projection.

Table 18a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	0-3 in	1	6	4	3	3
		3-6 in	1	6	7	7	7
	>12 in	6-12 in	4	7	7	8	8
		>12 in	0	0	0	0	0
	Flame length (ft)	Litter	1	1	1	1	1
		Duff	15	10	14	14	15
	Torching index	Moderate	3	1	2	3	3
		Severe	5	2	4	5	5
	Crowning index	Severe	0	557	203	0	0
		Severe	30	38	36	30	30
Type of fire	Moderate	Passive	Surface	Surface	Surface	Surface	Passive
	Severe	Passive	Surface	Surface	Surface	Surface	Passive
Potential basal area mortality (%)	Moderate	31	9	8	11	13	31
	Severe	95	9	8	12	94	95
Pile and burn	Surface fuel loadings (tons/ac)	0-3 in		2	1	1	1
		3-6 in		2	2	2	2
	>12 in	6-12 in		2	2	2	2
		>12 in		0	0	0	0
	Flame length (ft)	Litter		1	1	1	1
		Duff		12	13	13	13
	Torching index	Moderate		1	1	3	3
		Severe		1	1	5	5
	Crowning index	Severe		736	761	0	0
		Severe		36	30	30	30
Type of fire	Moderate		Surface	Surface	Surface	Surface	Passive
	Severe		Surface	Surface	Surface	Surface	Passive
Potential basal area mortality (%)	Moderate		8	11	13	31	
	Severe		8	11	94	95	
Prescribed fire	Surface fuel loadings (tons/ac)	0-3 in		0	0	0	0
		3-6 in		2	2	2	2
	>12 in	6-12 in		4	4	4	4
		>12 in		0	0	0	0
	Flame length (ft)	Litter		1	1	1	1
		Duff		9	10	10	10
	Torching index	Moderate		1	1	1	1
		Severe		2	1	1	2
	Crowning index	Severe		686	752	753	563
		Severe		39	34	34	38
Type of fire	Moderate		Surface	Surface	Surface	Surface	Surface
	Severe		Surface	Surface	Surface	Surface	Surface
Potential basal area mortality (%)	Moderate		7	9	9	9	
	Severe		7	9	9	9	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 18b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	3	9	19	25	27	28	1	8	10	11	14	15
	0–3 in	7	7	8	8	7	8	1	3	3	3	3	3
	3–6 in	8	9	11	12	13	13	4	7	9	8	8	9
	6–12 in	0	4	10	18	25	33	0	6	14	17	21	28
	>12 in	1	2	2	2	1	1	1	1	1	1	1	1
	Litter	15	15	15	15	15	15	10	10	10	10	10	10
	Duff	3	4	6	8	8	8	1	3	5	5	6	7
	Moderate	5	5	9	11	11	12	2	5	7	8	9	10
	Severe	0	0	0	13	24	37	557	134	109	124	142	129
	Severe	30	19	19	23	29	46	38	41	40	43	48	53
Flame length (ft)	Moderate	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Torching index	185	221	230	209	172	140	245	58	32	30	40	38
	Crowning index	21	25	32	32	34	33	30	27	22	24	31	31
	Type of fire	7	8	10	13	15	15	11	10	9	10	12	14
	Hard snags (stems/ac)												
	0–17.9 in												
	18–29.9 in												
	30–36 in												
None	Surface fuel loadings (tons/ac)	6	8	10	13	17	18	4	8	13	16	19	20
	0–3 in	6	6	6	5	6	6	7	7	7	7	7	7
	3–6 in	7	7	7	7	8	8	7	8	9	11	12	12
	6–12 in	0	3	6	10	15	23	0	3	9	16	24	32
	>12 in	1	1	1	1	1	1	1	1	1	1	1	1
	Litter	13	13	13	13	12	12	14	14	14	14	13	13
	Duff	3	3	4	5	6	7	2	3	5	7	8	8
	Moderate	4	5	6	7	9	10	4	5	8	9	11	11
	Severe	137	146	0	122	129	134	203	130	97	92	80	85
	Torching index	36	37	40	45	49	59	30	34	39	45	47	51
Flame length (ft)	Severe	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Crowning index	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Type of fire	61	44	33	40	45	39	68	67	60	57	54	46
	Hard snags (stems/ac)	14	14	19	27	26	33	16	21	29	33	34	35
	0–17.9 in												
	18–29.9 in												
	30–36 in												

Table 18b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	2	5	9	13	16	19	1	6	12	17	18	19
	0–3 in	2	5	9	13	16	19	1	6	12	17	18	19
	3–6 in	2	2	3	3	4	4	2	3	4	5	5	5
	6–12 in	2	3	4	4	5	6	2	3	6	8	9	10
	>12 in	0	2	6	10	14	22	0	3	9	16	24	32
	Litter	1	1	1	1	1	1	1	1	1	1	1	1
	Duff	12	12	11	11	11	11	13	12	12	12	12	12
	Moderate	1	2	3	5	6	7	1	2	4	6	7	8
	Severe	1	3	5	7	8	10	1	3	6	9	10	11
	Severe	736	508	205	132	161	145	761	375	109	105	93	93
	Severe	36	35	38	40	50	53	30	34	38	41	43	47
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Prescribed fire	Surface fuel loadings (tons/ac)	0	5	8	12	15	17	0	6	10	15	17	19
	0–3 in	0	5	8	12	15	17	0	6	10	15	17	19
	3–6 in	2	3	3	3	3	3	2	3	3	5	5	5
	6–12 in	4	5	6	6	5	6	4	7	8	9	9	10
	>12 in	0	4	9	12	15	19	0	4	10	15	22	28
	Litter	1	1	1	1	1	1	1	1	1	1	1	1
	Duff	9	9	9	9	9	9	13	10	10	10	10	10
	Moderate	1	2	4	5	6	6	1	3	4	6	7	7
	Severe	2	3	5	7	8	9	1	4	6	8	10	10
	Severe	686	332	0	31	50	151	752	210	0	6	21	26
	Severe	39	38	40	40	44	44	34	33	37	40	45	48
	Moderate	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface
Pile and burn	Surface fuel loadings (tons/ac)	57	40	36	36	46	57	69	47	57	61	51	53
	0–17.9 in	57	40	36	36	46	57	69	47	57	61	51	53
	18–29.9 in	22	20	20	17	23	29	22	20	25	24	33	30
	>30 in	8	7	8	8	11	15	8	7	9	12	14	14
	Severe	8	7	8	8	11	15	8	7	9	12	14	14
	Severe	8	7	8	8	11	15	8	7	9	12	14	14
	Moderate	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface
	Severe	57	40	36	36	46	57	69	47	57	61	51	53
	Hard snags (stems/ac)	22	20	20	17	23	29	22	20	25	24	33	30
	18–29.9 in	22	20	20	17	23	29	22	20	25	24	33	30
	30–36 in	8	7	8	8	11	15	8	7	9	12	14	14

Table 18b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	0–3 in	3	8	15	19	23	23	3	8	15	21	22	25
		3–6 in	7	7	7	7	8	8	7	7	7	7	7	8
		6–12 in	8	8	10	11	12	13	8	8	10	12	13	13
		>12 in	0	3	9	16	24	34	0	3	10	17	24	32
		Litter	1	2	1	1	1	1	1	2	1	1	1	1
		Duff	14	14	14	14	14	14	15	14	14	14	14	14
		Moderate	3	3	6	7	8	8	3	3	6	7	8	8
		Severe	5	5	8	10	11	12	5	5	8	10	11	12
		Torching index	0	20	22	73	68	69	0	12	18	21	21	58
		Crowning index	30	32	36	45	49	51	30	32	37	39	46	48
Pile and burn	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface
		Severe	Passive	Surface	Surface	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface
		Hard snags (stems/ac)	80	94	95	89	64	49	87	136	115	84	90	63
		0–17.9 in	18	23	28	33	36	37	18	23	31	32	34	35
		18–29.9 in	7	7	10	13	16	17	7	7	9	11	14	17
		30–36 in	1	6	14	18	21	23	1	6	14	20	22	24
		Surface fuel loadings (tons/ac)	0–3 in	2	3	4	4	5	2	3	4	4	5	6
			3–6 in	2	4	6	9	10	2	4	6	9	10	11
			6–12 in	0	3	9	16	24	0	3	9	17	24	32
			>12 in	1	2	1	1	1	1	2	1	1	1	1
None	Litter	13	13	13	13	13	13	13	13	13	13	13	13	13
	Duff	3	2	5	7	8	8	3	2	5	7	7	8	
	Moderate	5	3	7	9	11	12	5	3	7	10	11	12	
	Severe	0	68	29	78	78	76	0	50	25	25	60	46	
	Torching index	30	32	36	43	52	56	30	32	37	40	46	51	
	Crowning index	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface
		Severe	Passive	Surface	Surface	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface
		Hard snags (stems/ac)	80	94	81	90	76	52	87	136	117	82	90	64
		0–17.9 in	18	23	29	32	38	37	18	23	31	32	34	35
		18–29.9 in	7	7	10	12	14	15	7	7	9	11	14	17
	30–36 in	1	6	14	18	21	23	1	6	14	20	22	24	

Table 18b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	6	10	15	17	18	0	7	9	11	15	16
	0–3 in												
	3–6 in	2	3	4	5	5	5	2	4	4	4	5	5
	6–12 in	4	7	8	9	10	10	4	8	9	9	9	9
Flame length (ft)	>12 in	0	4	10	15	23	30	0	6	14	18	22	28
	Litter	1	1	1	1	1	1	1	1	1	1	1	1
	Duff	10	10	10	10	10	10	10	10	10	10	10	10
	Moderate	1	3	4	6	7	7	1	3	5	6	6	7
Torching index	Severe	1	4	7	9	10	11	2	5	7	8	9	10
	Severe	753	181	108	106	98	93	563	119	99	113	118	113
	Severe	34	35	39	43	46	50	38	39	41	44	46	49
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Hard snags (stems/ac)	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	0–17.9 in	95	49	52	50	44	53	128	58	41	40	50	39
	18–29.9 in	22	21	25	30	33	33	30	27	24	26	28	31
	30–36 in	8	8	9	13	15	18	11	10	10	11	14	16

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 18c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	776	565	406	270	183	97	62	61	60	53	43	37
	Quadratic mean diameter (in)	8.3	10.0	11.8	14.5	17.6	24.1	8.3	27.9	30.2	32.8	36.3	39.0
	Total volume (ft ³)	11,693	13,764	15,053	16,298	17,045	17,531	10,817	12,422	15,718	17,678	18,358	18,765
	Merchantable volume (ft ³)	10,745	12,648	13,828	15,001	15,682	16,317	10,055	11,577	14,711	16,582	17,293	17,668
	Basal area (ft ²)	291	310	309	310	308	306	241	261	300	314	308	308
	Stand density index	575	568	530	491	453	397	300	319	355	360	339	330
	Canopy closure (percent)	60	66	65	63	61	58	47	49	54	56	55	55
	Crown competition factor	85	116	102	89	79	68	55	58	64	65	61	60
	Canopy base height (ft)	2	3	10	21	31	40	31	45	52	59	69	74
	Canopy bulk density (kg/m ³)	0.07	0.13	0.13	0.11	0.08	0.04	0.06	0.05	0.05	0.05	0.04	0.03

Table 18c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	776	53	102	88	72	53	43	100	109	87	70	54	45
	Quadratic mean diameter (in)	8.3	29.4	22.7	25.3	27.9	33.2	36.0	22.9	22.7	25.4	28.4	32.3	35.2
	Total volume (ft ³)	11,693	12,340	13,972	16,223	17,199	18,698	18,764	13,266	14,299	15,947	16,843	17,662	18,539
	Merchantable volume (ft ³)	10,745	11,500	13,044	15,203	16,141	17,582	17,660	12,289	13,300	14,919	15,803	16,588	17,445
	Basal area (ft ²)	291	250	288	305	306	318	307	286	306	306	306	306	308
	Stand density index	575	299	381	388	373	363	339	378	406	389	372	353	343
	Canopy cover (percent)	60	48	52	55	55	56	55	54	55	55	55	54	54
	Crown competition factor	85	54	60	65	63	63	59	70	70	68	65	62	60
	Canopy base height (ft)	2	31	46	4	58	65	77	29	41	49	54	60	69
	Canopy bulk density (kg/m ³)	0.07	0.06	0.06	0.05	0.04	0.04	0.03	0.07	0.06	0.05	0.04	0.04	0.04
Pile and burn	Trees per acre	776	53	128	108	92	74	63	100	122	98	77	68	46
	Quadratic mean diameter (in)	8.3	29.4	20.3	22.8	25.2	27.5	30.4	22.9	21.5	23.9	27.1	29.1	35.1
	Total volume (ft ³)	11,693	12,340	13,972	16,235	17,732	18,057	19,310	13,266	14,299	15,858	17,141	18,127	18,425
	Merchantable volume (ft ³)	10,745	11,500	13,044	15,209	16,630	16,949	18,140	12,289	13,300	14,835	16,068	17,027	17,321
	Basal area (ft ²)	291	250	288	306	317	303	316	286	306	306	309	311	308
	Stand density index	575	299	399	405	403	373	374	378	415	398	382	375	344
	Canopy cover (percent)	60	48	52	56	57	57	57	54	55	55	55	55	54
	Crown competition factor	85	54	60	68	68	64	64	70	70	69	66	64	60
	Canopy base height (ft)	2	31	44	52	57	73	77	29	41	48	56	62	69
	Canopy bulk density (kg/m ³)	0.07	0.06	0.06	0.06	0.05	0.04	0.03	0.07	0.06	0.06	0.05	0.05	0.04
Prescribed fire	Trees per acre	776	53	197	173	153	128	101	100	140	120	85	74	56
	Quadratic mean diameter (in)	8.3	29.4	15.8	17.6	19.7	21.4	23.6	22.9	19.3	21.7	25.5	27.4	32.3
	Total volume (ft ³)	11,693	11,540	13,078	15,451	18,082	18,719	18,263	12,307	13,572	15,968	16,917	17,686	18,992
	Merchantable volume (ft ³)	10,745	10,762	12,222	14,458	16,906	17,509	17,093	11,427	12,645	14,929	15,864	16,603	17,863
	Basal area (ft ²)	291	250	266	292	323	318	305	286	285	306	303	304	318
	Stand density index	575	299	408	429	453	433	398	378	403	414	383	375	367
	Canopy cover (percent)	60	48	50	57	60	59	57	54	54	56	57	56	57
	Crown competition factor	85	54	56	73	77	72	66	70	66	71	66	64	64
	Canopy base height (ft)	2	32	45	4	17	29	69	31	42	4	11	23	73
	Canopy bulk density (kg/m ³)	0.07	0.05	0.05	0.05	0.05	0.05	0.04	0.06	0.07	0.06	0.05	0.04	0.04

Table 18c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	776	200	169	120	75	60	51	300	222	168	129	80	65
	Quadratic mean diameter (in)	8.3	16.3	18.3	21.7	27.4	30.4	33.0	13.3	15.9	18.2	20.9	26.5	29.2
	Total volume (ft ³)	11,693	13,148	14,097	15,666	16,492	17,063	17,911	13,177	13,976	15,481	16,818	17,244	17,670
	Merchantable volume (ft ³)	10,745	12,121	13,030	14,578	15,431	15,995	16,813	12,131	12,912	14,353	15,626	16,130	16,544
	Basal area (ft ²)	291	291	306	306	306	302	303	291	307	305	307	304	302
	Stand density index	575	439	443	414	377	356	347	476	469	440	421	380	363
	Canopy cover (percent)	60	57	57	56	55	55	55	57	59	58	57	56	55
	Crown competition factor	85	80	78	72	66	63	61	85	83	77	72	66	63
	Canopy base height (ft)	2	4	9	18	50	58	64	2	7	16	25	51	57
	Canopy bulk density (kg/m ³)	0.07	0.07	0.07	0.06	0.04	0.04	0.03	0.07	0.07	0.06	0.05	0.04	0.04
Pile and burn	Trees per acre	776	200	173	137	85	61	53	300	229	172	136	84	68
	Quadratic mean diameter (in)	8.3	16.3	18.0	20.2	25.7	30.1	32.2	13.3	15.7	18.1	20.3	25.8	28.5
	Total volume (ft ³)	11,693	13,148	14,097	15,709	16,668	17,082	17,855	13,177	13,976	15,501	16,798	17,260	17,693
	Merchantable volume (ft ³)	10,745	12,121	13,030	14,596	15,599	16,019	16,781	12,131	12,912	14,372	15,597	16,138	16,547
	Basal area (ft ²)	291	291	306	307	306	299	300	291	307	305	307	305	302
	Stand density index	575	439	445	426	387	354	347	476	471	443	425	384	367
	Canopy cover (percent)	60	57	57	57	56	55	55	57	59	58	57	56	55
	Crown competition factor	85	80	78	74	67	62	61	85	83	78	73	66	63
	Canopy base height (ft)	2	4	9	18	48	59	65	2	7	16	25	50	47
	Canopy bulk density (kg/m ³)	0.07	0.07	0.07	0.06	0.05	0.04	0.03	0.07	0.07	0.06	0.05	0.04	0.04
Prescribed fire	Trees per acre	776	200	120	99	79	68	46	300	102	95	81	57	51
	Quadratic mean diameter (in)	8.3	16.3	21.1	23.8	26.7	28.9	35.0	13.3	21.7	23.8	26.3	31.4	33.4
	Total volume (ft ³)	11,693	12,247	13,896	15,967	17,243	18,144	18,357	10,829	12,460	15,264	17,155	18,167	18,931
	Merchantable volume (ft ³)	10,745	11,362	12,921	14,937	16,183	17,034	17,262	10,066	11,612	14,283	16,083	17,065	17,812
	Basal area (ft ²)	291	291	294	306	309	311	308	291	261	291	306	309	311
	Stand density index	575	439	401	398	384	375	344	476	353	379	383	360	354
	Canopy cover (percent)	60	57	54	55	55	55	54	57	50	54	55	55	55
	Crown competition factor	85	80	67	69	67	64	61	85	58	65	66	63	62
	Canopy base height (ft)	2	31	40	48	55	61	66	31	42	49	56	63	71
	Canopy bulk density (kg/m ³)	0.07	0.06	0.06	0.05	0.05	0.04	0.04	0.06	0.05	0.05	0.05	0.04	0.04

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 18d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only								
	Fuel models			Fuel models			Fuel models			Fuel models					
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight
None	1	10	100				8	93	5						
	10	10	83	12	17		10	99	12	1					
	20	12	91	13	9		10	55	12	45					
	30	13	71	12	29		12	61	10	39					
	40	13	100				12	94	10	6					
50	13	100				12	74	13	26						

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit								
	Fuel models			Fuel models			Fuel models			Fuel models					
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight
None	1	10	67	8	33		8	55	10	45					
	10	10	100				10	98	12	2					
	20	10	77	12	23		12	62	10	38					
	30	12	55	10	45		12	89	13	11					
	40	12	98	13	2		13	56	12	44					
50	12	71	13	29		13	86	12	14						
Pile and burn	1	8	100				8	100							
	10	8	78	10	22		8	66	10	34					
	20	10	88	8	12		10	69	12	31					
	30	10	61	12	39		12	97	10	3					
	40	12	75	10	25		12	62	13	38					
50	12	76	13	24		13	64	12	36						
Prescribed fire	1	8	98	5	2		8	100							
	10	8	60	10	40		10	67	8	33					
	20	10	91	12	9		10	70	12	30					
	30	10	59	12	41		12	87	10	13					
	40	12	73	10	27		12	74	13	26					
50	12	97	13	3		13	56	12	44						

Table 18d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit						Thin from below to 300 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent
None	1	10	100					10	100				
	10	10	95	12	5			10	94	12	6		
	20	12	78	10	22			12	80	10	20		
	30	12	70	13	30			12	55	13	45		
	40	13	79	12	21			13	78	12	22		
50	13	100					13	100					
Pile and burn	1	10	100					10	100				
	10	8	60	10	40			8	58	10	42		
	20	10	53	12	47			10	51	12	49		
	30	12	89	13	11			12	76	13	24		
	40	13	56	12	44			13	63	12	37		
50	13	96	12	4			13	100					
Prescribed fire	1	8	100					8	94	5	6		
	10	10	73	8	27			10	97	12	3		
	20	10	67	12	33			10	51	12	49		
	30	12	88	10	12			12	69	10	31		
	40	12	72	13	28			12	94	13	6		
50	13	54	12	46			12	61	13	39			

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 18e—FVS fuel model selection

Fire weather conditions	Windspeed Miles/hour	Temperature °F	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff Live	
Severe—98 th percentile	17	83	2	5	10	15	50	100
Moderate—75 th percentile	11	72	5	7	15	17	125	150

Table 18f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

Site: Elevation = 4,500 ft, slope = 40 percent, aspect = 360°.

Species (based on trees per acre): Hardwoods = 77 percent, sugar pine (*Pinus lambertiana*) = 13 percent, white fir (*Abies concolor*) = 4 percent, ponderosa pine (*Pinus ponderosa*) = 4 percent.

Stand attributes: Stem density = 1,817 tpa, basal area = 289 ft²/ac, top height = 112 ft, stand density index = 676, quadratic mean diameter = 5.4 in, crown competition factor = 136, canopy cover = 69 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has 1,817 trees per acre (tpa) composed primarily of white fir and hardwood understory with ponderosa pine and sugar pine overstory. Canopy bulk density is 0.05 kg/m^3 (0.0031 lb/ft^3), and canopy base height is 6 ft, so ladder fuels and canopy fuels are not sufficient to enable crown fire under moderate or severe fire weather. Woody fuel loading is 18 tons/ac, and litter and duff loading is 16 tons/ac. Potential flame lengths are 3 ft, and potential basal area mortality is 15 percent for severe fire. With no action, canopy base height decreases and canopy bulk density increases in 10 years as smaller trees grow into the overstory, and passive crown fire is predicted for moderate and severe fire weather. In 20 years, canopy base height increases again, but surface fuels also increase potential flame lengths, so passive crown fire remains likely for severe fire weather, and surface fire is predicted for moderate fire weather. Surface fuels continue to accumulate contributing to higher potential flame lengths; in 50 years flame lengths are 9 ft and 12 ft for moderate and severe fire weather, respectively.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment reduces crown fire potential, flame lengths, and basal area mortality, but creates many snags that contribute to higher surface fuel loadings and potential flame lengths in 10 years. In the short term, all thinning treatments increase canopy base height and reduce crown fire potential and basal area mortality; the greater the thinning, the greater is the reduction in crown fire potential and basal area mortality. However, if no surface fuel treatment is applied, activity fuels increase potential flame lengths in all treatments. Both the pile and burn and prescribed fire treatments reduce surface fuel loading in all size classes, decreasing potential flame lengths and basal area mortality to below initial conditions. Canopy bulk density is low enough under initial conditions that none of the treatments are sufficient to reduce canopy bulk density, but active crown fire is unlikely, so reductions in canopy bulk density are not necessary in this stand.

Silvicultural and surface fuel treatments—long-term effects

In the prescribed fire only treatment, crown fire potential increases slightly over time as surface fuels accumulate, but predicted fire type remains surface fire for 50 years, and potential flame lengths remain low. Surface fuels accumulate rapidly in the low-density treatments with no surface fuel treatment, and flame lengths exceed 10 ft in 20 years, but canopy base height also increases as the trees grow and the stand self-thins. Canopy base height remains high relative to flame lengths in the 50 tpa treatment with a pile and burn, and in the 100 tpa treatment with no surface fuel treatment and pile and burn, so predicted fire type is surface fire for 50 years. In the 50 tpa treatment without surface fuel treatment the combination of regeneration and high activity fuels creates conditions conducive to passive crown fire in 20 years. Regeneration causes a decrease in canopy base height in the 50 tpa and 100 tpa treatments with prescribed fire in 20 years, and passive crown fire is the predicted fire type for severe and moderate fire weather. In the higher density treatments, canopy base height continues to increase, and the predicted fire type remains surface fire for the 50-year projection.

Table 19a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit	
None	Surface fuel loadings (tons/ac)	0-3 in	1	5	5	4	4	
		3-6 in	1	7	7	7	7	
		6-12 in	4	7	7	8	8	
		>12 in	0	0	0	0	0	
		Litter	1	1	1	1	1	
		Duff	15	10	14	15	15	
		Moderate	2	1	3	3	3	
		Severe	3	1	4	4	4	
		Torching index	50	994	205	144	128	75
		Crowning index	43	46	43	43	43	43
Pile and burn	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	
		Surface	Surface	Surface	Surface	Surface	Surface	
	Potential basal area mortality (%)	15	9	8	10	12	13	
		15	9	8	11	13	14	
	Surface fuel loadings (tons/ac)	0-3 in	1	1	1	1	1	
		3-6 in	2	2	2	2	2	
		6-12 in	2	2	2	2	2	
		>12 in	0	0	0	0	0	
		Litter	1	1	1	1	1	
		Duff	12	12	13	13	13	
Prescribed fire	Flame length (ft)	Moderate	0	1	1	1	1	
		Severe	1	1	1	1	1	
	Torching index	Severe	1,060	697	522	315	315	
	Crowning index	Severe	43	43	43	43	43	
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	
		Severe	Surface	Surface	Surface	Surface	Surface	
	Potential basal area mortality (%)	Moderate	8	10	10	12	13	
		Severe	8	10	12	12	13	
	Surface fuel loadings (tons/ac)	0-3 in	0	0	0	0	0	
		3-6 in	2	2	2	2	2	
Pile and burn		6-12 in	4	4	4	4	5	
		>12 in	0	0	0	0	0	
		Litter	1	1	1	1	1	
		Duff	9	10	10	10	10	
		Moderate	1	1	1	1	1	
		Severe	1	1	1	1	1	
	Torching index	Severe	1,015	1,046	972	983	983	
	Crowning index	Severe	46	46	46	46	46	
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	
		Severe	Surface	Surface	Surface	Surface	Surface	
Potential basal area mortality (%)	Moderate	7	8	9	9	9		
	Severe	7	8	9	9	9		

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 19b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action												
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	0–3 in	3	7	15	20	23	25	1	6	7	8	11	13
		3–6 in	7	7	8	8	10	12	1	3	3	3	3	3
	Torching index	6–12 in	8	8	9	10	11	12	4	5	6	5	5	5
		>12 in	0	3	10	16	22	28	0	4	10	12	13	16
	Crowning index	Litter	1	1	1	2	2	2	1	1	1	1	1	1
		Duff	15	15	15	15	14	15	10	10	10	10	10	10
	Flame length (ft)	Moderate	2	3	6	7	8	9	1	3	4	4	5	6
		Severe	3	5	8	10	11	12	1	4	5	6	7	8
	Type of fire	Severe	50	0	1	1	6	15	994	270	146	74	75	82
		Moderate	43	34	27	25	25	26	46	42	39	41	41	42
Hard snags (stems/ac)	Surface	Surface	Passive	Surface										
	Surface	Surface	Passive	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	246	472	403	289	259	213	475	42	27	26	27	28	
None	Surface fuel loadings (tons/ac)	18–29.9 in	29	32	31	28	27	25	32	29	21	15	13	
		30–36 in	8	9	11	12	13	14	9	8	7	7	7	

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit										Thin from below to 100 tpa, 18-in d.b.h. limit									
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs		
None	Surface fuel loadings (tons/ac)	0–3 in	5	7	8	9	10	11	5	6	8	9	12	15							
		3–6 in	7	7	6	5	5	4	4	7	7	6	5	5							
	Torching index	6–12 in	7	7	6	5	5	4	7	7	7	6	6	7							
		>12 in	0	3	7	8	9	10	0	3	6	8	10	14							
	Crowning index	Litter	1	1	1	1	1	1	1	1	1	1	1	1							
		Duff	13	13	13	13	12	12	14	14	14	13	13	13							
	Flame length (ft)	Moderate	3	3	4	4	4	5	3	3	4	4	5	6							
		Severe	5	5	6	6	6	7	4	5	6	6	7	9							
	Type of fire	Severe	205	170	0	15	47	69	144	122	98	106	112	117							
		Moderate	43	40	38	40	42	45	43	38	36	39	40	44							
None	Surface fuel loadings (tons/ac)	18–29.9 in	Surface	Surface	Passive	Surface	Surface														
		Surface	Surface	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface								
Hard snags (stems/ac)	0–17.9 in	40	34	24	17	14	15	41	35	25	26	34	41								
	18–29.9 in	26	23	19	14	12	12	26	23	18	16	16	19								
None	Surface fuel loadings (tons/ac)	30–36 in	7	7	6	6	6	6	7	7	6	6	7								

Table 19b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	1	4	6	8	10	12	1	4	6	9	12	15
		3–6 in	2	2	2	2	2	3	2	2	2	3	3	3
		6–12 in	2	3	3	3	2	3	2	3	3	3	4	5
	Flame length (ft)	>12 in	0	3	6	8	9	11	0	3	6	8	11	14
		Litter	1	1	1	1	1	1	1	1	1	1	1	1
		Duff	12	12	11	11	11	11	13	12	12	12	12	12
	Torching index	Moderate	1	2	3	3	4	5	1	2	3	3	5	6
		Severe	1	2	4	5	6	7	1	3	5	5	7	8
		Severe	1,060	734	25	244	206	187	697	499	120	25	124	121
	Crowning index	Moderate	43	38	36	37	39	41	43	37	35	37	39	41
		Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	40	34	24	18	19	18	41	35	28	28	34	37
		18–29.9 in	26	23	19	14	12	12	26	23	19	16	16	19
		30–36 in	7	7	6	6	6	6	7	7	6	6	7	10
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	4	6	8	10	11	0	4	6	8	10	11
		3–6 in	2	3	2	2	3	3	2	3	3	3	3	3
		6–12 in	4	5	5	5	4	4	4	6	6	5	5	4
	Flame length (ft)	>12 in	0	4	10	12	13	15	0	4	10	11	13	14
		Litter	1	1	1	1	1	1	1	1	1	1	1	1
		Duff	9	9	9	9	9	9	13	10	9	9	9	9
	Torching index	Moderate	1	2	3	4	5	5	1	3	4	4	5	5
		Severe	1	3	5	6	7	7	1	4	5	6	7	7
		Severe	1,015	432	0	39	66	71	1,046	325	0	17	42	50
	Crowning index	Moderate	46	42	40	42	44	45	46	41	39	40	40	40
		Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	49	41	28	28	26	22	58	41	28	19	21	20
		18–29.9 in	32	28	22	17	14	12	32	28	22	15	13	12
		30–36 in	9	8	7	7	7	6	9	8	8	7	6	6

Table 19b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	4	6	9	11	14	19	4	6	9	12	17	20
	0–3 in	7	6	6	6	6	8	7	7	6	6	7	7
	3–6 in	8	7	7	7	7	9	8	8	8	7	9	11
	6–12 in	0	3	7	9	13	18	0	3	7	10	14	20
	>12 in	1	1	1	1	1	1	1	1	1	1	1	1
	Litter	15	14	14	14	14	14	15	15	15	14	14	14
	Duff	3	3	4	5	6	7	3	3	5	5	7	8
	Moderate	4	5	6	7	8	10	4	5	6	7	9	11
	Severe	128	113	82	86	78	57	75	66	43	51	45	40
	Torching index	43	38	36	38	37	37	43	39	37	41	40	40
Pile and burn	Crowning index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	44	46	41	37	54	53	49	55	53	68	71	68
	0–17.9 in	26	24	21	17	19	17	26	25	22	20	22	24
	18–29.9 in	7	7	7	7	9	9	7	7	7	8	10	12
	30–36 in	1	4	7	10	14	19	1	4	8	11	17	22
	Surface fuel loadings (tons/ac)	2	2	3	3	4	6	2	2	3	3	5	6
	0–3 in	2	3	3	4	5	7	2	3	4	4	6	9
	3–6 in	0	3	7	9	13	18	0	3	7	10	14	21
	6–12 in	1	1	1	1	1	1	1	1	1	1	1	1
>12 in	13	13	13	13	12	12	13	13	13	13	13	13	
Litter	1	2	3	4	6	7	1	2	3	5	6	8	
Duff	1	3	5	6	8	10	1	3	5	6	9	11	
Moderate	522	423	115	107	83	73	315	256	69	64	50	47	
Severe	43	38	36	38	37	39	43	39	37	41	41	43	
Torching index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Crowning index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Moderate	44	46	41	37	55	51	49	55	53	69	77	69	
Severe	26	24	21	17	19	21	26	25	22	20	24	23	
0–17.9 in	7	7	7	7	9	11	7	7	7	8	10	11	
18–29.9 in	7	7	7	7	9	11	7	7	7	8	10	11	
30–36 in													

Table 19b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	5	7	8	10	12	0	5	7	8	11	13
	0–3 in	2	3	3	3	3	3	2	4	3	3	3	4
	3–6 in	4	6	6	5	5	5	5	6	6	5	5	5
	6–12 in	0	4	10	11	12	14	0	4	10	11	13	15
	>12 in	1	1	1	1	1	1	1	1	1	1	1	1
Flame length (ft)	Duff	10	10	10	10	10	10	10	10	10	10	10	10
	Moderate	1	3	4	4	5	5	1	3	4	4	5	6
	Severe	1	4	6	6	7	7	1	4	6	6	7	8
	Severe	972	275	145	17	51	68	983	263	141	19	53	64
Torching index	Severe	46	42	39	40	41	41	46	41	39	41	41	42
	Crowning index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	76	41	27	22	23	25	97	41	28	27	26	34
Hard snags (stems/ac)	0–17.9 in	32	28	21	15	14	14	32	28	21	16	14	16
	18–29.9 in	9	8	7	7	7	7	9	8	7	7	7	8
	30–36 in												

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 19c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	1,817	1,306	948	694	461	312	144	143	142	132	122	109
	Quadratic mean diameter (in)	5.4	6.7	8.2	9.9	12.1	14.7	5.4	18.8	20.0	21.6	23.3	25.5
	Total volume (ft ³)	12,433	13,449	14,479	15,479	16,141	16,941	12,295	13,297	15,474	17,365	19,276	21,105
	Merchantable volume (ft ³)	11,325	12,047	12,729	13,468	14,311	15,437	11,386	12,275	14,265	16,081	17,979	19,720
	Basal area (ft ²)	289	322	349	370	369	367	260	276	310	337	364	387
	Stand density index	676	690	692	682	627	578	377	394	432	456	477	490
	Canopy closure (percent)	69	79	80	79	75	71	52	55	59	61	63	65
	Crown competition factor	136	218	193	170	140	119	66	70	77	81	85	87
	Canopy base height (ft)	6	3	10	15	20	26	40	44	45	28	32	38
	Canopy bulk density (kg/m ³)	0.05	0.06	0.08	0.09	0.09	0.09	0.04	0.05	0.05	0.05	0.05	0.05

Table 19c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	1,817	50	99	98	96	94	89	100	124	121	112	99	84
	Quadratic mean diameter (in)	5.4	30.7	22.8	24.0	25.2	26.2	27.5	22.3	21.2	22.5	24.1	26.2	28.4
	Total volume (ft ³)	12,433	12,951	13,971	15,870	17,932	19,697	21,222	13,284	14,407	16,682	18,510	19,887	20,831
	Merchantable volume (ft ³)	11,325	12,098	13,054	14,848	16,801	18,458	19,910	12,330	13,356	15,517	17,253	18,591	19,549
	Basal area (ft ²)	289	256	282	306	332	352	368	270	302	335	357	369	369
	Stand density index	676	302	373	397	423	441	453	361	412	445	461	462	448
	Canopy cover (percent)	69	48	52	55	58	60	62	53	57	61	62	63	62
	Crown competition factor	136	54	58	66	70	74	76	64	70	78	80	80	77
	Canopy base height (ft)	6	44	48	4	10	21	30	27	33	34	40	47	54
	Canopy bulk density (kg/m ³)	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.06	0.05	0.05	0.04
Pile and burn	Trees per acre	1,817	50	125	124	121	114	108	1,644	137	132	122	109	95
	Quadratic mean diameter (in)	5.4	30.7	20.3	21.3	22.5	23.8	25.0	5.0	20.1	21.5	23.1	24.9	26.6
	Total volume (ft ³)	12,433	12,951	13,971	15,881	17,953	19,602	21,133	13,284	14,407	16,492	18,421	19,935	20,611
	Merchantable volume (ft ³)	11,325	12,098	13,054	14,849	16,788	18,335	19,749	12,330	13,356	15,341	17,161	18,635	19,296
	Basal area (ft ²)	289	256	282	307	334	352	368	361	302	331	355	369	368
	Stand density index	676	302	391	418	444	458	470	64	421	449	468	472	459
	Canopy cover (percent)	69	48	52	57	60	62	63	53	57	60	62	63	62
	Crown competition factor	136	54	58	70	75	77	80	112	70	78	81	81	79
	Canopy base height (ft)	6	44	48	6	56	63	67	27	33	34	10	47	54
	Canopy bulk density (kg/m ³)	0.05	0.05	0.05	0.06	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05
Prescribed fire	Trees per acre	1,817	50	193	190	180	170	161	100	136	133	131	124	117
	Quadratic mean diameter (in)	5.4	30.7	15.7	16.7	17.8	18.8	20.0	22.3	19.0	20.1	21.3	22.6	23.9
	Total volume (ft ³)	12,433	12,143	13,092	14,924	16,552	18,099	19,849	12,293	13,296	15,187	17,238	18,969	20,637
	Merchantable volume (ft ³)	11,325	11,354	12,259	13,943	15,439	16,833	18,397	11,466	12,398	14,198	16,106	17,724	19,334
	Basal area (ft ²)	289	256	260	289	309	327	350	270	269	295	323	344	363
	Stand density index	676	302	399	432	451	467	488	361	382	410	440	457	472
	Canopy cover (percent)	69	48	49	57	60	62	64	53	51	56	59	61	63
	Crown competition factor	136	54	53	74	77	80	84	64	58	68	73	76	79
	Canopy base height (ft)	6	44	49	4	16	28	36	44	47	4	10	20	29
	Canopy bulk density (kg/m ³)	0.05	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05

Table 19c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	1,817	200	201	186	170	135	107	300	291	263	220	179	141
	Quadratic mean diameter (in)	5.4	16.0	16.9	18.4	20.0	22.4	25.5	13.2	14.1	15.6	17.5	19.4	21.9
	Total volume (ft ³)	12,433	13,403	14,425	16,514	18,522	19,163	20,311	13,443	14,361	16,343	17,952	18,696	19,217
	Merchantable volume (ft ³)	11,325	12,284	13,156	15,168	17,066	17,836	18,973	12,260	13,014	14,815	16,464	17,284	17,880
	Basal area (ft ²)	289	280	312	343	369	369	379	284	317	349	369	369	369
	Stand density index	676	426	465	494	515	492	481	467	507	537	541	520	496
	Canopy cover (percent)	69	57	60	63	65	64	63	60	64	66	67	66	64
	Crown competition factor	136	78	83	89	92	87	85	91	97	102	101	94	88
	Canopy base height (ft)	6	19	28	31	36	39	44	11	17	19	25	30	39
	Canopy bulk density (kg/m ³)	0.05	0.05	0.05	0.06	0.05	0.06	0.06	0.05	0.05	0.06	0.05	0.05	0.05
Pile and burn	Trees per acre	1,817	200	206	189	173	137	116	300	298	270	226	181	148
	Quadratic mean diameter (in)	5.4	16.0	16.7	18.2	19.8	22.2	24.2	13.2	14.0	15.4	17.3	19.3	21.3
	Total volume (ft ³)	12,433	13,403	14,425	16,504	18,506	19,144	19,707	13,443	14,361	16,357	17,926	18,744	19,660
	Merchantable volume (ft ³)	11,325	12,284	13,156	15,159	17,049	17,820	18,379	12,260	13,014	14,826	16,437	17,332	18,286
	Basal area (ft ²)	289	280	312	343	369	369	368	284	317	350	369	369	369
	Stand density index	676	426	467	496	517	494	477	467	509	540	545	521	501
	Canopy cover (percent)	69	57	60	63	65	64	63	60	64	66	67	66	65
	Crown competition factor	136	78	83	89	92	87	84	91	97	103	102	96	90
	Canopy base height (ft)	6	19	28	31	36	38	45	11	17	19	25	29	39
	Canopy bulk density (kg/m ³)	0.05	0.05	0.05	0.06	0.05	0.06	0.05	0.05	0.05	0.06	0.05	0.05	0.05
Prescribed fire	Trees per acre	1,817	200	133	131	126	118	110	300	154	151	141	131	116
	Quadratic mean diameter (in)	5.4	16.0	19.4	20.6	22.0	23.4	24.9	13.2	18.2	19.3	20.8	22.4	24.1
	Total volume (ft ³)	12,433	12,345	13,362	15,472	17,524	19,233	20,698	12,352	13,393	15,510	17,348	19,204	20,460
	Merchantable volume (ft ³)	11,325	11,461	12,378	14,354	16,341	17,956	19,359	11,451	12,384	14,337	16,121	17,906	19,135
	Basal area (ft ²)	289	280	274	305	333	353	369	284	276	309	334	358	369
	Stand density index	676	426	387	420	447	463	472	467	400	436	458	477	478
	Canopy cover (percent)	69	57	53	57	60	62	63	60	54	58	61	63	64
	Crown competition factor	136	78	63	72	76	79	80	91	66	75	79	82	82
	Canopy base height (ft)	6	40	46	46	10	23	32	40	46	45	11	25	32
	Canopy bulk density (kg/m ³)	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.05

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 19d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None			Percent			Percent			Percent				
	1	8	60	10	40		8	100					
	10	10	99	12	1		10	54		8	46		
	20	12	79	10	21		10	96		12	4		
	30	12	68	13	32		10	85		12	15		
40	13	78	12	22		10	65		12	35			
50	13	100				12	63		10	37			

Thin from below to 50 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None			Percent			Percent			Percent				
	1	10	65	8	35		10	59		8	41		
	10	10	90	8	10		10	90		8	10		
	20	10	89	12	11		10	89		12	11		
	30	10	82	12	18		10	77		12	23		
40	10	78	12	22		10	56		12	44			
50	10	68	12	32		12	81		10	19			

Pile and burn

1	8	100				8	100						
10	8	87	10	13		8	85		10	15			
20	10	57	8	43		10	100						
30	10	86	8	14		10	99		12	1			
40	10	91	12	9		10	72		12	28			
50	10	71	12	29		12	68		10	32			

Prescribed fire

1	8	100				8	100						
10	8	69	10	31		8	56		10	44			
20	10	90	8	10		10	99		12	1			
30	10	90	12	10		10	86		12	14			
40	10	73	12	27		10	73		12	27			
50	10	57	12	43		10	56		12	44			

Table 19d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit										
	Fuel models					Fuel models					Fuel models					Fuel models					
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None	1	8	52	10	48	8	53	10	47	8	53	10	47	8	53	10	47	8	53	10	47
	10	10	87	8	13	10	89	8	11	10	89	8	11	10	89	8	11	10	89	8	11
	20	10	80	12	20	10	73	12	27	10	73	12	27	10	73	12	27	10	73	12	27
	30	10	58	12	42	12	53	10	47	12	53	10	47	12	53	10	47	12	53	10	47
	40	12	75	10	25	12	98	13	2	12	98	13	2	12	98	13	2	12	98	13	2
50	12	68	13	32	12	54	13	46	12	54	13	46	12	54	13	46	12	54	13	46	
Pile and burn	1	8	100			8	100			8	100			8	100			8	100		
	10	8	83	10	17	8	81	10	19	8	81	10	19	8	81	10	19	8	81	10	19
	20	10	100			10	100			10	100			10	100			10	100		
	30	10	83	12	17	10	73	12	27	10	73	12	27	10	73	12	27	10	73	12	27
	40	12	55	10	45	12	84	10	16	12	84	10	16	12	84	10	16	12	84	10	16
50	12	82	13	18	13	52	12	48	13	52	12	48	13	52	12	48	13	52	12	48	
Prescribed fire	1	8	100			8	100			8	100			8	100			8	100		
	10	10	54	8	46	10	58	8	42	10	58	8	42	10	58	8	42	10	58	8	42
	20	10	96	12	4	10	94	12	6	10	94	12	6	10	94	12	6	10	94	12	6
	30	10	87	12	13	10	83	12	17	10	83	12	17	10	83	12	17	10	83	12	17
	40	10	71	12	29	10	63	12	37	10	63	12	37	10	63	12	37	10	63	12	37
50	10	52	12	48	12	60	10	40	12	60	10	40	12	60	10	40	12	60	10	40	

tpa = trees per acre, d.b.h. = diameter at breast height.

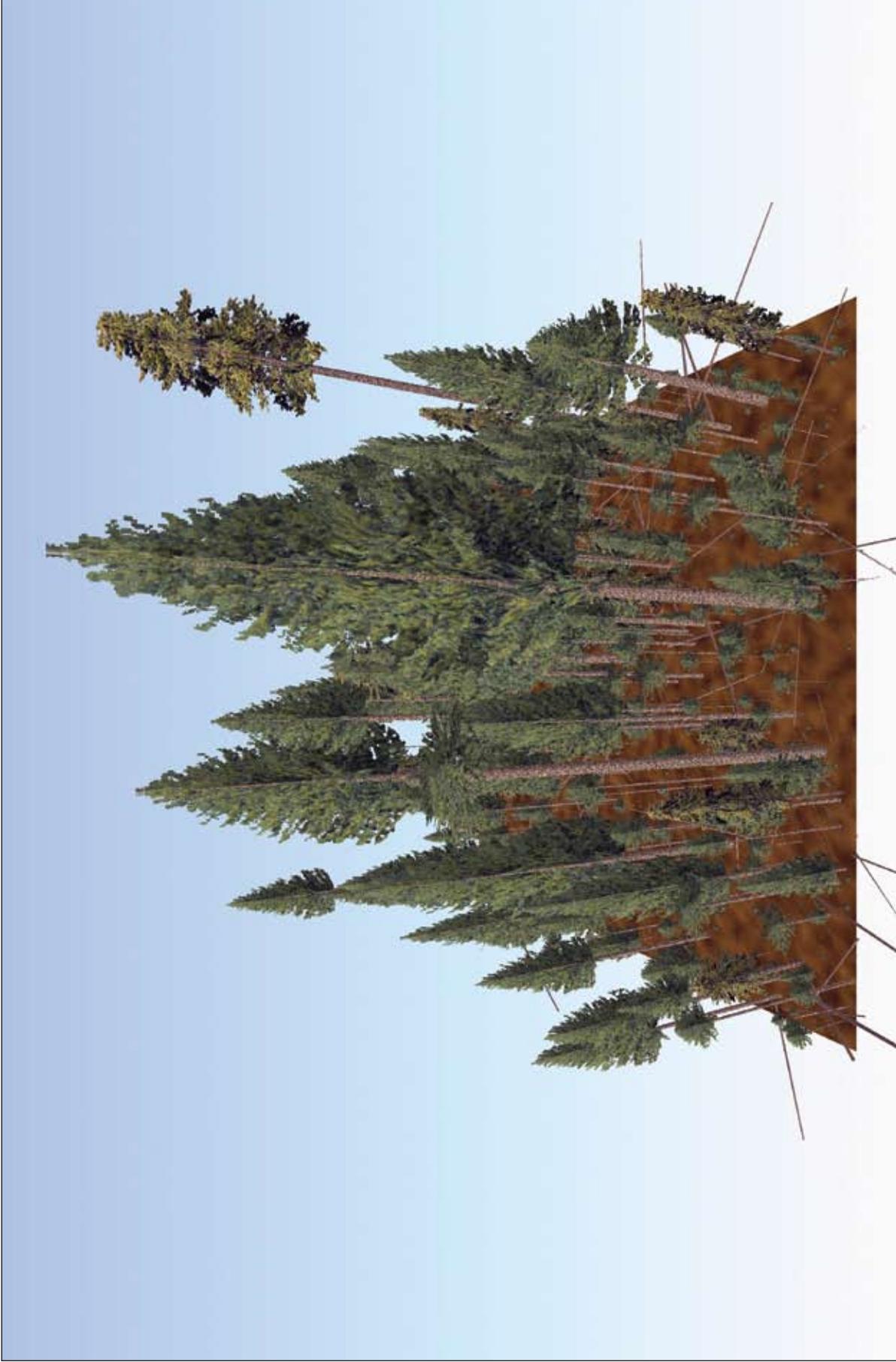
Table 19e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					Live
			1-hr (0-0.25 in)	10-hr (0.25-1 in)	100-hr (1-3 in)	1,000-hr (3+ in)	Duff	
Severe—98 th percentile	17	83	2	5	10	15	50	100
Moderate—75 th percentile	11	72	5	7	15	17	125	150

Table 19f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

Site: Elevation = 4,600 ft, slope = 20 percent, aspect = 135°.

Species (based on trees per acre): Hardwoods = 58 percent, white fir (*Abies concolor*) = 37 percent, sugar pine (*Pinus lambertiana*) = 3 percent, ponderosa pine (*Pinus ponderosa*) = 2 percent.

Stand attributes: Stem density = 1,991 tpa, basal area = 272 ft²/ac, top height = 112 ft, stand density index = 655, quadratic mean diameter = 5.0 in, crown competition factor = 103, canopy cover = 63 percent.



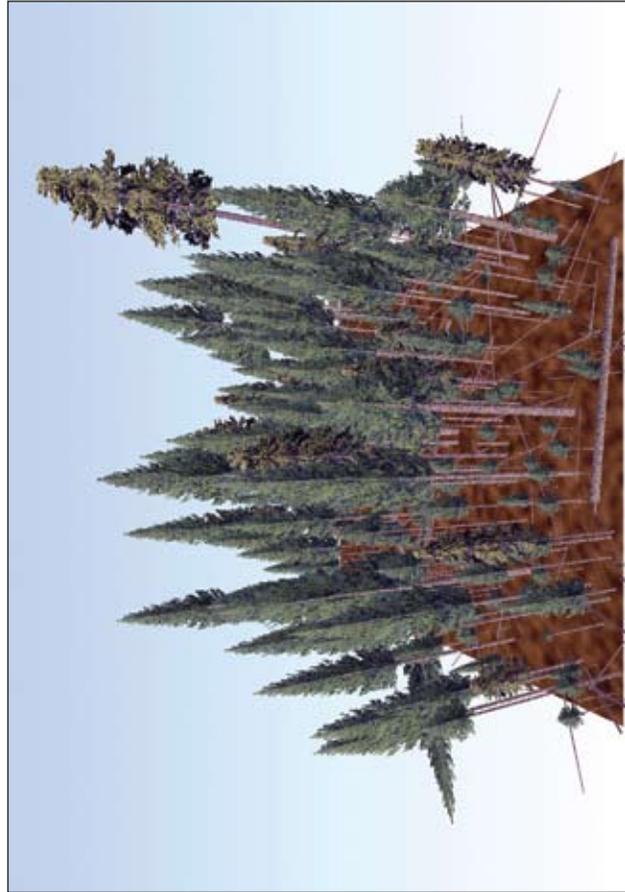
Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has 1,991 trees per acre (tpa) composed primarily of white fir and hardwood understory with ponderosa pine and sugar pine overstory. Canopy bulk density is 0.13 kg/m³ (0.0081 lb/ft³), and canopy base height is 6 ft, so ladder fuels are sufficient to enable passive crown fire, but active crown fire spread is unlikely under moderate and severe fire weather. Woody fuel loading is 18 tons/ac, and litter and duff loading is 22 tons/ac. Potential flame lengths are 4 ft, and potential basal area mortality is 87 percent for severe fire. With no action, canopy base height decreases and canopy bulk density increases in 10 years as smaller trees grow into the overstory, and active crown fire is predicted for severe fire weather. As trees grow and the stand self-thins, canopy base height increases and canopy bulk density decreases, so predicted fire type changes to passive crown fire for severe fire weather in 20 years and remains so for the 50-year projection. Surface fuels accumulate rapidly and flame lengths increase over time; in 50 years, flame lengths are 7 ft and 10 ft for moderate and severe fire weather, respectively.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment raises canopy base height and reduces crown fire potential, but it creates many snags that contribute to higher surface fuel loadings and potential flame lengths in 10 years. In the short term, all thinning treatments increase canopy base height, reducing crown fire potential. The greater the thinning, the more canopy base height increases, but there is little difference between the 200 and 300 tpa treatments. Only the lower density treatments reduce canopy bulk density. However, they increase surface fuels causing higher potential flame lengths; higher density treatments have little effect on surface fuels and flame lengths. The pile and burn and prescribed fire treatments reduce surface fuels, potential flame lengths, and basal area mortality. Mortality of smaller overstory trees in the prescribed fire treatment also further increases canopy base height. In the 50 tpa treatment, potential flame lengths remain high for severe fire weather despite reduction of activity fuels because the predominant fuel model is 5, suggesting that brush fuels would drive fire behavior in these open stands with low woody fuels. The FFE model does not track brush fuels directly, so results should be interpreted with caution.

Silvicultural and surface fuel treatments—long-term effects

In the prescribed fire only treatment, potential flame lengths increase over time as surface fuels accumulate, but canopy base height also increases, so predicted fire type remains surface fire for 50 years. Regeneration is sufficient to cause a decrease in canopy base height in 20 years in the 50 tpa treatment without surface fuel treatment and with prescribed fire, and in the 100 tpa treatment with prescribed fire. At this time, the predicted fire type becomes passive crown fire, but canopy base height increases again in 30 years and the fire type reverts to surface fire. Surface fuels and potential flame lengths increase over time in the 200 and 300 tpa treatment, but canopy base height also increases as trees grow and the stand self-thins, so crown fire potential remains low for the 50-year projection. Canopy bulk density remains low enough that active crown fire is unlikely in all treatments for the 50-year projection.

Table 20a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit	
None	Surface fuel loadings (tons/ac)	0-3 in	1	9	6	4	4	
		3-6 in	1	6	7	7	7	
		6-12 in	3	5	6	7	7	
	Flame length (ft)	>12 in	0	0	0	0	0	0
		Litter	1	1	1	1	1	1
		Duff	21	17	19	20	21	21
	Torching index	Moderate	3	3	3	3	3	3
		Severe	4	5	4	5	4	4
		Severe	15	121	82	53	18	18
	Crowning index	Severe	20	33	27	20	20	20
		Moderate	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Passive	Surface	Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Moderate	19	14	12	18	19	19
		Severe	87	14	13	21	22	22
		Severe	87	14	13	21	22	22
Pile and burn	Surface fuel loadings (tons/ac)	0-3 in	2	2	2	1	1	
		3-6 in	2	2	2	2	2	
		6-12 in	2	2	2	2	2	
	Flame length (ft)	>12 in	0	0	0	0	0	0
		Litter	1	1	1	1	1	1
		Duff	15	15	17	18	19	19
	Torching index	Moderate	1	1	1	3	3	3
		Severe	5	5	1	5	4	4
		Severe	208	208	468	53	18	18
	Crowning index	Severe	33	33	27	20	20	20
		Moderate	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Moderate	8	8	12	17	19	19
		Severe	9	9	12	19	20	20
		Severe	9	9	12	19	20	20
Prescribed fire	Surface fuel loadings (tons/ac)	0-3 in	0	0	0	0	0	
		3-6 in	2	2	2	2	2	
		6-12 in	3	3	4	4	4	
	Flame length (ft)	>12 in	0	0	0	0	0	0
		Litter	1	1	1	1	1	1
		Duff	12	12	13	14	15	15
	Torching index	Moderate	1	1	1	1	1	1
		Severe	5	5	1	5	4	4
		Severe	166	166	456	439	444	444
	Crowning index	Severe	36	36	32	26	26	26
		Moderate	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Moderate	8	8	11	13	14	14
		Severe	9	9	11	13	14	14
		Severe	9	9	11	13	14	14

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 20b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	4	11	23	28	30	33	1	8	11	13	15	19
	3–6 in	7	7	7	8	9	11	1	3	3	3	3	4
	6–12 in	7	9	12	15	18	20	3	9	10	9	9	11
	>12 in	0	3	9	14	19	27	0	4	9	11	13	18
	Litter	1	2	2	2	2	2	1	1	1	1	1	1
	Duff	21	21	20	20	20	20	15	14	14	14	14	14
	Moderate	3	3	6	7	7	7	1	3	4	5	5	6
	Severe	4	5	8	9	10	10	1	5	6	7	8	9
	Severe	15	0	4	6	13	23	444	134	121	101	118	101
	Severe	20	14	18	20	23	20	26	27	29	29	29	31
	Moderate	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Passive	Active	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	354	637	482	305	279	185	566	62	29	30	42	53
	0–17.9 in	18	19	19	18	20	25	21	18	13	11	14	22
	18–29.9 in	5	5	5	5	6	7	5	5	4	4	4	5
	30–36 in												

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	9	9	9	10	10	11	6	9	11	13	15	18
	3–6 in	6	5	5	4	4	3	7	6	5	5	4	4
	6–12 in	5	6	7	6	5	5	6	7	7	7	7	8
	>12 in	0	3	6	7	8	8	0	3	6	8	9	14
	Litter	1	1	1	1	1	1	1	1	1	1	1	1
	Duff	17	16	16	16	15	15	19	18	18	18	18	17
	Moderate	3	3	4	4	4	4	3	3	4	4	5	6
	Severe	5	6	6	6	6	6	4	5	6	6	7	8
	Severe	121	127	2	19	49	73	82	118	144	148	185	178
	Severe	33	36	38	39	37	37	27	27	30	29	29	30
	Moderate	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	70	53	21	11	9	9	71	54	23	21	28	43
	0–17.9 in	17	15	11	8	6	6	17	15	11	9	11	19
	18–29.9 in	5	4	4	4	3	3	5	4	4	4	4	4
	30–36 in												

Table 20b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	2	5	6	8	9	10	2	5	9	12	14	17
	0–3 in												
	3–6 in	2	2	2	2	2	2	2	2	2	2	2	3
	6–12 in	2	3	4	4	3	3	2	3	4	4	5	6
	>12 in	0	3	6	7	7	7	0	3	6	7	9	13
	Litter	1	1	1	1	1	1	1	1	1	1	1	1
	Duff	15	15	14	14	14	14	17	17	16	16	16	16
	Moderate	1	2	2	3	3	3	1	2	3	4	4	5
	Severe	5	4	4	4	5	5	1	3	4	5	6	8
	Severe	208	250	20	281	109	116	468	389	233	26	194	185
Prescribed fire	Surface fuel loadings (tons/ac)	33	34	36	36	35	34	27	27	29	29	29	32
	0–3 in												
	3–6 in	2	2	2	2	2	2	2	3	3	2	2	2
	6–12 in	3	5	6	5	5	4	4	7	8	7	7	7
	>12 in	0	4	9	10	10	10	0	4	9	11	12	13
	Litter	1	1	1	1	1	1	1	1	1	1	1	1
	Duff	12	11	11	11	11	11	17	13	13	13	12	12
	Moderate	1	2	3	3	3	4	1	2	4	4	4	5
	Severe	5	5	5	5	5	6	1	4	6	6	7	7
	Severe	166	189	11	44	77	85	456	219	2	16	36	46
Type of fire	Surface fuel loadings (tons/ac)	36	38	39	38	38	37	32	31	32	32	32	32
	0–3 in												
	3–6 in	2	2	2	2	2	2	2	3	3	2	2	2
	6–12 in	3	5	6	5	5	4	4	7	8	7	7	7
	>12 in	0	4	9	10	10	10	0	4	9	11	12	13
	Litter	1	1	1	1	1	1	1	1	1	1	1	1
	Duff	12	11	11	11	11	11	17	13	13	13	12	12
	Moderate	1	2	3	3	3	4	1	2	4	4	4	5
	Severe	5	5	5	5	5	6	1	4	6	6	7	7
	Severe	166	189	11	44	77	85	456	219	2	16	36	46
Type of fire	Surface fuel loadings (tons/ac)	72	53	25	12	12	19	86	62	28	17	22	22
	0–17.9 in												
	18–29.9 in	21	19	13	8	7	7	21	19	13	9	9	10
	30–36 in	5	5	4	4	3	3	5	5	4	4	4	3
	Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42
	0–17.9 in												
	18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21
	30–36 in	5	4	4	3	3	3	5	4	4	4	4	5
	Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42
	0–17.9 in												
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4	4	3	3	3	5	4	4	4	4	5	
Surface fuel loadings (tons/ac)	70	53	20	9	8	11	71	54	21	23	29	42	
0–17.9 in													
18–29.9 in	17	15	11	6	6	6	17	15	10	9	11	21	
30–36 in	5	4											

Table 20b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	4	9	14	18	21	22	4	9	14	19	24	25
	0–3 in												
	3–6 in	7	6	6	6	7	7	7	6	6	6	8	8
	6–12 in	7	8	9	11	14	18	7	8	9	11	16	21
	>12 in	0	3	7	10	15	23	0	3	7	10	17	25
	Litter	1	1	1	2	1	1	1	1	2	2	1	1
	Duff	20	20	20	19	19	19	21	20	20	20	20	20
	Moderate	3	3	5	6	7	7	3	3	5	6	7	8
	Severe	5	5	7	8	10	10	4	5	7	8	10	11
	Severe	53	75	71	79	102	89	18	57	51	45	39	41
Pile and burn	Crowning index	20	22	24	26	26	28	20	22	23	28	28	29
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	75	70	52	72	85	62	84	81	62	95	103	90
	0–17.9 in												
	18–29.9 in	16	15	13	14	14	22	17	16	13	18	19	21
	30–36 in	5	4	4	4	5	5	5	4	4	5	5	6
	Surface fuel loadings (tons/ac)	1	7	13	17	21	22	1	7	13	18	23	25
	0–3 in												
	3–6 in	2	2	3	3	4	5	2	2	3	4	5	6
6–12 in	2	4	6	8	12	16	2	4	6	8	13	19	
>12 in	0	3	7	10	15	23	0	3	7	10	17	25	
Litter	1	1	1	2	1	1	1	1	2	2	1	1	
Duff	18	18	18	17	17	17	19	18	18	18	18	18	
Moderate	3	3	4	5	6	7	3	3	4	5	7	8	
Severe	5	4	6	7	9	10	4	4	6	8	10	11	
Severe	53	91	87	85	113	93	18	69	64	53	42	57	
None	Crowning index	20	22	24	26	26	29	20	22	23	28	29	30
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	75	70	53	80	86	61	84	81	63	96	104	98
	0–17.9 in												
	18–29.9 in	16	15	13	13	14	23	17	16	13	19	19	20
	30–36 in	5	4	4	4	5	5	5	4	4	5	5	5

Table 20b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	7	10	13	15	17	0	7	10	13	15	18
	0–3 in												
	3–6 in	2	4	4	3	3	4	2	4	4	4	4	4
	6–12 in	4	9	10	10	10	11	4	10	10	10	10	12
	>12 in	0	4	9	11	14	17	0	4	9	11	14	18
	Litter	1	1	1	1	1	2	1	1	1	1	1	1
	Duff	14	14	14	14	13	13	15	14	14	14	14	14
	Moderate	1	3	4	5	5	6	1	3	4	5	5	6
	Severe	1	5	6	7	8	9	1	5	6	7	8	9
	Torching index	439	136	122	15	141	128	444	133	124	16	130	103
	Crowning index	26	26	29	29	29	31	26	26	28	29	29	31
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	101	62	34	34	41	47	124	62	38	36	46	62
	0–17.9 in												
	18–29.9 in	21	19	14	11	13	21	21	18	14	11	14	24
	30–36 in	5	5	4	4	4	7	5	5	5	4	4	5

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 20c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	1,991	1,312	914	677	453	352	139	138	135	122	106	89
	Quadratic mean diameter (in)	5.0	6.6	8.2	9.8	12.0	13.6	5.0	18.8	20.5	22.6	24.9	27.2
	Total volume (ft ³)	10,448	12,846	14,967	16,818	17,804	18,189	10,597	12,351	15,948	18,736	20,441	21,058
	Merchantable volume (ft ³)	9,483	11,605	13,472	15,034	15,907	16,440	9,751	11,393	14,828	17,482	19,158	19,765
	Basal area (ft ²)	272	313	337	358	358	357	241	264	310	342	357	358
	Stand density index	655	675	668	660	610	580	352	378	428	454	457	442
	Canopy closure (percent)	63	78	78	77	72	69	50	52	57	59	59	58
	Crown competition factor	103	204	174	154	128	115	65	69	78	81	81	77
	Canopy base height (ft)	6	3	10	14	19	25	19	43	53	47	55	58
	Canopy bulk density (kg/m ³)	0.13	0.22	0.16	0.13	0.11	0.13	0.09	0.09	0.08	0.08	0.08	0.07

Table 20c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	947	55	153	150	146	143	140	140	147	144	140	135	130
	Quadratic mean diameter (in)	7.0	23.4	14.2	14.5	14.9	15.3	15.7	15.7	16.6	17.2	17.8	18.4	19.0
	Total volume (ft ³)	8,192	5,961	6,089	6,298	6,514	6,734	6,947	6,947	7,540	8,193	8,528	8,850	9,152
	Merchantable volume (ft ³)	7,490	5,820	5,946	6,152	6,381	6,597	6,790	6,790	7,321	7,970	8,305	8,626	8,894
	Basal area (ft ²)	252	163	167	173	178	184	189	189	210	232	241	249	257
	Stand density index	532	213	268	273	279	284	289	289	332	344	352	359	366
	Canopy cover (percent)	62	36	36	37	37	38	39	39	46	48	48	49	49
	Crown competition factor	215	117	120	123	126	131	135	135	151	162	166	170	174
	Canopy base height (ft)	3	54	54	54	51	52	5	5	28	39	39	39	39
	Canopy bulk density (kg/m ³)	0.13	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.08	0.10	0.10	0.10	0.10
Pile and burn	Trees per acre	947	55	203	199	194	190	185	173	169	164	159	153	
	Quadratic mean diameter (in)	7.0	23.4	12.3	12.6	13.0	13.3	13.7	15.3	15.8	16.4	17.0	17.6	
	Total volume (ft ³)	8,192	5,961	6,089	6,297	6,524	6,733	6,964	7,540	8,161	8,527	8,868	9,174	
	Merchantable volume (ft ³)	7,490	5,820	5,946	6,152	6,390	6,597	6,799	7,321	7,939	8,304	8,642	8,913	
	Basal area (ft ²)	252	163	167	173	179	184	189	210	231	241	250	258	
	Stand density index	532	213	283	289	295	301	307	343	353	363	371	378	
	Canopy cover (percent)	62	36	36	37	37	38	40	46	47	48	49	49	
	Crown competition factor	215	117	120	123	126	132	137	151	156	161	166	170	174
	Canopy base height (ft)	3	54	54	51	51	52	5	28	35	38	39	39	39
	Canopy bulk density (kg/m ³)	0.13	0.04	0.04	0.04	0.04	0.04	0.04	0.08	0.09	0.10	0.10	0.10	0.11
Prescribed fire	Trees per acre	947	55	351	342	335	327	319	238	232	227	220	213	
	Quadratic mean diameter (in)	7.0	23.4	9.1	9.4	9.7	10.0	10.2	12.6	13.1	13.6	14.0	14.5	
	Total volume (ft ³)	8,192	5,691	5,813	6,011	6,228	6,450	6,667	7,109	7,330	7,701	8,090	8,414	
	Merchantable volume (ft ³)	7,490	5,557	5,677	5,876	6,103	6,316	6,504	6,908	7,120	7,499	7,881	8,204	
	Basal area (ft ²)	252	163	160	165	170	177	183	210	207	217	228	236	
	Stand density index	532	213	303	309	317	325	332	347	358	370	379	387	
	Canopy cover (percent)	62	36	35	36	37	39	41	46	45	46	47	47	
	Crown competition factor	215	117	115	117	121	131	146	151	147	152	157	162	
	Canopy base height (ft)	3	55	55	54	54	4	5	28	35	38	39	39	
	Canopy bulk density (kg/m ³)	0.13	0.04	0.04	0.04	0.04	0.04	0.04	0.07	0.08	0.09	0.09	0.09	

Table 20c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	947	200	211	199	191	181	170	300	308	291	274	252	228
	Quadratic mean diameter (in)	7.0	15.0	14.9	15.6	16.3	16.9	17.5	12.4	12.5	13.2	13.9	14.5	15.2
	Total volume (ft ³)	8,192	8,257	8,559	8,957	9,438	9,724	9,771	8,444	8,749	9,222	9,669	9,695	9,738
	Merchantable volume (ft ³)	7,490	7,655	7,876	8,455	8,910	9,139	9,188	7,751	7,954	8,600	9,027	8,970	8,913
	Basal area (ft ²)	252	245	254	264	276	283	283	250	264	276	288	287	286
	Stand density index	532	383	399	406	418	421	416	422	443	454	464	455	445
	Canopy cover (percent)	62	56	57	57	58	57	57	59	60	60	61	60	59
	Crown competition factor	215	189	192	195	201	203	200	203	209	214	219	215	210
	Canopy base height (ft)	3	9	16	23	27	32	35	5	5	5	5	5	5
	Canopy bulk density (kg/m ³)	0.13	0.13	0.11	0.11	0.12	0.13	0.14	0.13	0.12	0.12	0.13	0.13	0.14
Pile and burn	Trees per acre	947	200	224	210	202	192	180	300	321	304	287	264	243
	Quadratic mean diameter (in)	7.0	15.0	14.4	15.2	15.8	16.4	17.0	12.4	12.3	12.9	13.5	14.1	14.6
	Total volume (ft ³)	8,192	8,257	8,559	8,955	9,440	9,732	9,782	8,444	8,749	9,243	9,533	9,582	9,633
	Merchantable volume (ft ³)	7,490	7,655	7,876	8,453	8,912	9,146	9,198	7,751	7,954	8,618	8,888	8,853	8,787
	Basal area (ft ²)	252	245	254	264	277	283	283	250	264	277	284	284	284
	Stand density index	532	383	404	411	423	427	421	422	446	459	463	456	448
	Canopy cover (percent)	62	56	57	57	58	57	57	59	60	61	61	60	59
	Crown competition factor	215	189	192	195	201	203	200	203	209	215	217	213	210
	Canopy base height (ft)	3	9	16	23	27	32	35	5	5	5	5	5	5
	Canopy bulk density (kg/m ³)	0.13	0.13	0.11	0.11	0.12	0.13	0.14	0.13	0.12	0.12	0.13	0.13	0.14
Prescribed fire	Trees per acre	947	200	235	221	213	205	198	300	262	247	232	217	197
	Quadratic mean diameter (in)	7.0	15.0	13.7	14.4	15.0	15.6	16.2	12.4	12.9	13.5	14.2	14.9	15.7
	Total volume (ft ³)	8,192	7,856	8,164	8,539	8,988	9,460	9,910	7,688	8,021	8,407	8,752	9,090	9,270
	Merchantable volume (ft ³)	7,490	7,362	7,601	8,121	8,560	8,987	9,445	7,205	7,463	7,979	8,321	8,599	8,766
	Basal area (ft ²)	252	245	241	250	262	273	285	250	237	247	255	264	266
	Stand density index	532	383	390	397	409	420	431	422	393	402	408	412	408
	Canopy cover (percent)	62	56	54	54	55	55	56	59	54	54	54	54	54
	Crown competition factor	215	189	179	183	189	194	200	203	180	184	187	190	189
	Canopy base height (ft)	3	9	16	23	27	32	35	9	6	6	6	6	35
	Canopy bulk density (kg/m ³)	0.13	0.10	0.10	0.10	0.11	0.12	0.12	0.09	0.09	0.10	0.10	0.11	0.11

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 20d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only								
	Fuel models			Fuel models			Fuel models			Fuel models					
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight
None	1	10	100				8	100							
	10	10	78	12	22		10	98	12	2					
	20	12	69	13	31		10	60	12	40					
	30	13	92	12	8		12	59	10	41					
	40	13	100				12	80	10	20					
50	13	100				12	77	13	23						

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit								
	Fuel models			Fuel models			Fuel models			Fuel models					
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight
None	1	10	99	5	1		10	70	8	30					
	10	10	92	12	8		10	94	12	6					
	20	10	82	12	18		10	71	12	29					
	30	10	82	12	18		10	57	12	43					
	40	10	81	12	19		12	62	10	38					
50	10	80	12	20		12	98	13	2						
Pile and burn	1	5	65	8	35		8	100							
	10	8	47	5	33		8	70	10	30					
	20	10	63	8	32		10	90	8	10					
	30	10	83	8	17		10	83	12	17					
	40	10	94	8	6		10	57	12	43					
50	10	96	12	4		12	83	10	17						
Prescribed fire	1	5	73	8	27		8	100							
	10	5	46	8	29		10	59	8	41					
	20	10	82	8	12		10	84	12	16					
	30	10	95	12	5		10	69	12	31					
	40	10	89	12	11		10	54	12	46					
50	10	80	12	20		12	64	10	36						

Table 20d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit												
	Fuel models					Fuel models					Fuel models					Fuel models							
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight		
None	1	10	100																				
	10	10	91	12	9																		
	20	12	59	10	41																		
	30	12	100																				
	40	12	51	13	49																		
50	13	85	12	15																			
Pile and burn	1	10	100																				
	10	10	100																				
	20	10	74	12	26																		
	30	12	74	10	26																		
	40	12	66	13	34																		
50	13	72	12	28																			
Prescribed fire	1	8	100																				
	10	10	100	8																			
	20	10	60	12	40																		
	30	12	63	10	37																		
	40	12	85	10	15																		
50	12	87	13	13																			

tpa = trees per acre, d.b.h. = diameter at breast height.

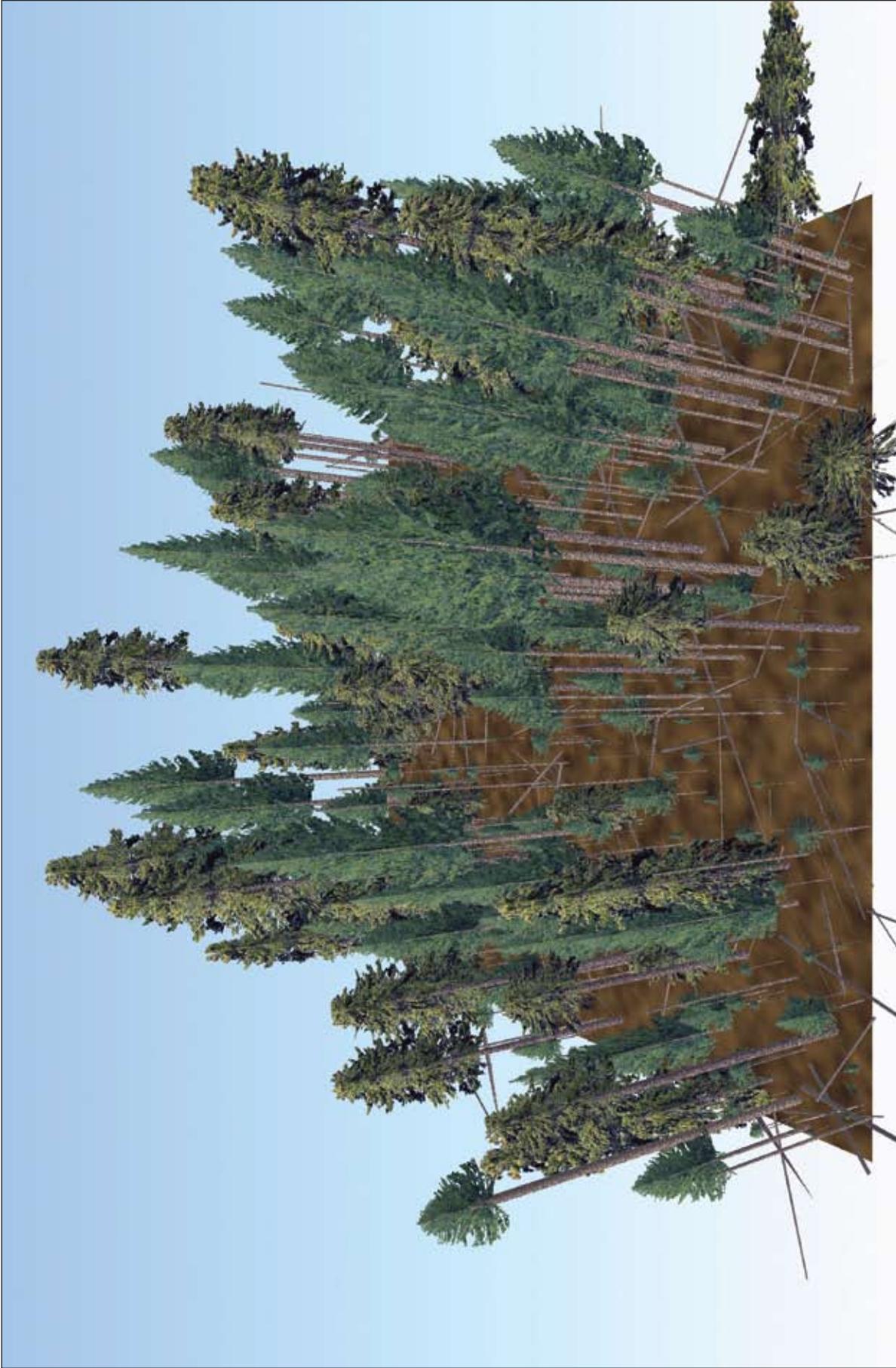
Table 20e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0-0.25 in)	10-hr (0.25-1 in)	100-hr (1-3 in)	1,000-hr (3+ in)	Live	
Severe—98 th percentile	17	83	2	5	10	15	50	100
Moderate—75 th percentile	11	72	5	7	15	17	125	150

Table 20f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).

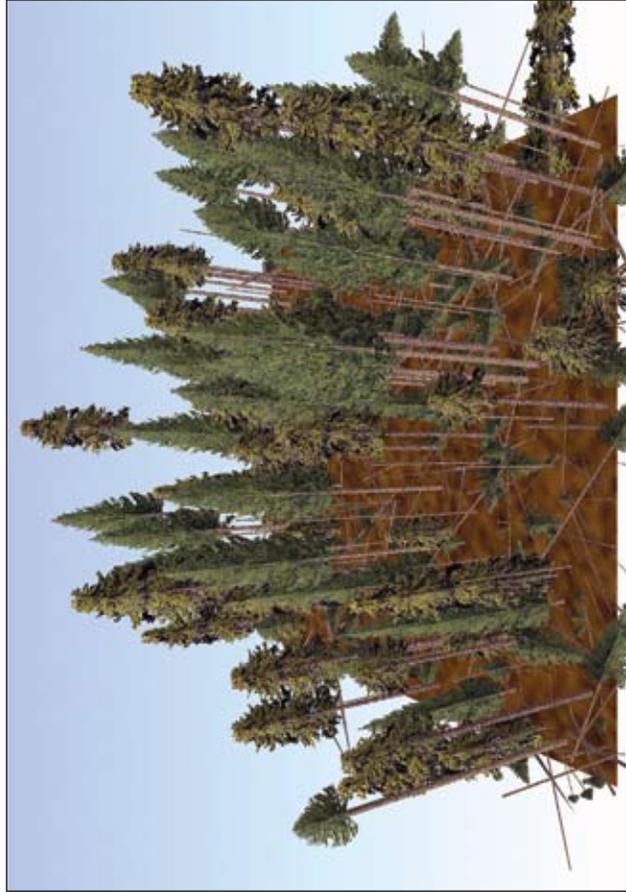


Initial stand conditions

Site: Elevation = 4,700 ft, slope = 30 percent, aspect = 135°.

Species (based on trees per acre): White fir (*Abies concolor*) = 99 percent, ponderosa pine (*Pinus ponderosa*) = 1 percent.

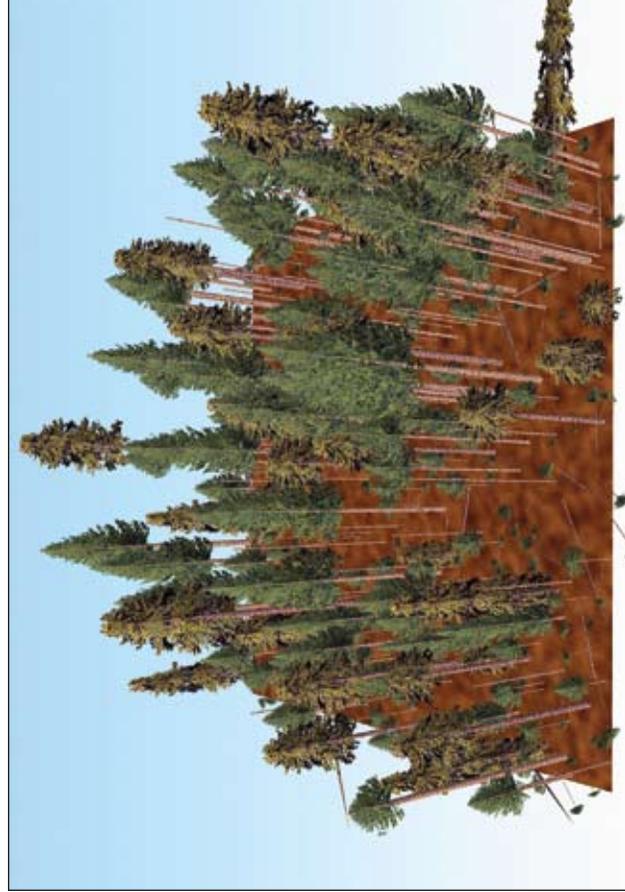
Stand attributes: Stem density = 1,345 tpa, basal area = 246 ft²/ac, top height = 106 ft, stand density index = 559, quadratic mean diameter = 5.8 in, crown competition factor = 195, canopy cover = 60 percent.



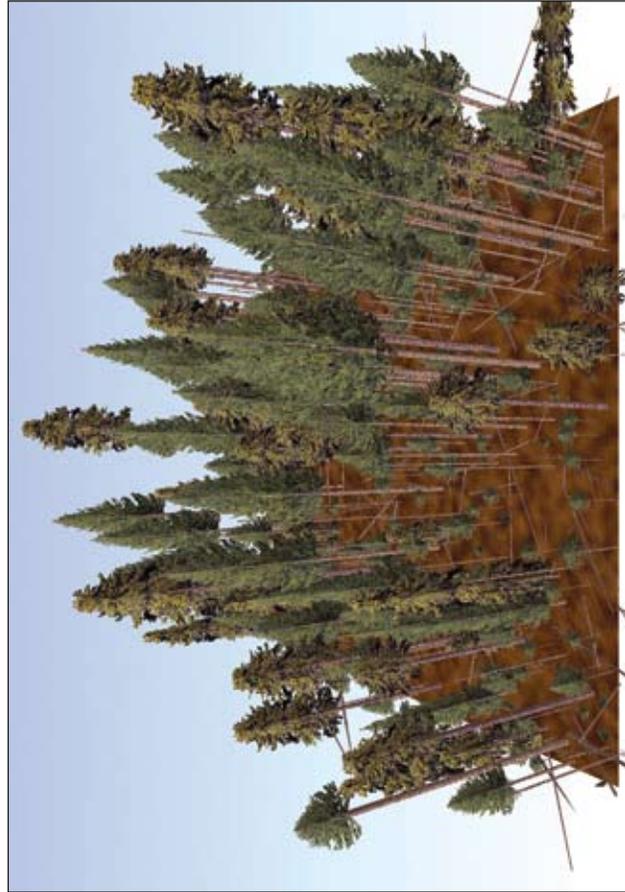
Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has 1,345 trees per acre (tpa) composed of primarily white fir understory with a ponderosa pine overstory. Canopy base height is 4 ft, and canopy bulk density is 0.21 kg/m³ (0.0131 lb/ft³), so initial conditions are conducive to passive crown fire and active crown fire spread. Potential flame lengths and mortality are high especially for severe fire weather for which 100-percent basal area mortality is predicted. Woody fuel and duff loadings are high at 30 tons/ac and 20 tons/ac respectively. With no action, canopy base height increases and canopy bulk density decreases as the trees grow and the stand self-thins. Within 10 years, canopy bulk density decreases sufficiently to prevent active crown fire spread, but passive crown fire remains likely for the 50-year projection.

Silvicultural and surface fuel treatments—immediate effects

Prescribed fire only increases canopy base height to 16 ft, reduces canopy bulk density to 0.10 kg/m³ (0.0062 lb/ft³), and decreases crown fire potential, but snag density doubles. Fuel loadings, potential flame lengths, and basal area mortality are also reduced. All thinning treatments effectively reduce canopy bulk density and increase canopy base height enough to reduce crown fire potential; the greater the thinning, the greater the reduction in fire hazard. Thinning without surface fuel treatments increases surface fuels; the greater the thinning, the greater are activity fuels and potential flame lengths. Pile and burn reduces woody surface fuels in all size classes, decreasing flame length and tree mortality. Prescribed fire reduces surface fuel loading even more, but reduces primarily litter, duff, and fine woody fuels. Woody fuel loading in the larger size classes remains high following prescribed fire, so fuel model 11 remains the predominant model and flame lengths are higher than in the pile and burn treatment.

Silvicultural and surface fuel treatments—long-term effects

Crown fire remains unlikely for the 50-year projection for all combinations of thinning and surface fuel treatments except the 50 tpa treatment, in which greater regeneration causes a decrease in canopy base height allowing for passive crown fire again in 50 years with no surface fuel treatment or with pile and burn, and in 40 years for the prescribed fire treatment. At this time, a second treatment would be necessary to reduce crown fire potential. It may seem contradictory that the treatment with the greatest reduction in surface fuel loading and tree density would have the most fleeting effect on crown fire potential, but this demonstrates the important influence of regeneration on crown fire potential as predicted with FFE. For all other treatments, canopy base height and canopy bulk density increase as the trees grow and the stand self-thins.

Table 21a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	0-3 in	4	12	9	8	7
		3-6 in	1	7	7	6	5
	>12 in	6-12 in	3	7	7	7	7
		>12 in	8	12	12	12	12
	Flame length (ft)	Litter	2	4	3	3	3
		Duff	20	14	20	20	20
	Torching index	Moderate	4	3	5	4	4
		Severe	5	4	7	5	6
	Crowning index	Severe	0	41	111	61	56
		Severe	14	26	32	23	18
Potential basal area mortality (%)	Moderate	Passive	Surface	Surface	Surface	Surface	Surface
	Severe	Active	Surface	Surface	Surface	Surface	Surface
Pile and burn	Surface fuel loadings (tons/ac)	0-3 in	12	10	13	14	18
		3-6 in	3	3	3	2	2
	>12 in	6-12 in	2	2	2	2	2
		>12 in	3	3	3	3	3
	Flame length (ft)	Litter	4	4	3	3	3
		Duff	18	18	18	18	18
	Torching index	Moderate	8	4	2	2	2
		Severe	1	5	3	3	3
	Crowning index	Severe	63	63	66	71	71
		Severe	32	32	23	18	15
Potential basal area mortality (%)	Moderate	Severe	Surface	Surface	Surface	Surface	
	Severe	Severe	Surface	Surface	Surface	Surface	
Prescribed fire	Surface fuel loadings (tons/ac)	0-3 in	5	5	9	13	14
		3-6 in	1	1	1	1	1
	>12 in	6-12 in	7	7	7	7	7
		>12 in	12	12	12	12	12
	Flame length (ft)	Litter	1	1	1	1	1
		Duff	4	4	4	4	4
	Torching index	Moderate	3	3	3	3	3
		Severe	4	4	4	4	4
	Crowning index	Severe	92	92	55	40	47
		Severe	34	34	26	26	26
Potential basal area mortality (%)	Moderate	Severe	Surface	Surface	Surface	Surface	
	Severe	Severe	Surface	Surface	Surface	Surface	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 21b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	6	6	6	6	6	6	4	6	5	4	4	4
	3–6 in	5	7	8	8	8	8	1	5	5	5	5	5
	6–12 in	7	11	15	15	14	14	3	11	13	13	12	11
	>12 in	12	18	23	28	29	30	8	15	21	25	26	24
	Litter	2	3	3	3	3	3	1	2	2	2	2	2
	Duff	20	21	21	21	21	21	14	14	14	15	15	15
	Moderate	4	5	6	6	6	6	3	5	5	6	5	5
	Severe	5	7	8	8	8	8	4	7	7	7	7	7
	Severe	0	0	0	0	0	0	41	27	26	29	37	45
	Severe	14	16	18	20	21	23	26	25	24	22	22	21
	Moderate	Passive	Passive	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Active	Passive	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	0–17.9 in	222	277	188	164	132	113	440	75	43	23	15	12
	18–29.9 in	25	23	19	13	10	8	27	23	17	10	6	4
	30–36 in	2	2	2	1	1	1	2	2	2	1	1	1

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	12	7	4	3	3	3	9	6	4	4	4	4
	3–6 in	7	8	9	8	7	6	7	8	9	8	7	7
	6–12 in	7	12	14	13	12	10	7	12	15	14	12	11
	>12 in	12	17	22	25	25	23	12	17	22	25	26	25
	Litter	4	1	1	2	2	2	3	2	2	2	2	2
	Duff	20	21	21	20	20	20	20	21	21	21	21	21
	Moderate	5	6	6	6	6	5	4	5	6	6	6	5
	Severe	7	8	8	8	7	7	6	7	8	8	8	7
	Severe	111	76	76	78	79	0	61	32	33	35	39	43
	Severe	32	31	30	30	29	29	23	22	21	20	19	19
	Moderate	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	0–17.9 in	143	101	34	19	11	9	144	102	38	24	17	13
	18–29.9 in	24	22	16	10	6	3	24	21	15	10	7	5
	30–36 in	2	2	2	1	1	1	2	2	2	1	1	1

Table 21b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
Pile and burn	Surface fuel loadings (tons/ac)	3	4	3	3	3	3	3	4	3	3	3	4	4
	3–6 in	2	4	5	5	4	4	2	4	5	5	5	5	4
	6–12 in	2	7	11	10	9	8	2	7	11	10	10	10	9
	>12 in	3	10	16	19	20	19	3	10	16	19	20	20	20
	Litter	4	1	1	2	2	2	3	2	2	2	2	2	2
	Duff	18	18	18	18	18	18	18	18	18	18	18	18	18
	Moderate	4	3	4	5	4	4	2	3	4	4	5	5	5
	Severe	5	5	6	6	6	6	3	5	6	6	6	6	6
	Severe	63	120	91	89	90	2	66	64	46	45	48	48	51
	Severe	32	31	30	30	29	29	23	22	21	20	19	19	19
	Moderate	Surface	Surface	Surface	Surface	Surface	Passive	Surface						
	Severe	Surface	Surface	Surface	Surface	Surface	Passive	Surface						
	Hard snags (stems/ac)	143	101	35	20	11	10	144	102	35	23	16	14	14
18–29.9 in	24	22	15	10	5	3	24	21	15	10	6	4	4	
30–36 in	2	2	2	1	1	1	2	2	2	1	1	1	1	
Prescribed fire	Surface fuel loadings (tons/ac)	1	3	3	2	3	3	1	4	3	3	3	3	3
	3–6 in	3	6	6	5	5	5	2	6	6	6	5	5	5
	6–12 in	7	13	15	13	12	11	7	14	16	15	14	12	12
	>12 in	12	18	24	27	27	25	12	19	24	28	28	27	27
	Litter	1	1	1	1	2	2	3	2	2	2	2	2	2
	Duff	4	4	5	5	5	5	18	4	5	5	5	5	6
	Moderate	3	5	6	6	5	5	3	5	6	6	6	6	6
	Severe	4	7	8	8	7	7	4	7	8	8	8	7	7
	Severe	92	79	76	78	0	0	55	32	32	33	36	40	40
	Severe	34	33	32	31	30	30	26	25	24	22	22	21	21
	Moderate	Surface	Surface	Surface	Surface	Surface	Passive	Surface						
	Severe	Surface	Surface	Surface	Surface	Surface	Passive	Surface						
	Hard snags (stems/ac)	103	64	36	26	20	15	119	74	43	28	19	15	15
18–29.9 in	27	24	17	10	6	3	27	23	17	11	7	4	4	
30–36 in	2	2	2	1	1	1	2	2	2	1	1	1	1	

Table 21b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit								
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs		
None	Surface fuel loadings (tons/ac)	0–3 in	8	6	5	5	5	6	7	6	5	6	6	6	6
		3–6 in	6	7	8	8	7	7	5	7	8	8	7	7	7
		6–12 in	7	11	14	14	13	13	7	11	15	14	14	14	13
	Flame length (ft)	>12 in	12	17	22	26	26	26	12	17	23	26	27	27	27
		Litter	3	3	3	3	3	3	3	3	3	3	3	3	3
		Duff	20	21	21	21	21	21	20	21	21	21	21	21	21
	Torching index	Moderate	4	5	6	6	6	6	4	5	6	6	6	6	6
		Severe	5	7	8	8	8	8	6	7	7	8	8	8	8
		Severe	56	28	27	28	30	32	22	17	14	14	18	18	18
	Type of fire	Severe	18	17	19	20	20	20	15	15	17	18	20	21	21
		Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface
	Pile and burn	Surface fuel loadings (tons/ac)	0–17.9 in	145	108	50	32	29	41	159	121	64	50	43	50
			18–29.9 in	24	21	16	11	8	8	25	22	17	12	8	8
			30–36 in	2	2	2	1	1	1	2	2	2	1	1	1
Flame length (ft)		0–3 in	2	4	5	5	5	6	2	4	5	5	6	7	
		3–6 in	2	4	5	5	5	5	2	4	5	5	5	6	
		6–12 in	2	7	11	11	10	10	2	7	11	11	11	11	
Torching index		>12 in	3	10	16	20	21	22	3	10	16	21	23	23	
		Litter	3	3	3	3	3	3	3	3	3	3	3	3	
		Duff	18	18	18	19	19	19	18	18	18	19	19	19	
Type of fire		Moderate	2	3	4	5	5	5	2	3	5	5	5	5	
		Severe	3	4	6	7	7	7	3	5	6	7	7	7	
		Severe	71	58	38	38	38	38	71	37	24	22	25	23	
Hard snags (stems/ac)		0–17.9 in	145	108	50	31	31	43	159	121	65	50	43	52	
		18–29.9 in	24	21	16	10	8	8	25	22	17	12	8	8	
		30–36 in	2	2	2	1	1	1	2	2	2	1	1	1	

Table 21b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	1	4	4	4	4	4	1	5	4	4	4	4
	0–3 in												
	3–6 in	2	7	7	6	6	5	2	7	7	6	6	6
	6–12 in	7	14	16	15	14	12	7	14	16	15	14	12
	>12 in	12	19	24	28	28	27	12	19	24	28	28	27
	Litter	1	2	2	2	2	2	1	2	2	2	2	2
	Duff	0	0	1	1	2	2	0	0	1	1	2	2
	Moderate	3	5	6	6	6	6	3	5	6	6	6	6
	Severe	4	7	8	8	8	8	4	7	8	8	8	7
	Torching index	40	24	25	32	35	39	47	24	24	25	29	33
	Crowning index	26	25	24	22	22	21	26	25	24	23	22	21
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Hard snags (stems/ac)	0–17.9 in	136	75	44	27	20	17	162	75	44	27	20	16
	18–29.9 in	27	23	17	11	7	4	27	23	17	11	6	4
	30–36 in	2	2	2	1	1	1	2	2	2	1	1	1

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 21c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	1,345	1,145	988	863	761	676	127	124	119	113	107	103
	Quadratic mean diameter (in)	5.8	6.4	7.0	7.6	8.2	8.9	5.8	18.3	19.4	20.4	21.5	22.5
	Total volume (ft ³)	8,959	9,333	9,676	9,982	10,238	10,495	8,421	8,761	9,362	9,976	10,437	10,924
	Merchantable volume (ft ³)	8,280	8,584	8,851	9,352	9,717	9,961	8,014	8,321	8,881	9,605	10,125	10,582
	Basal area (ft ²)	246	257	266	274	282	290	217	227	243	259	271	284
	Stand density index	559	561	560	559	559	558	318	327	343	357	367	378
	Canopy closure (percent)	60	60	59	58	58	57	45	46	47	48	48	49
	Crown competition factor	195	193	191	190	189	189	141	145	152	159	163	168
	Canopy base height (ft)	4	5	6	6	6	7	16	18	19	21	24	27
	Canopy bulk density (kg/m ³)	0.21	0.18	0.15	0.14	0.12	0.12	0.10	0.10	0.11	0.12	0.12	0.13

Table 2.1c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	1,345	50	149	145	141	137	132	100	147	142	135	129	124
	Quadratic mean diameter (in)	5.8	26.0	15.6	16.2	16.9	17.6	18.2	20.1	17.2	18.1	19.1	19.9	20.8
	Total volume (ft ³)	8,959	7,789	8,025	8,522	9,001	9,419	9,825	8,996	9,330	9,964	10,466	10,927	11,370
	Merchantable volume (ft ³)	8,280	7,600	7,829	8,318	8,774	9,176	9,595	8,654	8,969	9,607	10,067	10,656	11,069
	Basal area (ft ²)	246	184	196	208	219	230	240	220	238	255	267	279	291
	Stand density index	559	232	302	315	327	337	347	306	352	369	379	390	400
	Canopy cover (percent)	60	35	35	36	37	38	39	44	45	46	47	47	48
	Crown competition factor	195	111	116	122	127	132	138	139	147	154	159	164	168
	Canopy base height (ft)	4	44	48	48	48	47	5	21	22	24	25	26	27
	Canopy bulk density (kg/m ³)	0.21	0.07	0.08	0.08	0.08	0.08	0.09	0.11	0.12	0.13	0.13	0.14	0.14
Pile and burn	Trees per acre	1,345	50	199	194	188	184	178	100	173	169	162	155	149
	Quadratic mean diameter (in)	5.8	26.0	13.5	14.1	14.6	15.2	15.8	20.1	15.9	16.7	17.5	18.3	19.1
	Total volume (ft ³)	8,959	7,789	8,025	8,532	9,011	9,469	9,878	8,996	9,330	10,038	10,598	11,082	11,548
	Merchantable volume (ft ³)	8,280	7,600	7,829	8,327	8,784	9,224	9,644	8,654	8,969	9,677	10,192	10,799	11,243
	Basal area (ft ²)	246	184	196	208	220	231	241	220	238	257	271	284	296
	Stand density index	559	232	320	334	347	360	370	306	364	385	398	409	420
	Canopy cover (percent)	60	35	35	36	37	38	40	44	45	47	47	48	49
	Crown competition factor	195	111	116	122	127	133	140	139	147	155	161	166	171
	Canopy base height (ft)	4	44	48	48	48	47	5	21	22	24	25	26	27
	Canopy bulk density (kg/m ³)	0.21	0.07	0.08	0.08	0.08	0.08	0.09	0.11	0.12	0.13	0.14	0.14	0.15
Prescribed fire	Trees per acre	1,345	50	346	340	329	316	306	100	227	218	208	199	191
	Quadratic mean diameter (in)	5.8	26.0	9.9	10.4	10.8	11.3	11.8	20.1	13.2	13.9	14.7	15.3	16.0
	Total volume (ft ³)	8,959	7,417	7,641	8,158	8,598	8,991	9,403	8,297	8,597	9,174	9,677	10,131	10,575
	Merchantable volume (ft ³)	8,280	7,238	7,455	7,962	8,377	8,763	9,181	8,026	8,313	8,900	9,368	9,881	10,305
	Basal area (ft ²)	246	184	187	199	210	220	231	220	217	231	244	255	267
	Stand density index	559	232	343	360	373	384	397	306	356	372	384	395	407
	Canopy cover (percent)	60	35	34	35	36	39	40	44	41	42	43	44	44
	Crown competition factor	195	111	111	117	122	132	140	139	132	139	144	149	154
	Canopy base height (ft)	4	44	48	48	48	4	5	21	22	24	25	26	28
	Canopy bulk density (kg/m ³)	0.21	0.07	0.07	0.08	0.08	0.08	0.08	0.10	0.10	0.11	0.12	0.12	0.13

Table 21c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	1,345	200	216	199	188	171	150	300	301	272	245	220	190
	Quadratic mean diameter (in)	5.8	14.7	14.9	15.9	16.9	18.0	19.2	12.2	12.6	13.7	14.7	15.8	17.0
	Total volume (ft ³)	8,959	9,348	9,688	10,219	10,835	11,158	11,182	9,245	9,592	10,136	10,576	10,899	10,948
	Merchantable volume (ft ³)	8,280	8,684	8,965	9,434	10,237	10,763	10,798	8,535	8,817	9,241	9,846	10,394	10,416
	Basal area (ft ²)	246	237	260	275	292	301	301	243	263	278	290	299	301
	Stand density index	559	372	407	419	435	437	426	412	439	450	457	458	447
	Canopy cover (percent)	60	52	54	54	55	55	53	57	58	58	58	57	56
	Crown competition factor	195	163	174	179	185	187	182	180	187	191	193	194	189
	Canopy base height (ft)	4	15	18	20	21	22	23	12	13	14	15	17	17
Canopy bulk density (kg/m ³)	0.21	0.15	0.16	0.14	0.14	0.13	0.13	0.20	0.19	0.17	0.15	0.13	0.12	
Pile and burn	Trees per acre	1,345	200	229	211	200	181	158	300	314	284	256	230	198
	Quadratic mean diameter (in)	5.8	14.7	14.4	15.5	16.4	17.5	18.7	12.2	12.4	13.4	14.4	15.5	16.7
	Total volume (ft ³)	8,959	9,348	9,688	10,243	10,871	11,162	11,189	9,245	9,592	10,140	10,589	10,946	10,982
	Merchantable volume (ft ³)	8,280	8,684	8,965	9,454	10,271	10,768	10,807	8,535	8,817	9,244	9,858	10,452	10,458
	Basal area (ft ²)	246	237	260	275	293	301	301	243	263	278	291	301	301
	Stand density index	559	372	412	425	442	442	431	412	443	454	461	464	451
	Canopy cover (percent)	60	52	54	55	55	55	53	57	58	58	58	58	56
	Crown competition factor	195	163	174	179	186	187	182	180	187	191	194	195	189
	Canopy base height (ft)	4	15	18	20	21	22	23	12	13	14	15	17	17
Canopy bulk density (kg/m ³)	0.21	0.15	0.16	0.14	0.14	0.13	0.13	0.20	0.19	0.17	0.15	0.13	0.12	
Prescribed fire	Trees per acre	1,345	200	189	181	171	163	156	300	190	182	173	164	157
	Quadratic mean diameter (in)	5.8	14.7	14.8	15.7	16.6	17.4	18.2	12.2	14.7	15.6	16.5	17.3	18.1
	Total volume (ft ³)	8,959	8,428	8,755	9,361	9,896	10,371	10,834	8,403	8,724	9,345	9,876	10,374	10,855
	Merchantable volume (ft ³)	8,280	8,024	8,319	8,887	9,503	10,070	10,520	8,017	8,319	8,899	9,472	10,066	10,517
	Basal area (ft ²)	246	237	226	242	256	269	282	243	225	241	255	268	282
	Stand density index	559	372	355	372	385	397	408	412	354	371	384	396	408
	Canopy cover (percent)	60	52	45	46	47	48	48	57	45	46	47	48	48
	Crown competition factor	195	163	143	150	156	161	166	180	142	150	155	161	166
	Canopy base height (ft)	4	15	18	20	24	25	26	18	18	20	21	22	23
Canopy bulk density (kg/m ³)	0.21	0.10	0.10	0.11	0.12	0.12	0.12	0.10	0.10	0.11	0.12	0.12	0.12	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 21d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent
None	1	10	74	12	26	10	67	9	30	2	4		
	10	12	66	10	34	10	52	12	48				
	20	12	98	13	2	12	68	10	32				
	30	12	87	13	13	12	75	10	25				
	40	12	85	13	15	12	71	10	29				
50	12	86	13	14	12	64	10	36					

Thin from below to 50 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent
None	1	14	89	11	11	14	62	11	38				
	10	12	69	10	31	12	67	10	33				
	20	12	80	10	20	12	83	10	17				
	30	12	77	10	23	12	87	10	13				
	40	12	67	10	33	12	82	10	18				
50	12	55	10	45	12	73	10	27					
Pile and burn	1	2	61	10	39	9	74	10	21	2	6		
	10	10	91	6	8	10	98	9	2				
	20	10	72	12	28	10	68	12	32				
	30	10	65	12	35	10	57	12	43				
	40	10	68	12	32	10	56	12	44				
50	10	75	12	25	10	60	12	40					
Prescribed fire	1	11	64	2	20	11	67	10	17	2	9	9	8
	10	10	55	12	45	12	56	10	44				
	20	12	67	10	33	12	81	10	19				
	30	12	71	10	29	12	87	10	13				
	40	12	66	10	34	12	83	10	17				
50	12	54	10	46	12	73	10	27					

Table 21d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit						Thin from below to 300 tpa, 18-in. d.b.h. limit						
	Fuel models						Fuel models						
	Years	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent
None	1	11	61	14	39	10	69	12	31	10	69	12	31
	10	12	62	10	38	12	65	10	35	12	65	10	35
	20	12	89	10	11	12	92	10	8	12	92	10	8
	30	12	95	10	5	12	97	13	3	12	97	13	3
	40	12	96	10	4	12	95	13	5	12	95	13	5
50	12	97	10	3	12	94	13	6	12	94	13	6	
Pile and burn	1	9	94	10	6	9	100	12	5	9	100	12	5
	10	10	100			10	95	12	46	10	95	12	46
	20	10	59	12	41	10	54	12	35	10	54	12	35
	30	12	56	10	44	12	65	10	27	12	65	10	27
	40	12	62	10	38	12	73	10	20	12	73	10	20
50	12	69	10	31	12	80	10	14	12	80	10	14	
Prescribed fire	1	11	66	10	16	10	83	9	33	10	83	9	33
	10	12	63	10	37	12	67	10	14	12	67	10	14
	20	12	85	10	15	12	86	10	8	12	86	10	8
	30	12	92	10	8	12	92	10	12	12	92	10	12
	40	12	89	10	11	12	88	10	22	12	88	10	22
50	12	80	10	20	12	78	10	3	12	78	10	3	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 21e—FVS fuel model selection

Fire weather conditions	Windspeed Miles/hour	Temperature °F	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Live	
Severe—98 th percentile	14	90	3	5	8	15	50	100
Moderate—75 th percentile	9	71	5	8	11	24	125	150

Table 21f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

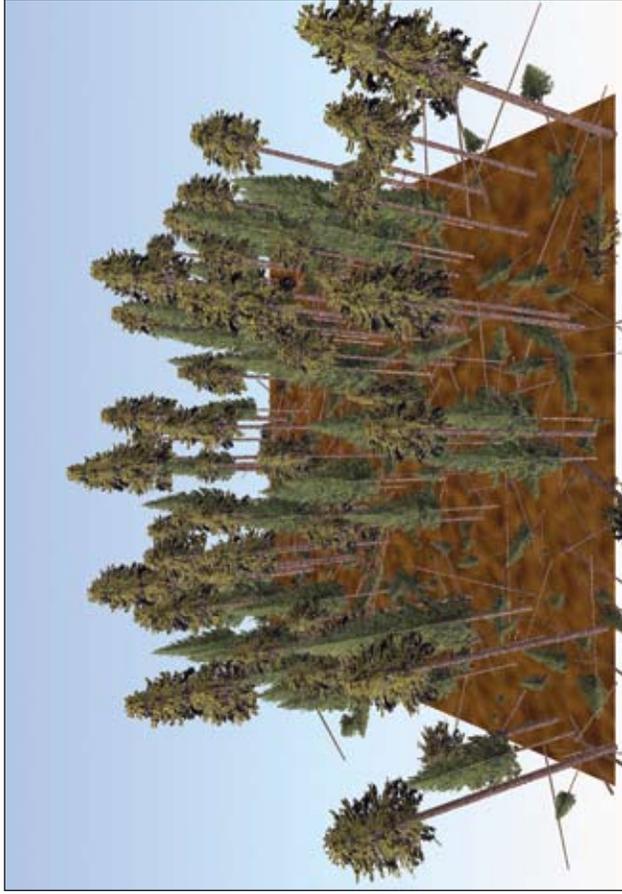
Site: Elevation = 5,300 ft, slope = 20 percent, aspect = 180°.

Species (based on trees per acre): White fir (*Abies concolor*) = 83 percent, ponderosa pine (*Pinus ponderosa*) = 11 percent, lodgepole pine (*Pinus contorta*) = 6 percent.

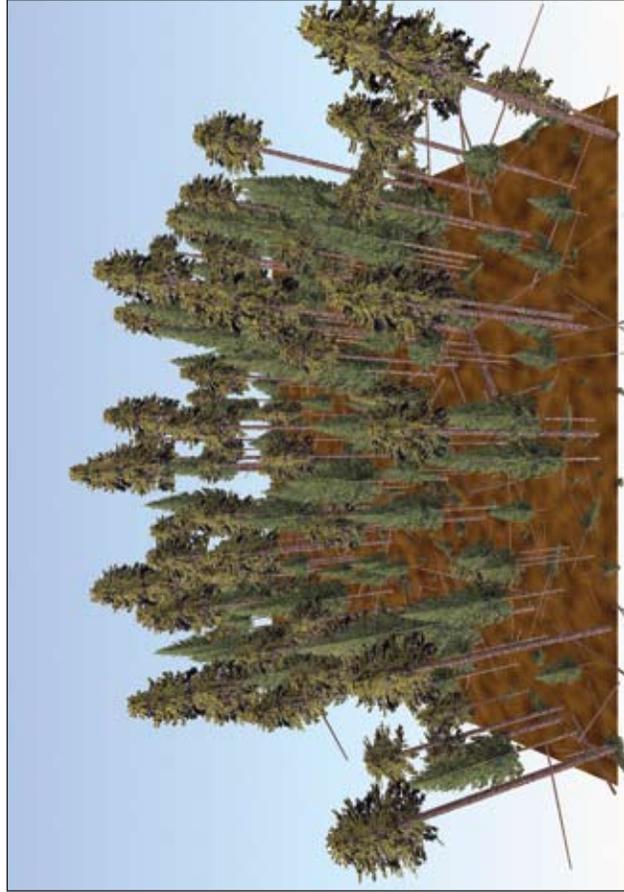
Stand attributes: Stem density = 947 tpa, basal area = 252 ft²/ac, top height = 91 ft, stand density index = 532, quadratic mean diameter = 7.0 in, crown competition factor = 215, canopy cover = 62 percent.



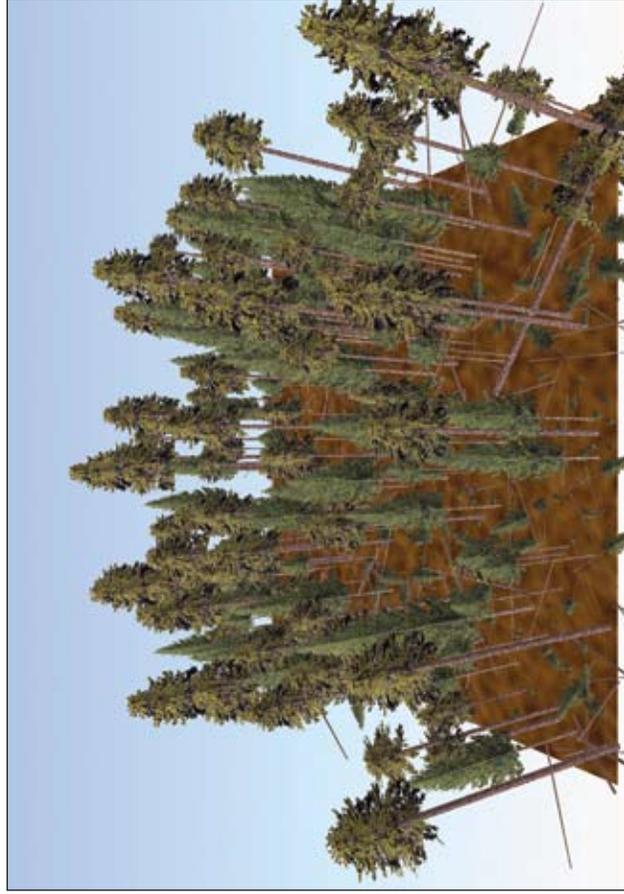
Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has 947 trees per acre (tpa) composed primarily of white fir understory with ponderosa pine and lodgepole pine overstory. Canopy bulk density is 0.13 kg/m³ (0.0081 lb/ft³), and canopy base height is 3 ft, so ladder fuels are sufficient to enable passive crown fire but not active crown fire under severe fire weather. Potential tree mortality under severe weather is 83 percent. Woody surface fuel loading is 15 tons/ac, and duff and litter loading is 12 tons/ac. With no action, surface fuels accumulate and flame lengths increase over time, and canopy base height increases only slightly with tree growth and self-thinning, so passive crown fire remains likely for the duration of the 50-year projection for severe fire weather. For moderate fire weather, the predicted fire type is surface fire for the 50-year projection.

Silvicultural and surface fuel treatments—immediate effects

Prescribed fire only increases canopy base height and reduces canopy bulk density and surface fuel loading, so crown fire potential decreases, but many snags are created that contribute to surface fuel loading in the future. All thinning treatments increase canopy base height, but the lower density treatments (50 and 100 tpa) increase canopy base height to a much greater extent than the higher density treatments (200 and 300 tpa) and also reduce canopy bulk density. The lower density treatments generate greater activity fuels and cause higher potential flame lengths. The pile and burn, and to a greater extent the prescribed fire surface fuel treatments, reduce activity fuels and potential flame lengths. In the 50 tpa treatment, fuel model 6 is the predominant model used, so flame lengths are predicted to be higher than initial conditions regardless of surface fuel treatment.

Silvicultural and surface fuel treatments—long-term effects

Canopy base height continues to increase as trees grow in the 100, 200, and 300 tpa treatments, and regeneration is not sufficient to affect canopy base height, so crown fire potential remains low for the duration of the 50-year projection. Canopy base height also increases over time in the prescribed fire only treatment, and surface fire is predicted for 50 years. Regeneration is highest in the 50 tpa treatment so canopy base height declines in 40 or 50 years, at which time a second treatment would be necessary to prevent passive crown fire. Surface fuel loading and potential flame lengths remain fairly stable over time in stands treated with a pile and burn or prescribed fire treatment. All thinning prescriptions reduce canopy bulk density sufficiently that active crown fire remains unlikely for the 50-year projection.

Table 22a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	5	4	12	9	6	5
		1	0	3	3	2	2
		2	1	2	2	2	2
		7	5	7	7	7	7
		2	1	4	3	2	2
		10	7	10	10	10	10
		2	2	4	3	2	2
		3	3	5	3	3	3
		7	35	254	209	26	16
		22	30	52	32	22	22
Pile and burn	Surface fuel loadings (tons/ac)	Surface	Surface	Surface	Surface	Surface	Surface
		Passive	Surface	Surface	Surface	Surface	Surface
		16	12	5	9	14	16
		83	12	5	9	15	17
		0-3 in	3	3	2	2	2
		3-6 in	1	1	1	1	1
		6-12 in	0	0	0	0	0
		>12 in	2	2	2	2	2
		Litter	3	3	3	2	2
		Duff	9	9	9	9	9
Prescribed fire	Flame length (ft)	Moderate	1	3	2	2	2
		Severe	5	5	3	2	2
		Severe	76	76	130	55	32
		Severe	52	52	32	22	22
		Moderate	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Surface
		Moderate	5	5	9	14	16
		Severe	5	5	9	15	16
		0-3 in	1	1	1	1	1
		3-6 in	1	1	1	1	1
Pile and burn	Surface fuel loadings (tons/ac)	1	1	1	1	1	1
		16	12	5	9	14	16
		83	12	5	9	15	17
		0-3 in	3	3	2	2	2
		3-6 in	1	1	1	1	1
		6-12 in	0	0	0	0	0
		>12 in	2	2	2	2	2
		Litter	3	3	3	2	2
		Duff	9	9	9	9	9
	Prescribed fire	Flame length (ft)	Moderate	1	3	2	2
		Severe	5	5	3	2	2
		Severe	72	72	103	49	30
		Severe	55	55	37	30	30
		Moderate	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Surface
		Moderate	5	5	8	11	12
		Severe	6	6	8	11	12
		0-3 in	1	1	1	1	1
		3-6 in	1	1	1	1	1

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 22b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	5	5	5	5	5	5	4	5	4	4	3	3	
	0–3 in	1	2	2	3	3	4	0	3	3	3	3	3	
	3–6 in	2	2	3	4	5	6	1	5	6	6	6	6	
	6–12 in	7	7	7	8	9	9	5	6	7	7	8	8	
	>12 in	2	3	3	3	3	3	1	2	2	2	2	2	
	Litter	10	10	10	10	11	11	7	7	7	7	8	8	
	Duff	2	2	2	2	2	3	2	2	2	2	2	2	
	Moderate	3	3	3	4	4	4	3	4	4	4	4	4	
	Severe	7	7	10	9	13	12	35	45	74	100	116	129	
	Severe	22	22	22	21	20	19	30	31	28	26	24	24	
Flame length (ft)	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	76	100	100	89	81	73	266	39	18	12	13	12	
	18–29.9 in	1	1	2	3	4	4	3	3	2	2	2	2	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
	Torching index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Passive	Passive	Passive	Passive	Passive	Passive	Surface						
		0–17.9 in	76	100	100	89	81	73	266	39	18	12	13	12
		18–29.9 in	1	1	2	3	4	4	3	3	2	2	2	2
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
Crowning index		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Passive	Passive	Passive	Passive	Passive	Passive	Surface						
		0–17.9 in	76	100	100	89	81	73	266	39	18	12	13	12
		18–29.9 in	1	1	2	3	4	4	3	3	2	2	2	2
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Passive	Passive	Passive	Passive	Passive	Passive	Surface						
		0–17.9 in	76	100	100	89	81	73	266	39	18	12	13	12
		18–29.9 in	1	1	2	3	4	4	3	3	2	2	2	2
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	12	6	3	2	2	2	9	5	4	3	3	3	
	0–3 in	3	3	3	3	3	3	3	3	3	3	3	3	
	3–6 in	2	2	2	2	2	2	2	2	2	2	2	2	
	6–12 in	7	7	7	6	6	6	7	7	7	7	7	7	
	>12 in	4	1	1	1	1	1	3	2	2	2	2	2	
	Litter	10	10	10	10	10	10	10	10	10	10	10	10	
	Duff	4	3	4	4	3	3	3	2	2	2	2	2	
	Moderate	5	5	5	5	5	5	3	4	3	3	3	3	
	Severe	254	125	122	111	108	8	209	101	114	122	123	122	
	Severe	52	51	50	49	49	49	32	28	26	26	25	25	
Flame length (ft)	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	36	26	10	6	6	6	38	28	12	9	11	11	
	18–29.9 in	1	1	1	2	2	2	1	1	1	1	2	2	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
	Torching index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Passive	Passive	Passive	Passive	Passive	Passive	Surface						
		0–17.9 in	36	26	10	6	6	6	38	28	12	9	11	11
		18–29.9 in	1	1	1	2	2	2	1	1	1	1	2	2
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
Crowning index		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Passive	Passive	Passive	Passive	Passive	Passive	Surface						
		0–17.9 in	36	26	10	6	6	6	38	28	12	9	11	11
		18–29.9 in	1	1	1	2	2	2	1	1	1	1	2	2
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Passive	Passive	Passive	Passive	Passive	Passive	Surface						
		0–17.9 in	36	26	10	6	6	6	38	28	12	9	11	11
		18–29.9 in	1	1	1	2	2	2	1	1	1	1	2	2
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

Table 22b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	3	2	2	2	2	2	2	3	3	3	3	3
	0–3 in												
	3–6 in	1	1	1	1	2	2	1	1	1	2	2	2
	6–12 in	0	1	1	2	1	1	0	1	2	2	2	2
	>12 in	2	2	3	3	3	4	2	2	3	4	4	4
	Litter	3	1	1	1	1	1	3	2	2	2	2	2
	Duff	9	9	9	9	9	9	9	9	9	9	9	9
	Moderate	3	4	4	4	3	3	2	2	2	2	2	2
	Severe	5	6	5	5	5	5	3	3	3	3	3	3
	Severe	76	114	107	106	105	9	130	160	153	157	154	146
Prescribed fire	Torching index	52	51	50	49	49	48	32	28	26	26	25	25
	Crowning index												
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	0–17.9 in	36	26	11	7	7	7	38	28	13	6	9	10
	18–29.9 in	1	1	1	1	2	2	1	1	1	1	1	1
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
	Surface fuel loadings (tons/ac)	1	2	2	2	2	2	1	3	3	2	2	3
	0–3 in												
	3–6 in	1	1	2	2	2	2	1	2	2	2	2	2
6–12 in	2	2	3	3	2	2	2	3	5	5	4	4	
>12 in	7	7	8	8	8	7	7	8	9	9	9	8	
Litter	0	1	1	1	1	1	3	1	1	2	2	2	
Duff	0	0	0	0	1	1	9	0	0	1	1	1	
Moderate	3	4	4	4	3	3	2	3	2	2	2	2	
Severe	5	6	6	5	5	4	3	4	4	3	3	3	
Severe	72	121	125	119	6	9	103	84	100	108	113	113	
Prescribed fire	Torching index	55	53	52	51	51	50	37	32	30	29	29	28
	Crowning index												
	Type of fire	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Moderate	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	0–17.9 in	35	25	15	11	11	10	53	38	17	11	12	12
	18–29.9 in	3	3	2	2	2	2	3	3	2	2	2	2
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
	Surface fuel loadings (tons/ac)	1	2	2	2	2	2	1	3	3	2	2	3
	0–3 in												
3–6 in	1	1	2	2	2	2	1	2	2	2	2	2	
6–12 in	2	2	3	3	2	2	2	3	5	5	4	4	
>12 in	7	7	8	8	8	7	7	8	9	9	9	8	
Litter	0	1	1	1	1	1	3	1	1	2	2	2	
Duff	0	0	0	0	1	1	9	0	0	1	1	1	
Moderate	3	4	4	4	3	3	2	3	2	2	2	2	
Severe	5	6	6	5	5	4	3	4	4	3	3	3	
Severe	72	121	125	119	6	9	103	84	100	108	113	113	
Prescribed fire	Torching index	55	53	52	51	51	50	37	32	30	29	29	28
	Crowning index												
	Type of fire	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Moderate	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	0–17.9 in	35	25	15	11	11	10	53	38	17	11	12	12
	18–29.9 in	3	3	2	2	2	2	3	3	2	2	2	2
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

Table 22b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit								
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs		
None	Surface fuel loadings (tons/ac)	0–3 in	6	5	5	4	4	5	5	5	4	4	5	5	
		3–6 in	2	2	3	3	3	3	2	2	2	3	3	4	
		6–12 in	2	2	3	4	4	5	2	2	3	4	4	5	
	Flame length (ft)	>12 in	7	7	7	8	8	8	7	7	7	7	7	9	
		Litter	2	2	2	2	2	2	2	2	2	2	2	2	
		Duff	10	10	10	10	10	11	10	10	10	10	11	11	
	Torching index	Moderate	2	2	2	2	2	2	2	2	2	2	2	3	
		Severe	3	3	3	3	3	4	3	3	3	3	4	4	
		Severe	26	54	78	93	111	118	16	16	16	16	14	12	
	Type of fire	Severe	22	24	24	23	21	21	22	22	22	21	21	21	
		Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
		Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Passive	
	Pile and burn	Surface fuel loadings (tons/ac)	0–17.9 in	51	42	28	18	17	32	48	43	30	26	46	50
			18–29.9 in	1	1	2	2	2	4	1	1	1	2	4	5
			30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	2	4	4	4	4	5	2	4	4	4	5	5	
		3–6 in	1	1	2	2	2	3	0	1	1	2	2	3	
		6–12 in	0	1	2	3	4	4	0	1	2	3	4	5	
	Flame length (ft)	>12 in	2	3	4	4	5	6	2	2	3	4	5	6	
		Litter	2	2	2	2	2	2	2	2	2	3	2	2	
		Duff	9	9	9	9	9	10	9	9	9	9	9	10	
	Torching index	Moderate	2	2	2	2	2	2	2	2	2	2	2	2	
		Severe	2	3	3	3	3	3	2	2	3	3	3	4	
		Severe	55	75	87	99	114	122	32	27	21	20	16	13	
	Type of fire	Severe	22	24	24	23	21	21	22	22	22	21	22	21	
		Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
		Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Hard snags (stems/ac)	0–17.9 in	51	42	28	18	17	34	48	43	29	28	48	51	
		18–29.9 in	1	1	2	2	2	4	1	1	1	2	4	5	
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 22b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	1	4	3	3	3	3	1	4	3	3	3	3
	0–3 in	1	3	3	3	3	3	1	3	3	3	3	3
	3–6 in	2	6	7	6	6	6	2	6	7	7	6	6
	6–12 in	7	8	9	9	9	8	7	8	9	9	9	9
	>12 in	1	2	2	2	2	2	1	2	2	2	2	2
Flame length (ft)	Litter	0	0	1	1	1	1	0	0	1	1	1	1
	Duff	2	2	3	2	2	2	2	3	3	2	2	2
	Moderate	3	4	4	4	4	4	2	4	4	4	4	4
	Severe	121	93	74	87	97	114	49	45	71	85	101	115
Torching index	Severe	30	30	29	27	26	25	30	30	29	27	26	25
	Crowning index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Hard snags (stems/ac)	0–17.9 in	70	39	17	12	14	14	92	40	20	14	15	14
	18–29.9 in	3	3	2	2	2	2	3	3	2	2	2	2
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 22c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	947	865	785	712	647	588	150	148	144	139	133	128
	Quadratic mean diameter (in)	7.0	7.4	7.9	8.4	8.9	9.4	7.0	16.7	17.3	18.0	18.7	19.4
Total volume (ft ³)	Total volume (ft ³)	8,192	8,636	8,916	9,194	9,466	9,756	7,383	7,664	8,125	8,489	8,854	9,222
	Merchantable volume (ft ³)	7,490	7,848	8,325	8,611	8,782	9,084	6,979	7,197	7,771	8,141	8,467	8,748
Basal area (ft ²)	Basal area (ft ²)	252	262	268	274	280	285	218	224	237	246	255	264
	Stand density index	532	539	538	538	537	535	329	336	349	357	365	373
Canopy closure (percent)	Canopy closure (percent)	62	62	62	61	61	61	50	50	51	52	52	53
	Crown competition factor	215	218	219	219	218	218	163	167	173	178	182	186
Canopy base height (ft)	Canopy base height (ft)	3	3	4	4	5	5	9	15	24	32	37	41
	Canopy bulk density (kg/m ³)	0.13	0.12	0.13	0.13	0.14	0.15	0.08	0.08	0.09	0.10	0.11	0.11

Table 22.c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	947	55	153	150	146	143	140	100	147	144	139	134	130
	Quadratic mean diameter (in)	7.0	23.4	14.2	14.5	14.9	15.3	15.7	19.6	16.6	17.2	17.8	18.5	19.1
	Total volume (ft ³)	8,192	5,961	6,088	6,301	6,512	6,736	6,945	7,540	7,775	8,215	8,549	8,879	9,196
	Merchantable volume (ft ³)	7,490	5,820	5,944	6,153	6,387	6,599	6,773	7,321	7,532	7,996	8,326	8,671	8,939
	Basal area (ft ²)	252	163	167	173	178	183	189	210	221	233	242	250	258
	Stand density index	532	213	268	273	279	284	289	295	332	344	352	360	367
	Canopy cover (percent)	62	36	36	37	37	38	39	46	47	48	48	49	49
	Crown competition factor	215	117	120	123	126	131	135	151	156	162	166	170	174
	Canopy base height (ft)	3	54	54	54	51	52	5	28	35	38	39	39	39
	Canopy bulk density (kg/m ³)	0.13	0.04	0.04	0.04	0.04	0.04	0.04	0.08	0.09	0.10	0.10	0.10	0.11
Pile and burn	Trees per acre	947	55	203	199	194	190	185	100	173	169	166	160	155
	Quadratic mean diameter (in)	7.0	23.4	12.3	12.6	13.0	13.3	13.7	19.6	15.3	15.9	16.4	17.0	17.6
	Total volume (ft ³)	8,192	5,961	6,088	6,300	6,520	6,735	6,960	7,540	7,775	8,186	8,609	8,980	9,317
	Merchantable volume (ft ³)	7,490	5,820	5,944	6,153	6,391	6,599	6,789	7,321	7,532	7,969	8,383	8,769	9,057
	Basal area (ft ²)	252	163	167	173	178	184	189	210	221	232	243	253	262
	Stand density index	532	213	283	289	295	301	307	295	343	354	367	376	384
	Canopy cover (percent)	62	36	36	37	37	38	40	46	47	48	49	49	50
	Crown competition factor	215	117	120	123	126	131	137	151	156	162	168	172	177
	Canopy base height (ft)	3	54	54	51	51	52	5	28	35	38	39	39	39
	Canopy bulk density (kg/m ³)	0.13	0.04	0.04	0.04	0.04	0.04	0.04	0.08	0.09	0.10	0.10	0.11	0.11
Prescribed fire	Trees per acre	947	55	351	342	335	327	319	100	233	229	221	214	207
	Quadratic mean diameter (in)	7.0	23.4	9.1	9.4	9.7	10.0	10.2	19.6	12.5	13.0	13.5	14.0	14.5
	Total volume (ft ³)	8,192	5,691	5,814	6,014	6,223	6,454	6,664	6,883	7,085	7,489	7,800	8,126	8,435
	Merchantable volume (ft ³)	7,490	5,557	5,678	5,878	6,103	6,320	6,494	6,690	6,873	7,298	7,600	7,937	8,207
	Basal area (ft ²)	252	163	160	165	170	176	183	210	200	211	219	228	236
	Stand density index	532	213	303	310	317	324	332	295	335	348	357	365	374
	Canopy cover (percent)	62	36	35	36	37	39	41	46	43	44	45	46	46
	Crown competition factor	215	117	115	117	121	131	146	151	141	147	151	156	160
	Canopy base height (ft)	3	55	55	54	54	4	5	29	35	38	38	39	39
	Canopy bulk density (kg/m ³)	0.13	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.08	0.08	0.08	0.09	0.09

Table 22c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	947	200	211	199	191	183	166	300	308	291	274	242	214
	Quadratic mean diameter (in)	7.0	15.0	14.9	15.6	16.3	17.0	17.8	12.4	12.5	13.2	13.9	14.8	15.7
	Total volume (ft ³)	8,192	8,257	8,559	8,957	9,438	9,915	9,999	8,444	8,749	9,222	9,669	9,785	9,901
	Merchantable volume (ft ³)	7,490	7,655	7,876	8,455	8,910	9,323	9,425	7,751	7,954	8,600	9,027	9,091	9,131
	Basal area (ft ²)	252	245	254	264	276	288	288	250	264	276	288	288	288
	Stand density index	532	383	399	406	418	429	420	422	443	454	464	453	442
	Canopy cover (percent)	62	56	57	57	58	58	57	59	60	60	61	60	58
	Crown competition factor	215	189	192	195	201	206	203	203	209	214	219	214	210
	Canopy base height (ft)	3	9	16	23	27	32	36	5	5	5	5	5	5
	Canopy bulk density (kg/m ³)	0.13	0.13	0.11	0.11	0.12	0.13	0.13	0.13	0.12	0.12	0.13	0.13	0.13
Pile and burn	Trees per acre	947	200	224	210	202	194	175	300	321	304	286	251	223
	Quadratic mean diameter (in)	7.0	15.0	14.4	15.2	15.8	16.5	17.4	12.4	12.3	12.9	13.6	14.5	15.4
	Total volume (ft ³)	8,192	8,257	8,559	8,955	9,440	9,917	10,001	8,444	8,749	9,243	9,677	9,783	9,906
	Merchantable volume (ft ³)	7,490	7,655	7,876	8,453	8,912	9,324	9,424	7,751	7,954	8,618	9,033	9,082	9,134
	Basal area (ft ²)	252	245	254	264	277	288	288	250	264	277	288	288	288
	Stand density index	532	383	404	411	423	433	424	422	446	459	468	456	445
	Canopy cover (percent)	62	56	57	57	58	58	57	59	60	61	61	60	58
	Crown competition factor	215	189	192	195	201	206	203	203	209	215	219	214	210
	Canopy base height (ft)	3	9	16	23	27	32	36	5	5	5	5	5	5
	Canopy bulk density (kg/m ³)	0.13	0.13	0.11	0.11	0.12	0.13	0.13	0.13	0.12	0.12	0.13	0.13	0.13
Prescribed fire	Trees per acre	947	200	206	202	195	188	181	300	223	217	208	201	194
	Quadratic mean diameter (in)	7.0	15.0	14.1	14.6	15.2	15.9	16.5	12.4	13.6	14.1	14.7	15.3	15.9
	Total volume (ft ³)	8,192	7,369	7,642	8,136	8,555	8,972	9,380	7,385	7,660	8,119	8,518	8,917	9,351
	Merchantable volume (ft ³)	7,490	6,982	7,201	7,797	8,206	8,602	9,037	6,981	7,201	7,760	8,144	8,518	8,906
	Basal area (ft ²)	252	245	223	236	247	258	268	250	224	236	247	257	268
	Stand density index	532	383	357	372	384	394	404	422	364	378	388	399	409
	Canopy cover (percent)	62	56	50	51	52	52	53	59	50	51	52	53	53
	Crown competition factor	215	189	164	171	177	181	187	203	166	173	178	183	189
	Canopy base height (ft)	3	25	31	24	28	31	36	9	15	23	27	32	36
	Canopy bulk density (kg/m ³)	0.13	0.08	0.08	0.09	0.10	0.10	0.11	0.08	0.08	0.09	0.10	0.10	0.11

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 22d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only									
	Fuel models			Fuel models			Fuel models			Fuel models						
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent
None	1	9	54	10	46		9	83	10	17		9	61	9	39	
	10	9	50	10	50		10	68	9	32		10	68	9	32	
	20	10	66	9	34		10	66	9	34		10	66	9	34	
	30	10	75	9	25		10	61	9	39		10	60	9	40	
	40	10	87	9	13		10	60	9	40		10	61	9	39	
50	10	98	9	2		10	61	9	39		10	61	9	39		

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit									
	Fuel models			Fuel models			Fuel models			Fuel models						
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent
None	1	11	61	14	39		11	96	14	4		11	96	14	4	
	10	10	53	6	42	9	10	53	9	47		10	53	9	47	
	20	6	62	10	27	9	9	60	10	40		9	60	10	40	
	30	6	68	9	19	10	9	69	10	31		9	69	10	31	
	40	6	64	9	28	10	9	69	10	31		9	69	10	31	
50	6	58	9	36	10	9	66	10	34		9	66	10	34		
Pile and burn	1	2	73	10	21	9	9	100				9	100			
	10	6	89	9	11		9	100				9	100			
	20	6	84	9	16		9	94	10	6		9	94	10	6	
	30	6	76	9	24		9	93	10	7		9	93	10	7	
	40	6	65	9	35		9	91	10	9		9	91	10	9	
50	6	55	9	45		9	87	10	13		9	87	10	13		
Prescribed fire	1	2	100				9	74	2	26		9	74	2	26	
	10	6	94	10	6		9	55	10	34		9	55	10	34	
	20	6	83	10	13	9	9	52	10	45	6	9	52	10	45	6
	30	6	71	9	16	10	9	57	10	43	3	9	57	10	43	3
	40	6	53	9	36	10	9	60	10	40		9	60	10	40	
50	9	54	6	38	10	9	60	10	40		9	60	10	40		

Table 22d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit										
	Fuel models					Fuel models					Fuel models					Fuel models					
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None	1	11	63	9	37	10	51	9	49	10	51	9	49	10	51	9	49	10	51	9	49
	10	10	56	9	44	9	51	10	49	9	51	10	49	9	51	10	49	9	51	10	49
	20	10	61	9	39	10	53	9	47	10	53	9	47	10	53	9	47	10	53	9	47
	30	10	61	9	39	10	54	9	46	10	54	9	46	10	54	9	46	10	54	9	46
	40	10	64	9	36	10	70	9	30	10	70	9	30	10	70	9	30	10	70	9	30
50	10	78	9	22	10	95	9	5	10	95	9	5	10	95	9	5	10	95	9	5	
Pile and burn	1	9	100			9	100			9	100			9	100			9	100		
	10	9	89	10	11	9	93	10	7	9	93	10	7	9	93	10	7	9	93	10	7
	20	9	71	10	29	9	77	10	23	9	77	10	23	9	77	10	23	9	77	10	23
	30	9	66	10	34	9	71	10	29	9	71	10	29	9	71	10	29	9	71	10	29
	40	9	58	10	42	9	51	10	49	9	51	10	49	9	51	10	49	9	51	10	49
50	10	58	9	42	10	75	9	25	10	75	9	25	10	75	9	25	10	75	9	25	
Prescribed fire	1	9	100			9	100			9	100			9	100			9	100		
	10	10	67	9	33	10	71	9	29	10	71	9	29	10	71	9	29	10	71	9	29
	20	10	72	9	28	10	73	9	27	10	73	9	27	10	73	9	27	10	73	9	27
	30	10	68	9	32	10	71	9	29	10	71	9	29	10	71	9	29	10	71	9	29
	40	10	65	9	35	10	69	9	31	10	69	9	31	10	69	9	31	10	69	9	31
50	10	66	9	34	10	68	9	32	10	68	9	32	10	68	9	32	10	68	9	32	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 22e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					Live
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff	
Severe—98 th percentile	14	90	3	5	8	15	50	100
Moderate—75 th percentile	9	71	5	8	11	24	125	150

Table 22f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).

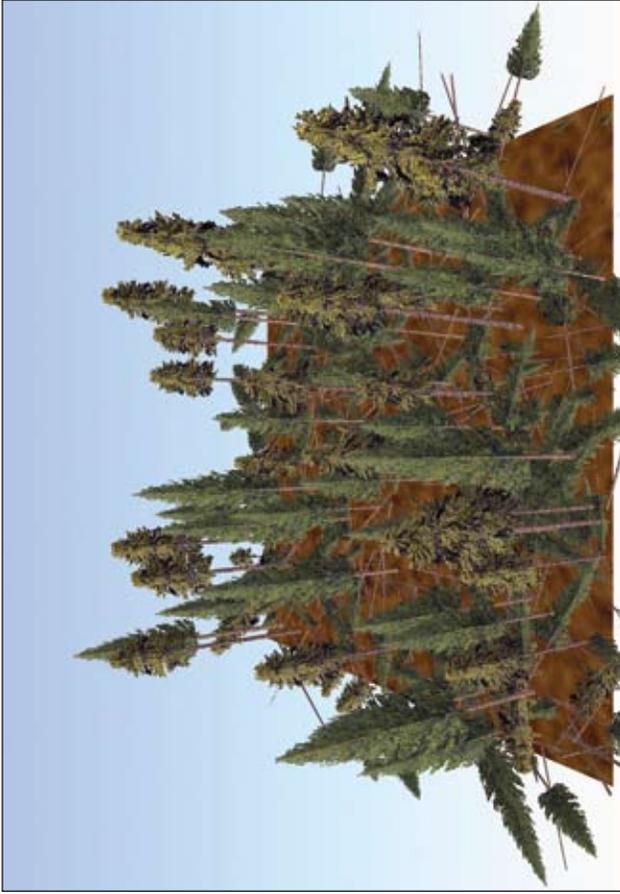


Initial stand conditions

Site: Elevation = 5,000 ft, slope = 35 percent, aspect = 270°.

Species (based on trees per acre): White fir (*Abies concolor*) = 93 percent, ponderosa pine (*Pinus ponderosa*) = 7 percent.

Stand attributes: Stem density = 544 tpa, basal area = 167 ft²/ac, top height = 84 ft, stand density index = 344, quadratic mean diameter = 7.5 in, crown competition factor = 153, canopy cover = 55 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has 544 trees per acre (tpa) composed of primarily white fir understory with ponderosa pine overstory. Canopy base height is 3 ft and canopy bulk density 0.14 kg/m^3 (0.0087 lb/ft^3), so there is high potential for passive crown fire and tree mortality but low potential for active crown fire spread under severe fire weather. Wood loading is 10 tons/ac, and litter and duff loading is 11 tons/ac. With no action, canopy base height will increase as trees grow and the stand self-thins, but flame lengths also increase as surface fuels accumulate, so crown fire potential remains essentially the same with passive crown fire likely. Canopy bulk density does not change for the 50-year projection, so the potential for active crown fire spread remains low.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment reduces tree density, which increases canopy base height enough to reduce crown fire potential, but it creates many more snags. This treatment also reduces woody surface fuels in all size classes, but potential flame lengths increase because conditions change from predominantly fuel model 9 to predominantly fuel model 2, suggesting that grass fuels drive fire behavior following the prescribed fire. This may or may not be true depending on the site. Thinning to 50 or 100 tpa greatly increases canopy base height and reduces canopy bulk density, thereby decreasing crown fire potential, but these treatments create high surface fuel loadings and increase potential flame lengths (fuel models change from predominantly 9 to predominantly 11). Thinning to 200 or 300 tpa is not sufficient to increase canopy base height, so these treatments have little effect on crown fire potential, but potential flame lengths remain low because removing fewer trees generates less activity fuels. The prescribed fire fuel treatment further decreases crown fire potential because fire-caused mortality of smaller trees further increases canopy base height. The pile and burn treatment reduces woody fuel loading to below initial conditions, and the prescribed fire treatment reduces woody fuel loading even more and consumes most of the duff layer, but these surface fuel treatments increase potential flame lengths because the more open stands with low woody fuel loading are characterized by fuel model 2. Again, grass fuels may or may not increase flame lengths depending on the site. Grass fuels are not tracked in FFE, so these results should be interpreted with caution.

Silvicultural and surface fuel treatments—long-term effects

Reductions in crown fire potential last for 30 years in the 50 tpa treatment, but then regeneration lowers canopy base height making passive crown fire likely again; at this time, another treatment would be necessary to prevent passive crown fire. In the 100 tpa treatment, the influence of regeneration on canopy base height and crown fire potential depends on the surface fuel treatment with the greatest regeneration occurring in the prescribed fire treatment. In the 200 and 300 tpa treatments, regeneration is low and canopy base height increases over time as the stand self-thins and crowns rise, so after 50 years, crown fire remains unlikely except in the prescribed fire treatment in which passive crown fire becomes likely again in 40 years.

Table 23a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit	
None	Surface fuel loadings (tons/ac)	0–3 in	3	10	7	5	4	
		3–6 in	0	4	4	3	3	
	>12 in	6–12 in	1	2	2	2	2	
		>12 in	1	1	1	1	1	
	Litter	Litter	2	4	3	3	2	
		Duff	9	6	9	9	9	
	Flame length (ft)	Moderate	2	3	3	2	2	
		Severe	3	5	4	3	3	
	Torching index	Severe	5	17	141	70	3	4
		Crowning index	19	25	43	22	19	19
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Surface	Surface	Passive	Passive	Passive	
Potential basal area mortality (%)	Moderate	24	19	11	17	22	24	
	Severe	98	31	11	17	97	98	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	3	3	2	2	1	
		3–6 in	1	1	1	1	1	
	>12 in	6–12 in	1	1	1	1	1	
		>12 in	0	0	0	0	0	
	Litter	Litter	4	4	3	2	2	
		Duff	8	8	8	8	8	
	Flame length (ft)	Moderate	4	4	4	2	2	
		Severe	7	7	6	3	3	
	Torching index	Severe	33	33	49	11	11	
		Crowning index	43	43	22	19	19	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface		
	Severe	Passive	Surface	Surface	Passive	Passive		
Potential basal area mortality (%)	Moderate	11	11	17	22	23		
	Severe	37	37	37	94	90		
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	1	1	1	1	1	
		3–6 in	2	2	2	1	1	
	>12 in	6–12 in	2	2	2	2	2	
		>12 in	1	1	1	1	1	
	Litter	Litter	1	1	1	1	1	
		Duff	0	0	0	0	0	
	Flame length (ft)	Moderate	4	4	4	4	3	
		Severe	7	7	6	5	5	
	Torching index	Severe	34	34	37	39	19	
		Crowning index	50	50	29	25	25	
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface		
	Severe	Passive	Surface	Surface	Surface	Surface		
Potential basal area mortality (%)	Moderate	10	10	15	19	19		
	Severe	38	38	43	35	31		

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 23b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	4	5	6	6	6	6	3	5	4	4	4	4
	0–3 in												
	3–6 in	3	3	4	5	5	6	0	3	3	3	4	4
	6–12 in	2	2	4	6	8	9	1	6	6	6	6	7
	>12 in	1	2	4	5	7	10	1	2	4	5	7	8
	Litter	2	3	3	3	3	3	1	2	2	2	2	2
	Duff	9	9	10	10	10	10	6	7	7	7	7	7
	Moderate	2	3	3	3	4	4	3	3	3	3	3	3
	Severe	3	4	4	4	5	6	5	5	5	4	4	5
	Severe	5	8	9	11	2	6	17	14	23	27	34	43
None	Surface fuel loadings (tons/ac)	72	100	95	87	89	79	131	18	20	22	22	22
	0–17.9 in												
	18–29.9 in	5	6	7	7	7	6	6	6	6	6	6	5
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Surface	Surface	Surface	Surface	Surface	Surface
	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Surface	Surface	Surface	Surface	Surface	Surface
None	Surface fuel loadings (tons/ac)	10	5	3	2	2	2	7	5	3	3	3	3
	0–3 in												
	3–6 in	4	3	4	4	4	3	4	3	4	4	4	4
	6–12 in	2	2	2	2	2	2	2	2	2	2	3	3
	>12 in	1	2	3	4	6	7	1	2	3	4	6	7
	Litter	4	1	1	1	1	1	3	2	2	2	2	2
	Duff	9	9	9	9	9	9	9	9	9	10	10	10
	Moderate	3	5	5	5	5	5	3	4	4	4	4	3
	Severe	4	7	7	7	7	6	4	6	5	5	5	5
	Severe	141	64	65	0	7	12	70	70	72	73	75	14
None	Surface fuel loadings (tons/ac)	43	40	38	37	35	34	22	22	22	22	21	21
	0–17.9 in												
	18–29.9 in	18	14	11	13	13	13	19	17	12	16	18	17
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Surface	Surface	Surface	Surface	Surface	Surface
	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Surface	Surface	Surface	Surface	Surface	Surface

Table 23b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
Pile and burn	Surface fuel loadings (tons/ac)	3	3	2	2	2	2	2	3	3	3	3	3	3
	0–3 in													
	3–6 in	1	1	2	2	2	2	1	1	2	2	2	2	2
	6–12 in	1	1	1	1	1	2	1	1	1	2	2	2	3
	>12 in	0	1	3	4	5	6	0	1	2	4	5	7	7
	Litter	4	1	1	1	1	1	3	2	2	2	2	2	2
	Duff	8	8	8	8	8	8	8	8	8	8	8	9	9
	Moderate	4	5	5	5	5	5	4	4	4	4	3	3	3
	Severe	7	7	7	7	7	6	6	6	6	5	5	5	5
	Severe	33	50	51	0	6	12	49	66	70	71	7	12	12
Prescribed fire	Surface fuel loadings (tons/ac)	43	40	38	37	35	34	22	22	22	22	21	20	
	0–3 in													
	3–6 in	2	2	2	3	3	3	1	3	3	3	3	3	
	6–12 in	2	3	3	3	3	3	2	5	5	5	5	5	
	>12 in	1	3	4	6	7	8	1	3	4	5	7	8	
	Litter	1	1	1	1	1	1	3	1	1	1	1	2	
	Duff	0	0	0	1	1	1	8	0	0	1	1	1	
	Moderate	4	5	5	5	5	4	4	5	5	4	4	4	
	Severe	7	7	7	7	6	5	6	7	6	6	6	5	
	Severe	34	49	60	0	8	12	37	69	74	0	7	10	
Surface fuel treatment	Surface fuel loadings (tons/ac)	50	46	44	42	27	23	29	28	28	27	26	26	
	0–3 in													
	3–6 in	2	2	2	3	3	3	1	3	3	3	3	3	
	6–12 in	2	3	3	3	3	3	2	5	5	5	5	5	
	>12 in	1	3	4	6	7	8	1	3	4	5	7	8	
	Litter	1	1	1	1	1	1	3	1	1	1	2	2	
	Duff	0	0	0	1	1	1	8	0	0	1	1	1	
	Moderate	4	5	5	5	5	4	4	5	5	4	4	4	
	Severe	7	7	7	7	6	5	6	7	6	6	6	5	
	Severe	34	49	60	0	8	12	37	69	74	0	7	10	
Type of fire	Surface fuel loadings (tons/ac)	23	17	16	19	19	19	33	18	16	20	20	30	
	0–17.9 in													
	18–29.9 in	6	6	7	6	6	5	6	6	6	6	6	5	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	
	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Passive	
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	

Table 23b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit								
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs		
None	Surface fuel loadings (tons/ac)	0–3 in	5	5	5	5	6	6	4	5	6	6	6	6	
		3–6 in	3	3	4	4	5	5	3	3	4	4	5	6	
		6–12 in	2	2	3	5	7	9	2	2	3	5	8	10	
	Flame length (ft)	>12 in	1	2	3	5	7	9	1	2	3	5	7	10	
		Litter	3	2	2	2	2	2	2	3	3	3	2	2	
		Duff	9	9	10	10	10	10	9	9	10	10	10	10	
	Torching index	Moderate	2	3	3	3	3	4	2	2	3	3	4	4	
		Severe	3	4	4	4	5	6	3	3	4	5	5	6	
		Severe	3	16	28	38	45	41	4	19	22	25	26	21	
	Type of fire	Severe	19	19	18	19	19	19	19	18	19	20	19	19	
		Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
		Severe	Passive	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	
	Pile and burn	Surface fuel loadings (tons/ac)	0–17.9 in	33	32	33	53	58	50	31	33	73	78	70	58
			18–29.9 in	5	6	6	7	7	6	5	6	6	7	7	6
			30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
Flame length (ft)		0–3 in	2	4	5	5	6	6	1	4	5	6	6	6	
		3–6 in	1	1	2	3	4	4	1	1	2	3	4	5	
		6–12 in	1	1	2	4	6	8	1	1	2	4	7	9	
Torching index		>12 in	0	1	3	4	6	9	0	1	3	4	7	9	
		Litter	2	2	2	2	2	2	2	3	3	3	2	2	
		Duff	8	8	9	9	9	9	8	8	9	9	9	9	
Type of fire	Moderate	2	2	2	3	3	4	2	2	3	3	3	4		
	Severe	3	3	3	4	5	5	3	3	4	4	5	6		
	Severe	11	26	33	40	49	77	11	29	25	26	31	27		
Hard snags (stems/ac)	0–17.9 in	33	32	33	56	60	53	31	33	74	79	71	60		
	18–29.9 in	5	6	6	7	7	6	5	6	6	7	7	6		
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0		

Table 23b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	1	4	3	3	3	4	1	4	4	3	4	4
	0–3 in												
	3–6 in	1	4	4	4	4	4	1	4	4	4	4	4
	6–12 in	2	7	7	7	7	7	2	7	7	7	7	7
	>12 in	1	3	4	6	7	8	1	3	4	6	7	9
	Litter	1	2	2	2	2	2	1	2	2	2	2	2
	Duff	0	0	1	1	1	1	0	0	1	1	1	1
	Moderate	4	4	3	3	3	3	3	3	3	3	3	3
	Severe	5	5	5	5	5	5	5	5	5	5	5	5
	Torching index	39	51	70	79	6	12	19	24	27	32	6	12
Crowning index	Severe	25	24	24	23	22	21	25	24	25	24	22	21
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Passive	Passive	
Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Surface	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Passive	Passive	
	46	18	22	24	23	27	68	24	26	26	30	29	
Hard snags (stems/ac)	0–17.9 in	6	6	6	6	6	5	6	7	6	6	5	
	18–29.9 in												
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 23c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	544	450	386	328	270	221	151	150	142	134	127	119
	Quadratic mean diameter (in)	7.5	8.4	9.3	10.1	11.2	12.4	7.5	13.2	14.0	14.9	15.9	16.8
	Total volume (ft ³)	5,004	5,325	5,616	5,817	5,899	5,950	4,306	4,541	4,932	5,328	5,729	6,097
	Merchantable volume (ft ³)	4,531	4,777	5,173	5,305	5,409	5,612	3,978	4,202	4,637	4,966	5,413	5,820
	Basal area (ft ²)	167	174	180	184	185	185	134	141	152	163	174	184
	Stand density index	344	341	340	335	324	311	223	232	244	255	266	275
	Canopy closure (percent)	55	54	53	53	51	49	40	41	42	43	43	44
	Crown competition factor	153	150	149	145	138	134	104	107	112	115	119	122
	Canopy base height (ft)	3	4	5	6	5	7	7	8	11	12	14	17
	Canopy bulk density (kg/m ³)	0.14	0.14	0.14	0.14	0.14	0.14	0.10	0.10	0.11	0.11	0.12	0.14

Table 23c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	544	50	148	143	138	133	127	100	146	143	136	129	122
	Quadratic mean diameter (in)	7.5	18.8	11.2	11.6	12.2	12.8	13.6	15.3	13.1	13.8	14.6	15.5	16.5
	Total volume (ft ³)	5,004	3,463	3,527	3,688	3,866	4,074	4,310	4,434	4,612	5,031	5,393	5,754	6,117
	Merchantable volume (ft ³)	4,531	3,342	3,423	3,574	3,737	3,948	4,161	4,212	4,425	4,811	5,155	5,558	5,906
	Basal area (ft ²)	167	96	100	105	112	119	128	127	137	148	159	170	181
	Stand density index	344	137	176	182	190	198	207	198	226	239	250	261	272
	Canopy cover (percent)	55	25	25	26	28	30	31	36	37	38	39	40	41
	Crown competition factor	153	67	68	70	79	83	88	93	96	101	106	112	117
	Canopy base height (ft)	3	30	35	35	4	7	9	29	33	35	36	36	8
	Canopy bulk density (kg/m ³)	0.14	0.05	0.05	0.06	0.06	0.06	0.07	0.12	0.12	0.12	0.12	0.12	0.13
Pile and burn	Trees per acre	544	50	198	192	185	178	171	100	172	166	157	149	142
	Quadratic mean diameter (in)	7.5	18.8	9.6	10.0	10.6	11.2	11.9	15.3	12.1	12.8	13.6	14.4	15.3
	Total volume (ft ³)	5,004	3,463	3,527	3,691	3,874	4,094	4,353	4,434	4,612	5,000	5,356	5,726	6,107
	Merchantable volume (ft ³)	4,531	3,342	3,423	3,577	3,742	3,963	4,181	4,212	4,425	4,782	5,121	5,529	5,895
	Basal area (ft ²)	167	96	100	106	113	121	131	127	137	147	158	169	181
	Stand density index	344	137	187	193	202	212	224	198	233	245	256	268	281
	Canopy cover (percent)	55	25	25	26	29	32	34	36	37	38	39	40	41
	Crown competition factor	153	67	68	70	83	88	94	93	96	100	106	113	119
	Canopy base height (ft)	3	30	35	35	4	7	9	29	33	35	36	5	7
	Canopy bulk density (kg/m ³)	0.14	0.05	0.05	0.06	0.06	0.06	0.07	0.12	0.12	0.12	0.12	0.12	0.13
Prescribed fire	Trees per acre	544	50	340	331	319	308	296	100	222	217	206	196	176
	Quadratic mean diameter (in)	7.5	18.8	7.0	7.2	7.7	8.2	8.7	15.3	9.7	10.2	10.8	11.5	12.5
	Total volume (ft ³)	5,004	3,142	3,184	3,304	3,456	3,647	3,883	3,777	3,897	4,201	4,482	4,791	4,979
	Merchantable volume (ft ³)	4,531	3,039	3,095	3,206	3,332	3,501	3,681	3,606	3,755	4,034	4,298	4,622	4,789
	Basal area (ft ²)	167	96	90	94	102	112	123	127	114	122	131	142	149
	Stand density index	344	137	190	196	208	222	239	198	211	223	234	246	250
	Canopy cover (percent)	55	25	23	25	30	34	38	36	31	32	35	37	37
	Crown competition factor	153	67	61	63	88	95	104	93	79	83	93	102	104
	Canopy base height (ft)	3	31	36	36	4	7	9	29	34	35	4	6	8
	Canopy bulk density (kg/m ³)	0.14	0.04	0.05	0.05	0.05	0.09	0.13	0.08	0.09	0.09	0.09	0.10	0.10

Table 23c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	544	200	207	190	161	137	118	300	304	251	208	174	147
	Quadratic mean diameter (in)	7.5	12.1	12.3	13.3	14.5	15.7	16.9	10.1	10.5	11.6	12.7	14.0	15.2
	Total volume (ft ³)	5,004	5,147	5,405	5,851	5,989	6,062	6,124	5,295	5,577	5,758	5,889	5,969	6,049
	Merchantable volume (ft ³)	4,531	4,665	4,919	5,478	5,588	5,735	5,865	4,730	4,995	5,292	5,368	5,478	5,666
	Basal area (ft ²)	167	161	172	183	184	184	185	166	182	183	184	184	185
	Stand density index	344	273	290	300	292	283	276	303	327	317	307	296	288
	Canopy cover (percent)	55	48	49	49	47	45	43	52	54	52	50	47	45
	Crown competition factor	153	128	131	134	129	124	121	143	149	142	136	130	125
	Canopy base height (ft)	3	3	6	10	14	17	33	3	6	8	10	13	15
Canopy bulk density (kg/m ³)	0.14	0.14	0.14	0.15	0.14	0.14	0.14	0.14	0.15	0.14	0.13	0.14	0.14	
Pile and burn	Trees per acre	544	200	220	202	170	144	123	300	317	261	215	179	150
	Quadratic mean diameter (in)	7.5	12.1	12.0	12.9	14.1	15.3	16.6	10.1	10.3	11.4	12.5	13.8	15.0
	Total volume (ft ³)	5,004	5,147	5,405	5,859	5,987	6,077	6,118	5,295	5,577	5,769	5,895	5,979	6,045
	Merchantable volume (ft ³)	4,531	4,665	4,919	5,486	5,590	5,729	5,849	4,730	4,995	5,303	5,376	5,488	5,665
	Basal area (ft ²)	167	161	172	183	184	185	185	166	182	184	184	185	185
	Stand density index	344	273	293	304	295	286	277	303	330	320	309	298	289
	Canopy cover (percent)	55	48	49	49	47	45	43	52	54	52	50	47	45
	Crown competition factor	153	128	131	134	129	125	121	143	149	143	136	130	125
	Canopy base height (ft)	3	3	6	10	14	18	33	3	6	8	10	13	15
Canopy bulk density (kg/m ³)	0.14	0.14	0.14	0.15	0.14	0.14	0.14	0.14	0.15	0.15	0.13	0.14	0.14	
Prescribed fire	Trees per acre	544	200	197	185	175	165	151	300	213	199	188	172	157
	Quadratic mean diameter (in)	7.5	12.1	11.4	12.1	13.0	13.8	14.9	10.1	10.9	11.7	12.5	13.5	14.5
	Total volume (ft ³)	5,004	4,280	4,492	4,863	5,280	5,694	6,009	4,296	4,456	4,822	5,241	5,589	5,919
	Merchantable volume (ft ³)	4,531	3,973	4,192	4,629	4,988	5,436	5,791	3,969	4,138	4,545	4,897	5,273	5,661
	Basal area (ft ²)	167	161	139	148	160	172	181	166	138	148	160	170	179
	Stand density index	344	273	241	252	265	278	284	303	245	255	269	276	284
	Canopy cover (percent)	55	48	39	40	41	43	43	52	40	41	42	43	43
	Crown competition factor	153	128	102	106	111	119	122	143	104	107	113	119	121
	Canopy base height (ft)	3	18	24	32	34	5	7	8	12	13	14	5	7
Canopy bulk density (kg/m ³)	0.14	0.10	0.10	0.11	0.11	0.12	0.12	0.10	0.10	0.10	0.11	0.12	0.12	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 23d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent
None	1	9	80	10	20	2	63	9	37				
	10	9	61	10	39	10	52	9	29	6	19		
	20	10	64	9	36	10	49	9	36	6	15		
	30	10	88	9	12	10	55	9	35	6	10		
	40	10	90	12	10	10	65	9	29	6	5		
	50	10	73	12	27	10	76	9	21	6	3		

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent
None	1	11	91	14	9	11	77	2	21	9	2		
	10	6	70	10	30	6	57	10	30	9	13		
	20	6	85	10	15	6	54	9	24	10	22		
	30	6	86	10	14	6	45	9	31	10	24		
	40	6	83	10	17	9	34	6	33	10	33		
	50	6	78	10	22	10	44	9	34	6	23		
Pile and burn	1	2	90	10	10	2	90	9	10				
	10	6	100			6	81	9	19				
	20	6	100			6	70	9	29				
	30	6	100			6	53	9	37	10	9		
	40	6	96	10	4	9	42	6	37	10	21		
	50	6	90	10	10	9	44	10	32	6	24		
Prescribed fire	1	2	100			2	100						
	10	6	100			6	80	10	20				
	20	6	94	10	6	6	74	10	26				
	30	6	87	10	13	6	69	10	31				
	40	6	81	10	19	6	53	10	37	9	10		
	50	6	54	10	25	9	48	6	41	9	12		

Table 23d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit						Thin from below to 300 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent
None	1	9	65	11	35	9	76	10	24	9	68	10	32
	10	9	64	10	36	9	68	10	32	9	54	9	46
	20	9	51	10	49	10	87	9	13	10	88	12	12
	30	10	70	9	30	10	72	12	28	10	72	12	28
	40	10	98	12	2	10	100	9	5	10	95	10	35
Pile and burn	1	9	100	10	7	9	95	10	5	9	65	10	29
	10	9	93	10	7	9	65	10	35	10	71	9	29
	20	9	72	10	28	10	97	12	3	10	97	12	3
	30	10	52	9	48	10	79	12	21	10	79	12	21
	40	10	87	9	13	10	65	9	35	2	65	9	35
Prescribed fire	1	2	76	9	24	2	65	9	35	10	52	9	24
	10	10	48	6	30	9	22	9	24	10	58	9	25
	20	10	52	9	25	6	23	9	17	10	65	9	10
	30	10	60	9	26	6	14	9	25	10	78	9	17
	40	10	67	9	25	6	8	9	6	10	93	9	6
50	10	83	9	14	6	4	6	6	10	6	6	6	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 23e—FVS fuel model selection

Fire weather conditions	Windspeed Miles/hour	Temperature °F	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Live	
Severe—98 th percentile	14	90	3	5	8	15	50	100
	9	71	5	8	11	24	125	150

Table 23f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

Site: Elevation = 4,600 ft, slope = 29 percent, aspect = 140°.

Species (based on trees per acre): Grand fir (*Abies grandis*) = 82 percent, Douglas-fir (*Pseudotsuga menziesii*) = 14 percent, ponderosa pine (*Pinus ponderosa*) = 3 percent, western larch (*Larix occidentalis*) = 2 percent.

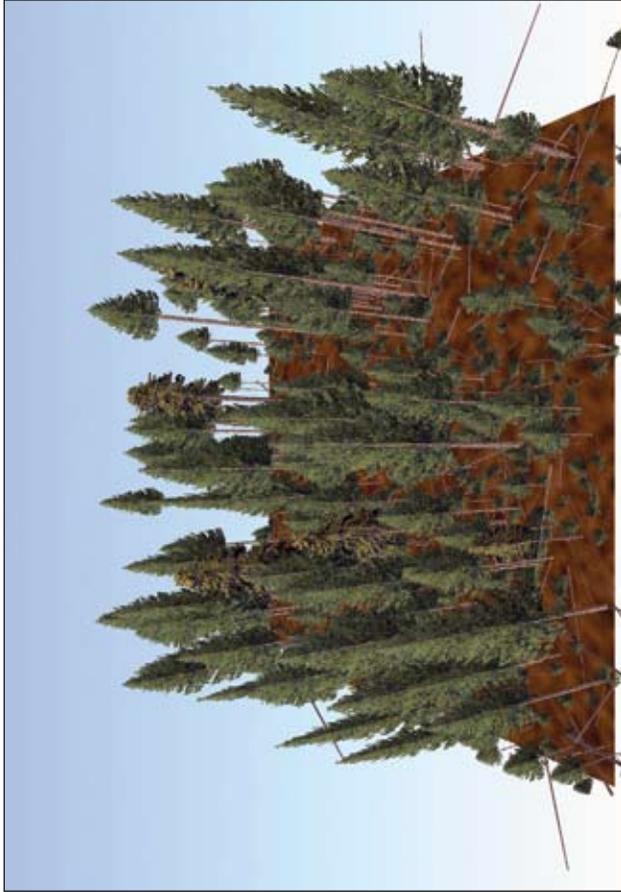
Stand attributes: Stem density = 1,216 tpa, basal area = 174 ft²/ac, top height = 93 ft, stand density index = 415, quadratic mean diameter = 5.1 in, crown competition factor = 199, canopy cover = 69 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has 1,216 trees per acre (tpa) composed of primarily grand fir understory with Douglas-fir and ponderosa pine overstory. Canopy base height is 3 ft, and canopy bulk density is 0.21 kg/m³ (0.0131 lb/ft³), so initial conditions are conducive to active crown fire spread for severe fire weather but not for moderate fire weather. Similarly, potential tree mortality is high for severe fire weather but low for moderate fire weather. Woody fuel loading is 19 tons/ac, and litter and duff loading is 27 tons/ac. With no action, canopy base height will increase and canopy bulk density will decrease as trees grow and the stand self-thins, but passive crown fire remains likely for severe fire weather for 50 years.

Silvicultural and surface fuel treatments— immediate effects

The prescribed fire only treatment reduces crown fire potential, surface fuel loading, potential flame lengths, and potential mortality but creates many snags that will contribute to surface fuels in the future. All thinning treatments are effective at reducing canopy bulk density and increasing canopy base height enough to reduce the potential for active and passive crown fire. The greater the thinning, the greater the reduction in crown fire potential, but the differences between the 300 tpa treatment and the 200 tpa treatment are minor. All thinning treatments increase surface fuel loadings; the greater the thinning, the greater the activity fuels. These activity fuels increase potential flame lengths, but potential tree mortality remains lower than initial conditions because canopy base height is higher. The pile and burn and prescribed fire treatments reduce surface fuels to below initial conditions and decrease potential flame lengths and mortality more than thinning without surface fuel treatments. The prescribed fire treatment also partially reduces the duff layer, but it still remains at 17 tons/ac after the treatment. The flame lengths of the 50 tpa treatment with a pile and burn or prescribed fire are higher than other thinnings with the same surface fuel treatments, because the 50 tpa treatment is the most open stand, and conditions are characterized by predominantly fuel model 5 rather than fuel model 8. The importance of brush as a driver of fire behavior is not predicted well in FFE and is site specific, so this result should be interpreted with caution.

Silvicultural and surface fuel treatments— long-term effects

Crown fire remains unlikely for thinning treatments with a pile and burn or no surface fuel treatment for the 50-year projection, because flame lengths remain low, preventing passive crown fire even when regeneration causes canopy case height to decrease. Passive crown fire is predicted in 30 to 40 years for all treatments with prescribed fire, because these treatments have the greatest regeneration and therefore the biggest decrease in canopy base height when regeneration moves into the canopy. All treatments reduce canopy bulk density enough that active crown fire remains unlikely for the 50-year projection.

Table 24a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	0–3 in	1	10	8	6	6
		3–6 in	1	8	8	7	7
	>12 in	6–12 in	3	7	7	7	7
		>12 in	0	1	1	1	1
	Flame length (ft)	Litter	1	3	3	3	3
		Duff	25	17	25	25	25
	Torching index	Moderate	2	1	4	3	2
		Severe	3	1	6	4	3
	Crowning index	Severe	10	155	109	90	63
		Severe	14	35	36	30	25
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Active	Surface	Surface	Surface	Surface	Surface
Potential basal area mortality (%)	Moderate	25	16	9	14	18	21
	Severe	100	16	15	20	22	24
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in		2	2	2	2
		3–6 in		2	2	2	2
	>12 in	6–12 in		2	2	2	2
		>12 in		0	0	0	0
	Flame length (ft)	Litter		3	3	2	2
		Duff		23	23	23	23
	Torching index	Moderate		2	1	1	1
		Severe		4	1	1	1
	Crowning index	Severe		151	424	300	217
		Severe		36	30	25	22
Type of fire	Moderate		Surface	Surface	Surface	Surface	
	Severe		Surface	Surface	Surface	Surface	
Potential basal area mortality (%)	Moderate		9	14	18	21	
	Severe		9	14	18	21	
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in		0	0	0	0
		3–6 in		2	2	2	2
	>12 in	6–12 in		4	4	4	4
		>12 in		0	0	0	0
	Flame length (ft)	Litter		1	1	1	1
		Duff		17	17	17	17
	Torching index	Moderate		2	1	1	1
		Severe		6	1	1	1
	Crowning index	Severe		106	472	273	259
		Severe		40	35	35	35
Type of fire	Moderate		Surface	Surface	Surface	Surface	
	Severe		Surface	Surface	Surface	Surface	
Potential basal area mortality (%)	Moderate		9	12	15	15	
	Severe		13	12	15	15	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 24b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	4	4	5	5	6	6	1	5	3	3	3	3
	0–3 in	7	7	7	6	6	5	1	4	4	4	3	3
	3–6 in	7	8	9	9	8	8	3	7	8	8	8	3
	6–12 in	1	2	4	5	6	7	0	3	5	7	8	3
	>12 in	2	2	3	3	3	3	1	2	2	2	2	2
	Litter	25	25	25	25	25	25	17	17	17	17	17	17
	Duff	2	2	3	3	3	3	1	2	2	2	2	2
	Moderate	3	3	4	4	4	4	1	4	4	4	4	4
	Severe	10	14	2	7	7	12	155	39	46	59	82	113
	Severe	14	15	17	18	17	15	35	33	30	28	25	24
Flame length (ft)	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Active	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Torching index	65	62	54	55	50	44	308	34	23	13	11	10
	Crowning index	5	4	4	4	4	4	7	6	5	4	4	4
	Type of fire	0	0	0	0	1	1	0	0	0	0	1	1
	Hard snags (stems/ac)												
	0–17.9 in												
	18–29.9 in												
	30–36 in												
None	Surface fuel loadings (tons/ac)	10	5	3	2	2	2	8	4	3	2	3	3
	0–3 in	8	8	8	7	6	5	8	8	8	7	6	6
	3–6 in	7	8	9	9	8	7	7	8	9	9	8	7
	6–12 in	1	2	4	5	5	6	1	2	4	5	6	6
	>12 in	3	1	1	1	1	1	3	1	2	2	2	2
	Litter	25	25	25	24	24	24	25	25	25	25	24	24
	Duff	4	3	3	3	2	2	3	3	3	3	3	2
	Moderate	6	5	5	4	4	4	5	4	4	4	4	4
	Severe	109	90	121	9	24	36	90	91	102	123	157	17
	Severe	36	36	37	38	38	37	30	29	28	28	28	26
Flame length (ft)	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	Torching index	51	38	14	8	6	6	51	39	16	9	7	7
	Crowning index	5	5	4	3	3	3	5	4	4	3	3	3
	Type of fire	0	0	0	0	0	0	0	0	0	0	0	1
	Hard snags (stems/ac)												
	0–17.9 in												
	18–29.9 in												
	30–36 in												

Table 24b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	2	2	2	2	2	2	2	2	2	2	2	3
	0–3 in	2	2	2	2	2	2	2	2	2	2	2	3
	3–6 in	2	3	3	3	3	3	2	3	3	3	3	3
	6–12 in	2	4	5	6	5	5	2	4	5	6	5	5
	>12 in	0	2	3	5	5	5	0	2	3	5	5	6
	Litter	3	1	1	1	1	1	3	1	2	2	2	2
	Duff	23	22	22	22	22	22	23	22	22	22	22	22
	Moderate	2	1	1	2	2	2	1	1	2	2	2	2
	Severe	4	4	3	2	2	2	1	2	2	3	3	3
	Severe	151	271	388	38	62	67	424	483	311	288	31	39
Prescribed fire	Surface fuel loadings (tons/ac)	36	36	37	38	37	37	30	29	28	28	27	26
	0–3 in	36	36	37	38	37	37	30	29	28	28	27	26
	3–6 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	6–12 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	>12 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Litter	51	38	14	8	7	7	51	39	16	9	8	8
	Duff	5	5	4	3	2	3	5	4	4	3	3	3
	Moderate	0	0	0	0	0	0	0	0	0	0	0	0
	Severe	0	2	2	2	2	2	0	2	2	2	2	2
	Severe	2	3	3	3	3	3	2	4	4	4	3	3
Pile and burn	Surface fuel loadings (tons/ac)	4	7	8	8	7	6	4	8	9	9	8	7
	0–3 in	4	7	8	8	7	6	4	8	9	9	8	7
	3–6 in	0	3	5	7	7	7	0	3	5	7	7	7
	6–12 in	1	1	1	1	1	1	3	1	1	1	2	2
	>12 in	17	17	17	17	17	17	23	17	17	17	17	17
	Litter	2	2	2	2	2	2	1	2	2	2	2	2
	Duff	6	5	3	3	3	3	1	3	4	4	4	3
	Moderate	106	126	13	22	33	45	472	220	168	8	22	25
	Severe	40	40	41	34	27	23	35	34	33	32	32	31
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Prescribed fire	Surface fuel loadings (tons/ac)	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	0–3 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	3–6 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	6–12 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	>12 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Litter	42	28	18	11	9	9	52	33	20	10	8	7
	Duff	7	6	5	3	3	2	7	6	5	4	2	2
	Moderate	0	0	0	0	0	0	0	0	0	0	0	0
	Severe	0	0	0	0	0	0	0	0	0	0	0	0
	Severe	0	0	0	0	0	0	0	0	0	0	0	0

Table 24b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	6	4	3	3	3	4	6	4	3	3	4	4
	0–3 in												
	3–6 in	7	7	7	7	6	5	7	7	7	6	6	5
	6–12 in	7	8	9	9	8	8	7	8	9	9	8	8
	>12 in	1	2	4	5	6	6	1	2	4	5	6	6
	Litter	3	2	2	2	2	2	3	2	2	2	3	3
	Duff	25	25	25	25	25	25	25	25	25	25	25	25
	Moderate	3	3	3	3	3	3	2	3	3	3	3	3
	Severe	4	4	4	4	4	4	3	4	4	4	4	4
	Severe	63	64	81	91	125	141	46	42	47	80	90	110
Pile and burn	Torching index	25	23	22	21	20	19	22	23	22	20	18	17
	Crowning index												
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	0–17.9 in	53	41	19	12	11	11	54	43	21	15	13	12
	18–29.9 in	5	4	4	4	3	4	5	4	4	4	3	3
	30–36 in	0	0	0	0	0	1	0	0	0	0	0	1
	Surface fuel loadings (tons/ac)	2	3	3	3	3	4	2	3	3	3	4	4
	0–3 in												
	3–6 in	2	3	3	3	3	3	2	3	3	3	3	3
6–12 in	2	4	5	6	6	5	2	4	5	6	5	5	
>12 in	0	2	3	5	6	6	0	2	3	5	6	6	
Litter	2	2	2	2	2	2	2	2	2	2	3	3	
Duff	23	22	22	22	22	22	23	22	22	22	22	22	
Moderate	1	1	2	2	2	2	1	1	2	2	2	2	
Severe	1	2	3	3	3	3	1	2	3	3	3	3	
Severe	300	293	220	194	226	246	217	190	130	154	162	202	
None	Crowning index	25	23	22	21	20	18	22	23	22	20	18	16
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	0–17.9 in	53	41	19	12	11	11	54	43	21	14	13	14
	18–29.9 in	5	4	4	4	3	4	5	4	4	3	3	4
	30–36 in	0	0	0	0	0	1	0	0	0	0	0	1

Table 24b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	3	2	2	2	3	0	4	3	2	2	3
	0–3 in												
	3–6 in	2	5	4	4	4	3	2	5	5	4	4	3
	6–12 in	4	8	9	9	8	7	4	8	9	9	8	7
	>12 in	0	3	5	7	7	7	0	3	5	7	7	7
	Litter	1	1	1	2	2	2	1	1	2	2	2	2
	Duff	17	17	17	17	17	17	17	17	17	17	17	17
	Moderate	1	2	2	2	2	2	1	2	2	2	2	2
	Severe	1	3	4	4	4	4	1	4	4	4	4	4
	Torching index	273	107	106	120	19	21	259	87	88	90	13	21
	Crowning index	35	34	31	29	28	26	35	33	31	29	27	25
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Passive	Surface
	Hard snags (stems/ac)	69	33	20	10	8	8	88	33	21	11	8	8
	0–17.9 in												
	18–29.9 in	7	6	5	4	3	3	7	6	5	4	3	3
	30–36 in	0	0	0	0	0	1	0	0	0	0	0	1

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 24c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	1,216	1,186	1,149	1,105	1,067	1,033	209	206	201	197	192	187
	Quadratic mean diameter (in)	5.1	5.5	5.9	6.3	6.7	7.1	5.1	11.5	12.3	13.1	13.9	14.7
	Total volume (ft ³)	4,813	5,830	6,890	7,943	9,013	10,110	4,446	4,847	5,680	6,540	7,416	8,275
	Merchantable volume (ft ³)	4,041	4,945	5,927	6,864	7,762	8,651	3,965	4,343	5,141	5,927	6,674	7,446
	Basal area (ft ²)	174	198	220	241	262	283	139	148	166	184	202	220
	Stand density index	415	459	497	530	562	594	246	257	281	303	326	347
	Canopy closure (percent)	69	71	74	75	77	78	47	48	51	53	55	57
	Crown competition factor	199	215	228	239	250	261	115	120	131	141	151	161
	Canopy base height (ft)	3	4	4	5	5	6	7	8	10	13	17	22
	Canopy bulk density (kg/m ³)	0.21	0.18	0.16	0.14	0.15	0.18	0.06	0.07	0.08	0.08	0.09	0.10

Table 24c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	1,216	50	149	146	144	141	139	100	148	145	143	140	137
	Quadratic mean diameter (in)	5.1	20.4	12.3	13.0	13.7	14.5	15.2	16.0	13.9	14.9	15.8	16.7	17.6
	Total volume (ft ³)	4,813	4,186	4,484	5,108	5,693	6,245	6,740	4,880	5,315	6,242	7,199	8,157	9,053
	Merchantable volume (ft ³)	4,041	3,894	4,176	4,760	5,317	5,820	6,254	4,470	4,867	5,756	6,671	7,558	8,401
	Basal area (ft ²)	174	113	124	136	148	161	174	140	157	175	194	213	232
	Stand density index	415	157	209	224	240	255	271	213	252	274	297	319	340
	Canopy cover (percent)	69	31	32	34	37	39	42	42	44	47	49	51	53
	Crown competition factor	199	75	80	87	101	109	117	103	113	123	134	145	158
	Canopy base height (ft)	3	34	37	38	4	6	7	21	27	27	30	34	5
	Canopy bulk density (kg/m ³)	0.21	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.08	0.08	0.08	0.09
Pile and burn	Trees per acre	1,216	50	199	196	192	189	186	100	174	171	168	165	162
	Quadratic mean diameter (in)	5.1	20.4	10.7	11.3	11.9	12.6	13.2	16.0	12.9	13.7	14.6	15.4	16.3
	Total volume (ft ³)	4,813	4,186	4,484	5,108	5,701	6,284	6,769	4,880	5,315	6,252	7,217	8,179	9,081
	Merchantable volume (ft ³)	4,041	3,894	4,176	4,760	5,320	5,850	6,275	4,470	4,867	5,764	6,688	7,579	8,426
	Basal area (ft ²)	174	113	124	136	149	163	176	140	157	175	195	214	233
	Stand density index	415	157	221	237	255	273	289	213	261	284	307	331	352
	Canopy cover (percent)	69	31	32	35	38	41	44	42	44	47	49	51	53
	Crown competition factor	199	75	80	87	106	115	123	103	113	123	134	146	160
	Canopy base height (ft)	3	34	37	38	4	6	6	21	27	27	30	4	5
	Canopy bulk density (kg/m ³)	0.21	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.08	0.08	0.09	0.09
Prescribed fire	Trees per acre	1,216	50	343	338	332	327	321	100	225	221	217	213	209
	Quadratic mean diameter (in)	5.1	20.4	7.8	8.2	8.7	9.2	9.7	16.0	10.5	11.2	11.9	12.6	13.3
	Total volume (ft ³)	4,813	3,833	4,101	4,659	5,224	5,731	6,211	4,306	4,669	5,445	6,234	7,053	7,799
	Merchantable volume (ft ³)	4,041	3,572	3,821	4,339	4,860	5,308	5,725	3,965	4,302	5,051	5,784	6,548	7,256
	Basal area (ft ²)	174	113	113	124	138	151	166	140	135	151	167	185	202
	Stand density index	415	157	228	246	267	287	307	213	243	264	286	310	331
	Canopy cover (percent)	69	31	29	34	41	45	48	42	38	41	44	47	49
	Crown competition factor	199	75	73	81	113	123	133	103	95	104	118	135	145
	Canopy base height (ft)	3	35	38	3	4	5	6	24	29	29	3	5	6
	Canopy bulk density (kg/m ³)	0.21	0.05	0.05	0.05	0.06	0.09	0.11	0.06	0.07	0.07	0.07	0.07	0.07

Table 24c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	1,216	200	220	215	210	206	201	300	318	311	304	297	292
	Quadratic mean diameter (in)	5.1	12.0	12.1	13.0	13.9	14.9	15.8	10.0	10.3	11.1	11.9	12.7	13.5
	Total volume (ft ³)	4,813	5,138	5,635	6,734	7,933	9,213	10,493	5,209	5,723	6,846	8,085	9,426	10,818
	Merchantable volume (ft ³)	4,041	4,491	4,970	6,038	7,213	8,310	9,497	4,485	4,950	6,043	7,206	8,269	9,474
	Basal area (ft ²)	174	156	176	199	222	247	272	162	184	208	234	261	289
	Stand density index	415	266	299	328	358	388	417	298	334	366	400	435	470
	Canopy cover (percent)	69	52	54	57	59	62	64	57	60	63	66	68	70
	Crown competition factor	199	127	138	151	164	178	191	144	157	171	186	202	218
	Canopy base height (ft)	3	12	16	19	21	27	32	8	10	11	17	19	25
	Canopy bulk density (kg/m ³)	0.21	0.10	0.11	0.11	0.12	0.13	0.14	0.11	0.11	0.12	0.13	0.15	0.16
Pile and burn	Trees per acre	1,216	200	233	228	223	218	213	300	331	324	317	309	303
	Quadratic mean diameter (in)	5.1	12.0	11.8	12.6	13.5	14.4	15.3	10.0	10.1	10.9	11.6	12.4	13.2
	Total volume (ft ³)	4,813	5,138	5,635	6,742	7,941	9,215	10,492	5,209	5,723	6,854	8,105	9,440	10,773
	Merchantable volume (ft ³)	4,041	4,491	4,970	6,045	7,219	8,308	9,493	4,485	4,950	6,049	7,220	8,289	9,439
	Basal area (ft ²)	174	156	176	199	223	248	272	162	184	208	234	261	287
	Stand density index	415	266	303	332	362	393	422	298	337	369	404	439	472
	Canopy cover (percent)	69	52	54	57	60	62	64	57	60	63	66	68	70
	Crown competition factor	199	127	138	151	164	178	191	144	157	171	187	202	217
	Canopy base height (ft)	3	12	16	19	21	27	32	8	10	11	16	19	26
	Canopy bulk density (kg/m ³)	0.21	0.10	0.11	0.11	0.12	0.13	0.14	0.11	0.11	0.12	0.13	0.15	0.16
Prescribed fire	Trees per acre	1,216	200	187	183	180	176	173	300	205	201	198	194	190
	Quadratic mean diameter (in)	5.1	12.0	11.8	12.7	13.5	14.4	15.3	10.0	11.4	12.2	13.0	13.9	14.8
	Total volume (ft ³)	4,813	4,410	4,798	5,654	6,565	7,528	8,454	4,428	4,826	5,699	6,622	7,602	8,572
	Merchantable volume (ft ³)	4,041	3,976	4,337	5,188	6,051	6,941	7,830	3,971	4,349	5,193	6,065	6,899	7,897
	Basal area (ft ²)	174	156	143	160	179	200	219	162	145	164	183	204	225
	Stand density index	415	266	245	268	292	317	340	298	253	277	303	329	354
	Canopy cover (percent)	69	52	43	45	48	51	53	57	45	48	50	53	55
	Crown competition factor	199	127	105	115	126	142	153	144	110	121	133	147	161
	Canopy base height (ft)	3	13	18	21	25	5	5	12	16	18	19	4	5
	Canopy bulk density (kg/m ³)	0.21	0.06	0.06	0.07	0.08	0.08	0.09	0.06	0.07	0.07	0.08	0.09	0.10

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 24d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None			Percent			Percent			Percent				
	1	10	56	8	44			8	100				
	10	10	69	8	31			10	53	8	47		
	20	10	95	8	5			10	60	8	40		
	30	10	96	12	4			10	66	8	34		
40	10	94	12	6			10	66	8	34			
50	10	92	12	8			10	66	8	34			

Thin from below to 50 tpa, 18-in. d.b.h. limit

Thin from below to 100 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None			Percent			Percent			Percent				
	1	11	65	14	35			11	82	14	18		
	10	10	84	8	11	5	5	10	82	8	18		
	20	10	71	8	26	5	3	10	76	8	24		
	30	10	63	8	37			10	73	8	27		
40	10	53	8	47			10	68	8	32			
50	8	55	10	45			10	64	8	36			
Pile and burn	1	8	50	5	39	10	11	8	98	10	2		
	10	8	67	5	32			8	95	10	5		
	20	8	83	10	12	5	4	8	81	10	19		
	30	8	82	10	18			8	73	10	27		
	40	8	83	10	17			8	70	10	30		
50	8	84	10	16			8	68	10	32			
Prescribed fire	1	5	73	8	27			8	100				
	10	5	51	8	35	10	13	8	70	10	30		
	20	8	66	10	28	5	7	8	56	10	44		
	30	8	64	10	36			10	52	8	48		
	40	8	66	10	34			8	50	10	50		
50	8	70	10	30			8	55	10	45			

Table 24d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit										
	Fuel models					Fuel models					Fuel models					Fuel models					
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None	1	11	98	14	2	11	88	8	12	11	88	8	12	10	74	8	26	10	78	8	22
	10	10	77	8	23	10	74	8	26	10	78	8	22	10	78	8	22	10	78	8	22
	20	10	77	8	23	10	74	8	26	10	78	8	22	10	78	8	22	10	78	8	22
	30	10	80	8	20	10	81	8	19	10	81	8	19	10	81	8	19	10	81	8	19
	40	10	80	8	20	10	86	8	14	10	86	8	14	10	86	8	14	10	86	8	14
50	10	82	8	18	10	89	8	11	10	89	8	11	10	89	8	11	10	89	8	11	
Pile and burn	1	8	100			8	100			8	100			8	90	10	10	8	90	10	10
	10	8	92	10	8	8	90	10	10	8	90	10	10	8	73	10	27	8	73	10	27
	20	8	76	10	24	8	73	10	27	8	61	10	39	8	61	10	39	8	61	10	39
	30	8	64	10	36	8	61	10	39	8	52	10	48	8	52	10	48	8	52	10	48
	40	8	57	10	43	8	52	10	48	8	52	10	48	8	52	10	48	8	52	10	48
50	10	50	8	50	10	57	8	43	10	57	8	43	10	57	8	43	10	57	8	43	
Prescribed fire	1	8	100			8	100			8	100			8	51	10	49	8	51	10	49
	10	8	57	10	43	8	51	10	49	8	51	10	49	8	51	10	49	8	51	10	49
	20	10	54	8	46	10	58	8	42	10	63	8	37	10	58	8	42	10	63	8	37
	30	10	61	8	39	10	63	8	37	10	63	8	37	10	63	8	37	10	63	8	37
	40	10	59	8	41	10	60	8	40	10	60	8	40	10	60	8	40	10	60	8	40
50	10	57	8	43	10	58	8	42	10	58	8	42	10	58	8	42	10	58	8	42	

tpa = trees per acre, d.b.h. = diameter at breast height.

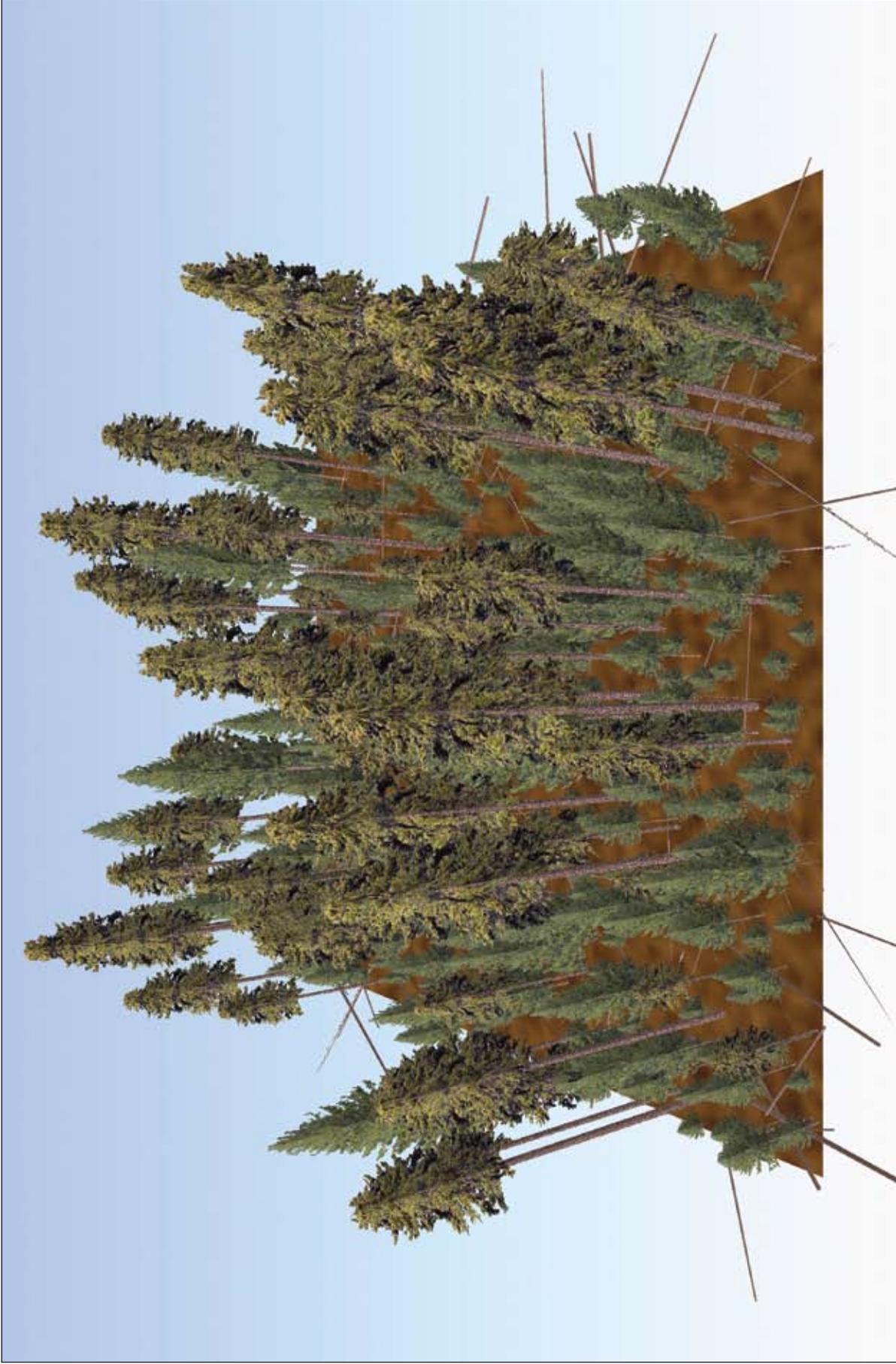
Table 24e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff	Live
Severe—98 th percentile	14	90	2	5	8	15	50	100
Moderate—75 th percentile	9	71	5	7	10	23	125	150

Table 24f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

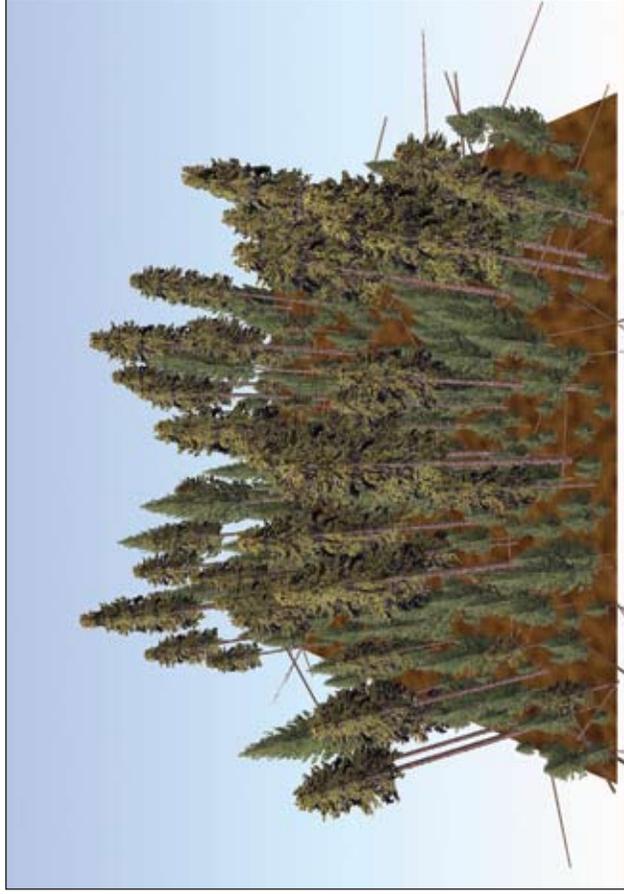
Site: Elevation = 4,400 ft, slope = 34 percent, aspect = 220°.

Species (based on trees per ac): Douglas-fir (*Pseudotsuga menziesii*) = 90 percent, ponderosa pine (*Pinus ponderosa*) = 9 percent.

Stand attributes: Stem density = 764 tpa, basal area = 174 ft²/ac, top height = 90 ft, stand density index = 379, quadratic mean diameter = 6.5 in, crown competition factor = 204, canopy cover = 65 percent.



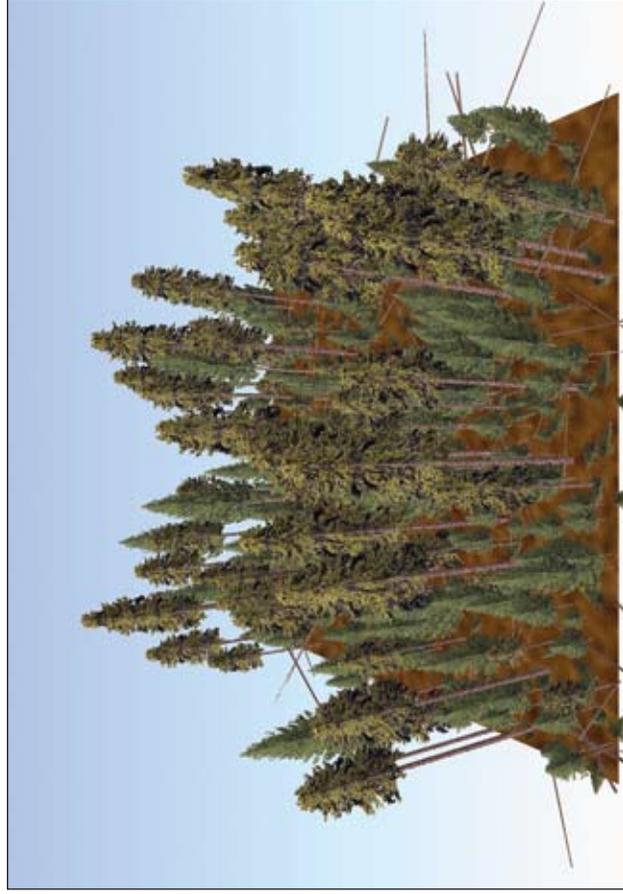
Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This stand has 764 trees per acre (tpa) composed of primarily understory Douglas-fir with overstory ponderosa pine. Canopy base height is only 2 ft and canopy bulk density is 0.08 kg/m³ (0.005 lb/ft³), so initial conditions have high potential for passive crown fire and low potential for active crown fire spread under severe fire weather. Potential basal area mortality is 70 percent for severe fire weather, but only 18 percent for moderate fire weather. Woody fuel loading is 9 tons/ac, and litter and duff loading is 7 tons/ac. With no action, canopy base height increases as the trees grow and the stand self-thins, making passive crown fire unlikely in 10 years, but crown fire potential declines only slightly because flame lengths increase as surface fuels accumulate.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment has little effect on canopy base height and crown fire potential and creates more snags. Surface fuel loading is reduced, but potential flame lengths increase because the more open stand is characterized by predominantly fuel model 6, brush fuels. Brush fuels are not tracked in FFE and the presence of brush following prescribed fire is site specific, so these results should be interpreted with caution. All thinning treatments increase canopy base height and reduce canopy bulk density. The 100 tpa thinning without a surface fuel treatment is the only treatment that remains susceptible to passive crown fire. Thinning to 50 tpa increases canopy base height much more than the other prescriptions because some larger overstory trees are removed as well as ladder fuels. All thinning treatments increase surface fuels, the greater the thinning, the greater is the increase in surface fuel loading. The 100 tpa treatment demonstrates that thinning must increase canopy base height enough to compensate for higher flame lengths associated with activity fuels if no surface fuel treatment is applied. The pile and burn treatment and, to a greater extent, the prescribed fire treatment reduce surface fuels, but flame lengths remain high because the low-density stands with scarce surface fuels are predominantly characterized by fuel model 6.

Silvicultural and surface fuel treatments—long-term effects

Canopy bulk density remains low enough in all treatments that active crown fire is unlikely for the 50-year projection. In the prescribed fire only treatment, crown fire potential decreases over time, and passive crown fire becomes unlikely in 10 years and remains unlikely for the 50-year projection. In all thinned stands, canopy base height continues to increase as trees grow and the stand self-thins, and passive crown fire remains unlikely for 50 years in the 100, 200, and 300 tpa treatments. Abundant regeneration causes a drop in canopy base height in 30 years in the 50 tpa treatments with a pile and burn and with no surface fuel treatment, and in 10 years in the 50 tpa treatment with prescribed fire. At this time, passive crown fire is predicted again, but the increase in crown fire potential is fleeting and soon decreases as the regeneration grows and crowns rise. Surface fuels accumulate over time in all thinned stands with pile and burn or prescribed fire treatments, but potential flame lengths decrease as the stand becomes less open and the assigned fuel model shifts from model 6 to model 9.

Table 25a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	1	7	6	4	4
	0–3 in	3	3	3	3	3
	3–6 in	3	1	2	2	2
	6–12 in	0	0	0	0	0
	>12 in	2	3	3	2	2
	Litter	5	3	3	5	5
	Duff	2	4	4	3	2
	Moderate	3	6	6	4	3
	Severe	0	81	26	12	17
	Severe	29	50	45	33	31
Pile and burn	Flame length (ft)	Surface	Surface	Surface	Surface	Surface
	Torching index	Passive	Surface	Surface	Passive	Surface
	Crowning index	Passive	Surface	Surface	Surface	Surface
	Type of fire	16	6	11	16	17
	Potential basal area mortality (%)	70	7	20	30	21
	0–3 in	2	2	1	1	1
	3–6 in	1	1	1	1	1
	6–12 in	0	0	0	0	0
	>12 in	3	3	3	2	2
	Litter	2	2	3	4	4
Duff	4	4	4	3	2	
Moderate	7	7	6	4	3	
Severe	61	61	20	13	20	
Severe	50	50	45	33	31	
Severe	Surface	Surface	Surface	Surface	Surface	
Moderate	Surface	Surface	Surface	Surface	Surface	
Potential basal area mortality (%)	6	15	12	15	17	
Severe	15	15	25	26	20	
Prescribed fire	Surface fuel loadings (tons/ac)	0	0	0	0	0
	0–3 in	1	1	1	1	1
	3–6 in	1	1	1	1	1
	6–12 in	0	0	0	0	0
	>12 in	0	0	0	0	0
	Litter	2	2	2	3	3
	Duff	4	4	4	4	4
	Moderate	7	7	6	6	5
	Severe	49	49	29	18	12
	Severe	53	53	48	48	47
Pile and burn	Flame length (ft)	Surface	Surface	Surface	Surface	Surface
	Torching index	Surface	Surface	Surface	Surface	Surface
	Crowning index	6	6	10	14	16
	Type of fire	15	15	24	25	33
	Potential basal area mortality (%)	6	6	10	14	16
	0–3 in	0	0	0	0	0
	3–6 in	1	1	1	1	1
	6–12 in	1	1	1	1	1
	>12 in	0	0	0	0	0
	Litter	0	0	0	0	0
Duff	2	2	2	3	3	
Moderate	4	4	4	4	4	
Severe	7	7	6	6	5	
Severe	49	49	29	18	12	
Severe	53	53	48	48	47	
Severe	Surface	Surface	Surface	Surface	Surface	
Moderate	Surface	Surface	Surface	Surface	Surface	
Potential basal area mortality (%)	6	6	10	14	16	
Severe	15	15	24	25	33	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 25b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	3	5	7	7	7	7	1	4	4	4	5	5	5
	3–6 in	3	3	4	5	5	6	0	3	3	3	3	4	5
	6–12 in	3	2	3	4	5	6	1	3	3	4	4	5	6
	>12 in	0	0	1	2	3	4	0	1	2	3	4	4	5
	Litter	2	3	3	3	3	3	1	2	2	2	2	2	2
	Duff	5	5	6	6	7	7	4	4	4	4	4	5	5
	Moderate	2	2	3	3	3	3	3	3	3	3	3	3	3
	Severe	3	3	4	4	4	5	5	5	5	5	5	5	5
	Torching index	0	11	16	19	21	21	10	29	42	60	39	97	97
	Crowning index	29	30	29	30	33	35	48	45	44	41	40	41	41
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Passive	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	
Hard snags (stems/ac)	0–17.9 in	42	106	115	92	86	76	164	12	23	33	35	34	
	18–29.9 in	0	1	1	1	1	1	1	1	1	1	2	2	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
None	Surface fuel loadings (tons/ac)	7	5	3	3	3	3	6	4	4	4	4	5	
	3–6 in	3	3	3	3	3	3	3	3	3	4	4	4	
	6–12 in	1	1	1	1	2	2	2	2	2	2	3	3	
	>12 in	0	0	0	1	1	2	0	0	0	1	1	2	
	Litter	3	1	2	2	2	2	3	2	2	2	2	2	
	Duff	3	3	3	3	3	4	3	4	4	4	5	5	
	Moderate	4	4	4	4	2	2	4	4	4	4	4	3	
	Severe	6	7	7	6	3	3	6	6	6	5	5	5	
	Torching index	81	94	93	0	25	32	26	52	57	75	89	98	
	Crowning index	50	48	48	47	47	47	45	43	42	42	42	41	
Type of fire	Moderate	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
Hard snags (stems/ac)	0–17.9 in	1	2	6	8	9	10	1	3	9	13	21	24	
	18–29.9 in	0	0	0	0	0	1	0	0	0	0	1	2	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 25b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	2	2	2	2	2	3	1	2	3	4	4	5
	0–3 in												
	3–6 in	1	1	1	2	2	2	1	1	1	2	2	3
	6–12 in	0	0	1	1	1	1	1	1	1	1	2	3
	>12 in	0	0	0	1	1	2	0	0	0	1	2	3
	Litter	3	1	2	2	2	2	3	2	2	2	2	2
	Duff	2	2	3	3	3	3	3	3	4	4	4	4
	Moderate	4	4	4	2	2	2	4	4	4	4	4	4
	Severe	7	7	7	3	3	3	6	6	6	6	6	5
	Severe	61	75	78	15	27	39	20	47	53	74	89	8
Prescribed fire	Surface fuel loadings (tons/ac)	50	48	48	47	47	47	45	43	42	41	41	41
	0–3 in												
	3–6 in	1	1	1	2	2	2	1	2	2	2	3	3
	6–12 in	1	1	1	2	2	2	1	2	3	3	3	4
	>12 in	0	1	1	2	3	4	0	1	2	3	3	4
	Litter	0	1	2	2	2	2	3	2	2	2	2	2
	Duff	2	2	2	2	3	3	3	3	3	3	3	4
	Moderate	4	2	2	2	2	2	4	4	4	4	2	2
	Severe	7	3	3	3	3	4	6	6	6	6	4	4
	Severe	49	0	16	27	30	29	29	37	63	4	13	14
Surface fuel treatment	Surface fuel loadings (tons/ac)	53	50	37	30	27	27	48	45	44	43	44	44
	0–3 in												
	3–6 in	7	7	13	17	34	44	15	10	14	12	21	31
	6–12 in	1	1	1	1	1	2	1	1	1	0	1	2
	>12 in	0	0	0	0	0	0	0	0	0	0	0	0
	Litter	0	0	0	0	0	0	0	0	0	0	0	0
	Duff	2	2	2	2	2	2	3	3	3	3	3	4
	Moderate	4	2	2	2	2	2	4	4	4	4	2	2
	Severe	7	3	3	3	3	4	6	6	6	6	4	4
	Severe	49	0	16	27	30	29	29	37	63	4	13	14
Type of fire	Surface	53	50	37	30	27	27	48	45	44	43	44	44
	Surface	7	7	13	17	34	44	15	10	14	12	21	31
	Passive	1	1	1	1	1	2	1	1	1	0	1	2
	Passive	0	0	0	0	0	0	0	0	0	0	0	0
	Surface	0	0	0	0	0	0	0	0	0	0	0	0
	Surface	0	0	0	0	0	0	0	0	0	0	0	0
	Passive	0	0	0	0	0	0	0	0	0	0	0	0
	Passive	0	0	0	0	0	0	0	0	0	0	0	0
	Surface	0	0	0	0	0	0	0	0	0	0	0	0
	Surface	0	0	0	0	0	0	0	0	0	0	0	0

Table 25b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	0–3 in	4	5	5	6	6	7	4	4	6	6	7	7
		3–6 in	3	3	3	4	5	6	3	3	3	4	5	6
		6–12 in	2	2	3	4	5	7	2	2	3	3	5	6
	Flame length (ft)	>12 in	0	0	1	2	3	5	0	0	1	1	2	4
		Litter	2	3	3	3	3	2	2	3	3	3	3	3
		Duff	5	5	5	5	6	6	5	5	6	6	6	7
	Torching index	Moderate	3	3	3	3	3	3	2	2	2	3	3	3
		Severe	4	4	4	5	5	5	3	3	4	4	4	5
		Severe	12	36	52	74	90	84	17	31	43	36	40	39
	Crowning index	Severe	33	39	39	39	38	39	31	33	32	35	35	36
		Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	14	20	34	42	45	43	15	25	38	48	55	55
		18–29.9 in	0	0	1	1	2	2	0	0	1	1	2	2
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	1	3	5	6	6	6	1	3	5	6	7	7
		3–6 in	1	1	2	3	4	5	1	1	2	3	4	5
		6–12 in	1	1	1	3	4	6	1	1	1	2	3	5
	Flame length (ft)	>12 in	0	0	1	2	3	5	0	0	1	1	2	3
		Litter	2	3	3	3	3	2	2	3	3	3	3	3
		Duff	4	4	5	5	5	6	4	5	5	5	6	6
	Torching index	Moderate	3	3	3	3	3	3	2	2	2	2	3	3
		Severe	4	4	4	5	5	5	3	3	3	4	4	4
		Severe	13	35	50	70	83	102	20	48	49	38	41	51
	Crowning index	Severe	33	38	38	39	38	39	31	33	31	34	35	35
		Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	14	20	34	43	46	45	15	25	38	47	53	53
		18–29.9 in	0	0	1	1	2	3	0	0	1	1	1	2
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

Table 25b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	3	4	4	5	5	0	4	4	5	5	5
		0-3 in											
		3-6 in	1	3	3	4	4	1	3	3	4	4	5
		6-12 in	1	3	3	4	5	1	3	3	4	5	6
		>12 in	0	1	2	3	3	0	1	2	3	4	5
		Litter	1	2	2	2	2	1	2	3	3	2	2
		Duff	3	3	4	4	4	3	4	4	4	5	5
		Moderate	3	3	3	3	3	2	3	3	3	3	3
		Severe	4	5	5	5	5	3	5	5	5	5	5
		Torching index	12	32	55	67	77	11	17	44	44	61	76
Crowning index		33	45	44	41	40	40	31	45	44	41	40	40
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Hard snags (stems/ac)		28	11	20	28	35	34	47	12	28	39	42	38
		0-17.9 in	1	1	1	1	2	1	1	1	1	2	2
		18-29.9 in	0	0	0	0	0	0	0	0	0	0	0
	30-36 in												

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 25c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	764	651	571	506	446	394	186	182	168	149	133	117
	Quadratic mean diameter (in)	6.5	7.2	7.8	8.4	9.0	9.7	6.5	12.6	13.5	14.4	15.4	16.5
	Total volume (ft ³)	5,287	5,717	5,994	6,350	6,635	6,954	4,981	5,273	5,621	5,854	6,093	6,301
	Merchantable volume (ft ³)	4,494	4,912	5,110	5,576	5,857	6,190	4,360	4,663	4,922	5,231	5,430	5,654
	Basal area (ft ²)	174	184	189	196	199	203	150	158	166	169	171	172
	Stand density index	379	384	383	384	379	377	255	265	271	268	264	260
	Canopy closure (percent)	65	66	64	64	63	62	49	50	50	49	48	46
	Crown competition factor	204	207	208	208	206	204	144	151	156	155	153	150
	Canopy base height (ft)	2	4	6	7	8	9	6	13	18	24	16	34
	Canopy bulk density (kg/m ³)	0.08	0.08	0.08	0.08	0.07	0.07	0.04	0.05	0.05	0.05	0.05	0.05

Table 25c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	764	50	149	146	141	135	128	100	148	143	137	126	116
	Quadratic mean diameter (in)	6.5	20.3	12.1	12.5	13.2	14.0	14.8	16.1	13.8	14.5	15.2	16.0	16.8
	Total volume (ft ³)	5,287	4,344	4,502	4,758	5,128	5,505	5,835	5,138	5,378	5,765	6,191	6,458	6,635
	Merchantable volume (ft ³)	4,494	3,956	4,155	4,343	4,712	5,030	5,346	4,549	4,813	5,099	5,474	5,720	5,883
	Basal area (ft ²)	174	112	119	124	134	144	152	142	154	163	172	176	178
	Stand density index	379	155	202	209	221	231	239	215	249	259	267	268	266
	Canopy cover (percent)	65	29	30	31	35	37	38	41	42	43	44	43	43
	Crown competition factor	204	88	93	96	109	116	122	121	130	136	141	143	144
	Canopy base height (ft)	2	41	45	45	4	7	9	13	23	25	32	37	40
	Canopy bulk density (kg/m ³)	0.08	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05
Pile and burn	Trees per acre	764	50	199	195	189	179	168	100	174	168	158	143	130
	Quadratic mean diameter (in)	6.5	20.3	10.5	10.8	11.5	12.2	13.0	16.1	12.8	13.3	14.0	14.9	15.7
	Total volume (ft ³)	5,287	4,344	4,502	4,759	5,131	5,515	5,863	5,138	5,378	5,766	6,084	6,357	6,494
	Merchantable volume (ft ³)	4,494	3,956	4,155	4,345	4,713	5,036	5,361	4,549	4,813	5,100	5,392	5,638	5,764
	Basal area (ft ²)	174	112	119	124	135	146	155	142	154	163	169	173	174
	Stand density index	379	155	214	221	235	247	257	215	257	267	271	271	268
	Canopy cover (percent)	65	29	30	31	36	39	40	41	42	43	43	43	43
	Crown competition factor	204	88	93	96	112	121	128	121	130	136	138	141	142
	Canopy base height (ft)	2	41	45	46	4	6	9	13	23	25	32	37	6
	Canopy bulk density (kg/m ³)	0.08	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05
Prescribed fire	Trees per acre	764	50	345	336	323	293	259	100	227	218	212	199	178
	Quadratic mean diameter (in)	6.5	20.3	7.8	8.3	9.0	9.8	10.7	16.1	10.5	10.9	11.5	12.1	13.0
	Total volume (ft ³)	5,287	4,088	4,236	4,525	4,919	5,118	5,459	4,668	4,873	5,173	5,566	5,813	6,025
	Merchantable volume (ft ³)	4,494	3,722	3,910	4,094	4,439	4,554	4,776	4,168	4,400	4,620	4,976	5,160	5,366
	Basal area (ft ²)	174	112	114	127	144	153	161	142	136	143	152	159	163
	Stand density index	379	155	231	251	274	283	288	215	245	252	265	270	270
	Canopy cover (percent)	65	29	34	41	46	48	48	41	37	38	40	42	42
	Crown competition factor	204	88	97	120	135	141	145	121	112	116	126	134	136
	Canopy base height (ft)	2	42	2	4	6	8	11	19	22	28	5	5	7
	Canopy bulk density (kg/m ³)	0.08	0.04	0.04	0.06	0.08	0.09	0.10	0.04	0.05	0.05	0.05	0.05	0.05

Table 25c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	764	200	206	182	160	138	119	300	300	273	241	209	180
	Quadratic mean diameter (in)	6.5	12.2	12.5	13.5	14.4	15.4	16.4	10.2	10.6	11.5	12.4	13.3	14.2
	Total volume (ft ³)	5,287	5,475	5,692	6,005	6,217	6,363	6,418	5,558	5,833	6,289	6,649	6,873	7,018
	Merchantable volume (ft ³)	4,494	4,723	4,982	5,214	5,543	5,666	5,765	4,736	5,018	5,351	5,818	6,081	6,270
	Basal area (ft ²)	174	163	174	180	180	179	176	169	185	196	201	201	199
	Stand density index	379	276	293	294	286	277	265	308	331	341	339	329	318
	Canopy cover (percent)	65	53	54	53	51	49	47	59	61	61	60	58	55
	Crown competition factor	204	160	168	169	166	160	154	178	191	198	198	192	185
	Canopy base height (ft)	2	6	14	20	27	30	33	5	8	12	11	13	26
Canopy bulk density (kg/m ³)	0.08	0.07	0.06	0.06	0.06	0.06	0.06	0.08	0.07	0.07	0.07	0.06	0.06	
Pile and burn	Trees per acre	764	200	219	194	169	147	126	300	313	285	254	223	193
	Quadratic mean diameter (in)	6.5	12.2	12.1	13.1	14.0	15.0	16.0	10.2	10.4	11.2	12.1	13.0	13.9
	Total volume (ft ³)	5,287	5,475	5,692	6,005	6,204	6,363	6,421	5,558	5,833	6,290	6,680	6,984	7,124
	Merchantable volume (ft ³)	4,494	4,723	4,982	5,213	5,536	5,668	5,771	4,736	5,018	5,352	5,856	6,175	6,349
	Basal area (ft ²)	174	163	175	180	180	179	176	169	185	196	202	204	203
	Stand density index	379	276	297	297	289	280	268	308	334	344	343	338	327
	Canopy cover (percent)	65	53	54	53	51	49	47	59	61	61	60	58	56
	Crown competition factor	204	160	168	169	165	160	154	178	191	199	199	196	189
	Canopy base height (ft)	2	6	14	20	27	30	33	5	8	12	11	13	16
Canopy bulk density (kg/m ³)	0.08	0.07	0.06	0.06	0.06	0.06	0.06	0.08	0.07	0.07	0.07	0.06	0.07	
Prescribed fire	Trees per acre	764	200	203	189	172	154	137	300	229	207	181	160	141
	Quadratic mean diameter (in)	6.5	12.2	11.8	12.5	13.3	14.1	15.1	10.2	11.2	12.1	13.0	13.9	14.9
	Total volume (ft ³)	5,287	4,938	5,199	5,571	5,920	6,082	6,316	4,978	5,272	5,592	5,865	6,046	6,276
	Merchantable volume (ft ³)	4,494	4,347	4,633	4,924	5,320	5,439	5,670	4,360	4,669	4,914	5,244	5,389	5,637
	Basal area (ft ²)	174	163	153	161	167	167	171	169	158	164	167	168	171
	Stand density index	379	276	263	270	273	268	266	308	276	279	276	270	267
	Canopy cover (percent)	65	53	46	46	46	45	44	59	49	48	47	46	45
	Crown competition factor	204	160	138	143	145	144	145	178	147	150	150	148	147
	Canopy base height (ft)	2	10	15	24	28	31	7	7	12	19	25	29	32
Canopy bulk density (kg/m ³)	0.08	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.05	

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 25d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent
None	1	9	96	10	4	6	65	9	35	6	65	9	35
	10	9	66	10	34	9	36	6	35	10	36	6	35
	20	10	68	9	32	10	36	9	33	6	36	9	33
	30	10	86	9	14	10	54	6	25	9	54	6	25
	40	10	99	12	1	10	71	6	18	10	71	6	18
50	10	92	12	8	10	88	6	8	10	88	6	8	

Thin from below to 50 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent
None	1	10	65	6	34	2	51	10	48	9	51	10	48
	10	6	83	10	17	6	71	10	21	9	71	10	21
	20	6	90	10	10	6	67	10	22	9	67	10	22
	30	6	93	10	7	6	61	10	25	9	61	10	25
	40	9	93	10	7	6	52	10	37	9	52	10	37
50	9	89	10	11	10	50	6	42	9	50	6	42	
Pile and burn	1	6	97	2	3	6	97	9	3	6	97	9	3
	10	6	100			6	90	9	10	6	90	9	10
	20	6	100			6	86	9	14	6	86	9	14
	30	9	100			6	75	9	13	6	75	9	13
40	9	100			6	61	10	27	6	61	10	27	
50	9	97	10	3	6	49	10	43	6	49	10	43	
Prescribed fire	1	6	88	2	12	6	100			6	100		
	10	9	100			6	100			6	100		
	20	9	100			6	88	10	12	6	88	10	12
	30	9	97	10	3	6	78	10	21	6	78	10	21
	40	9	85	10	15	9	71	10	29	9	71	10	29
50	9	70	10	30	9	58	10	42	9	58	10	42	

Table 25d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit										
	Fuel models					Fuel models					Fuel models					Fuel models					
	Years	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent
None	1	9	53	6	26	10	21	9	82	10	13	6	5	9	71	10	29	9	52	10	48
	10	9	50	10	29	6	21	9	71	10	29	6	5	9	52	10	48	10	68	9	32
	20	10	45	9	36	6	19	9	52	10	48	6	4	10	90	9	8	10	90	9	8
	30	10	67	9	19	6	14	10	68	9	32	6	4	10	90	9	8	10	90	9	8
	40	10	91	6	5	9	4	10	93	12	7	6	1	10	93	12	7	6	1	6	1
50	10	91	12	9	9	9	9	10	93	12	7	6	1	10	93	12	7	6	1	6	1
Pile and burn	1	9	67	6	33	10	1	9	94	6	6	3	6	9	94	6	6	9	94	6	6
	10	9	70	6	29	10	1	9	97	10	3	3	6	9	97	10	3	9	97	10	3
	20	9	49	10	26	6	25	9	71	10	29	6	4	9	71	10	29	9	52	9	48
	30	10	51	9	28	6	21	10	52	9	48	6	4	10	72	9	25	10	72	9	25
	40	10	76	6	13	9	11	10	93	9	5	1	6	10	93	9	5	10	93	9	5
50	10	99	6	1	1	1	10	93	9	5	1	6	10	93	9	5	1	10	93	9	5
Prescribed fire	1	6	83	9	17	10	19	6	71	9	29	6	24	6	43	9	33	10	24	10	24
	10	6	57	9	24	10	19	6	43	9	33	6	24	6	43	9	33	10	24	10	24
	20	6	49	10	29	9	22	6	37	10	36	6	24	6	37	10	36	9	27	9	27
	30	10	47	6	37	9	15	10	56	6	27	6	24	10	56	6	27	9	27	9	27
	40	10	62	6	29	9	9	10	75	6	17	6	24	10	75	6	17	9	27	9	27
50	10	80	6	16	9	4	10	94	6	5	2	6	10	94	6	5	9	27	9	27	

tpa = trees per acre, d.b.h. = diameter at breast height.

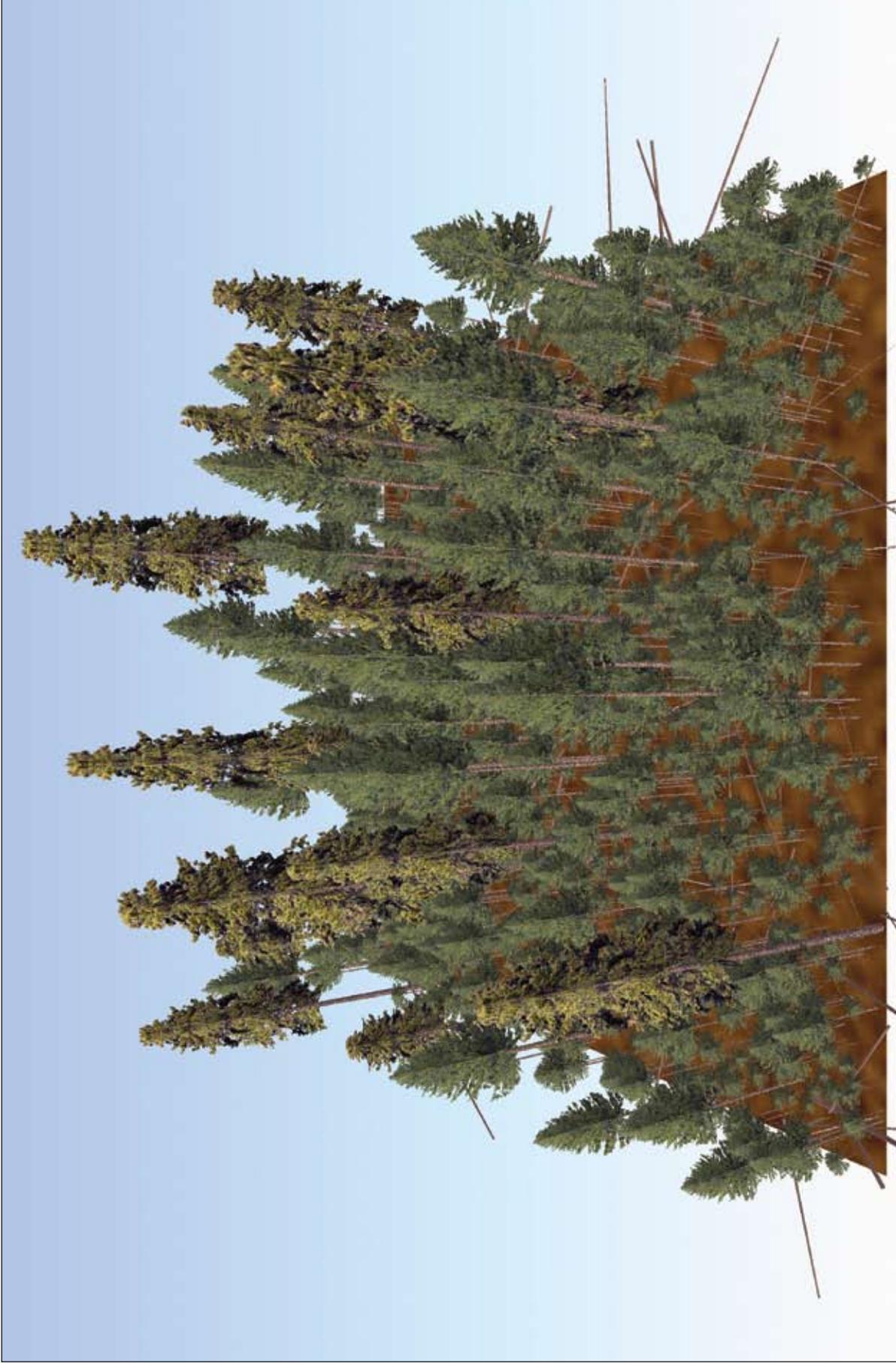
Table 25e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0-0.25 in)	10-hr (0.25-1 in)	100-hr (1-3 in)	1,000-hr (3+ in)	Duff	Live
	Miles/hour	°F	Percent					
Severe—98 th percentile	14	81	3	5	8	15	50	100
Moderate—75 th percentile	8	64	6	8	11	18	125	150

Table 25f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).

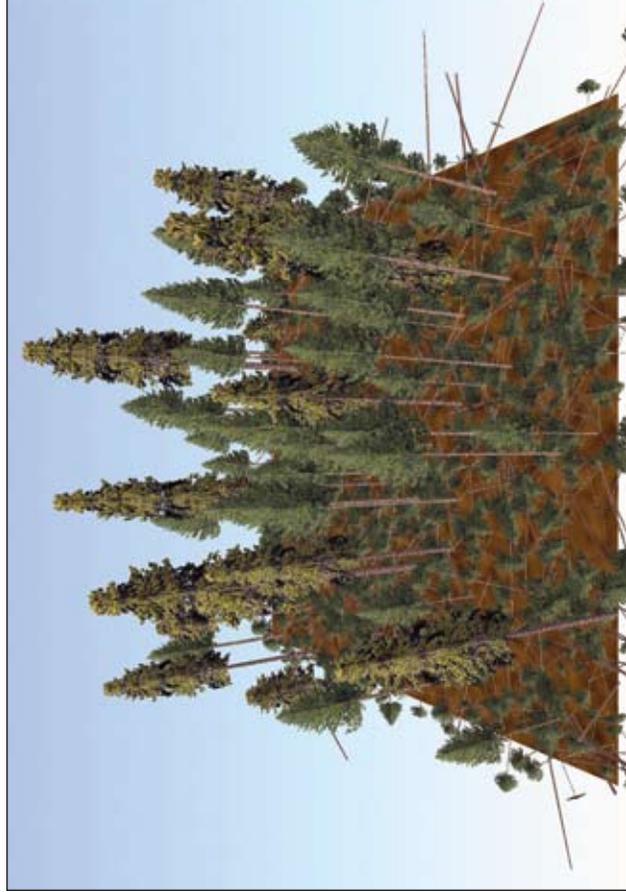


Initial stand conditions

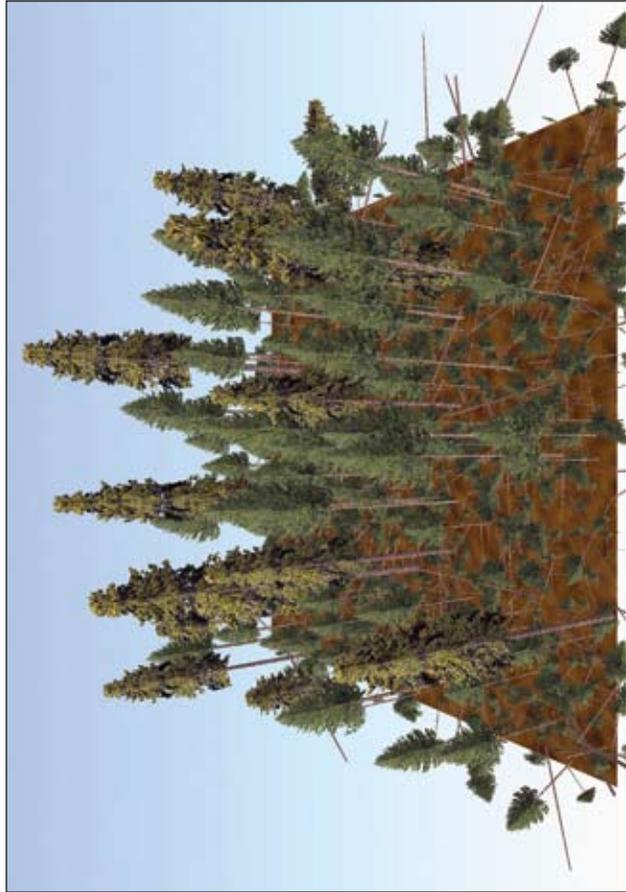
Site: Elevation = 4,800 ft, slope = 25 percent, aspect = 145°.

Species (based on trees per acre): Douglas-fir (*Pseudotsuga menziesii*) = 99 percent, ponderosa pine (*Pinus ponderosa*) = 1 percent.

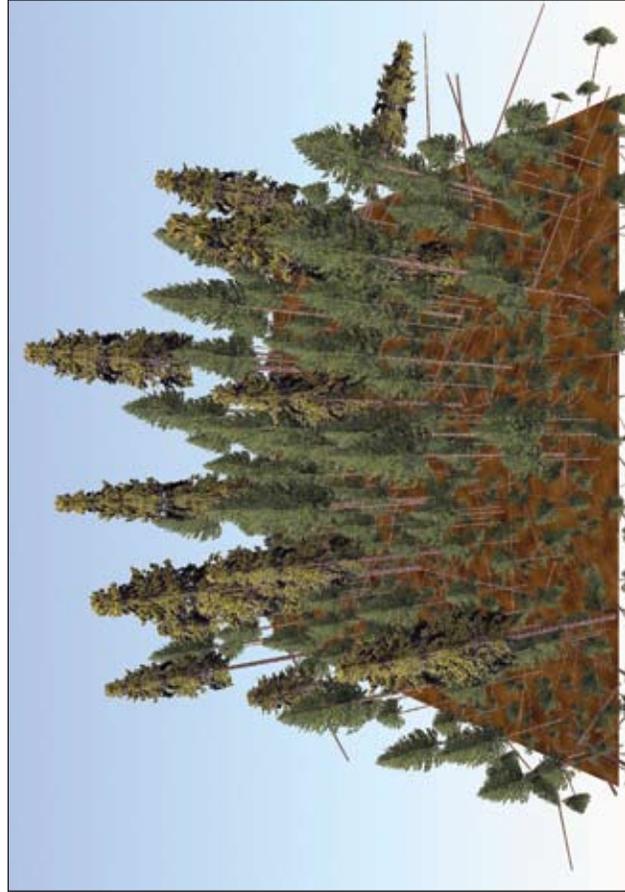
Stand attributes: Stem density = 2,514 tpa, basal area = 188 ft²/ac, top height = 86 ft, stand density index = 510, quadratic mean diameter = 3.7 in, crown competition factor = 369, canopy cover = 88 percent.



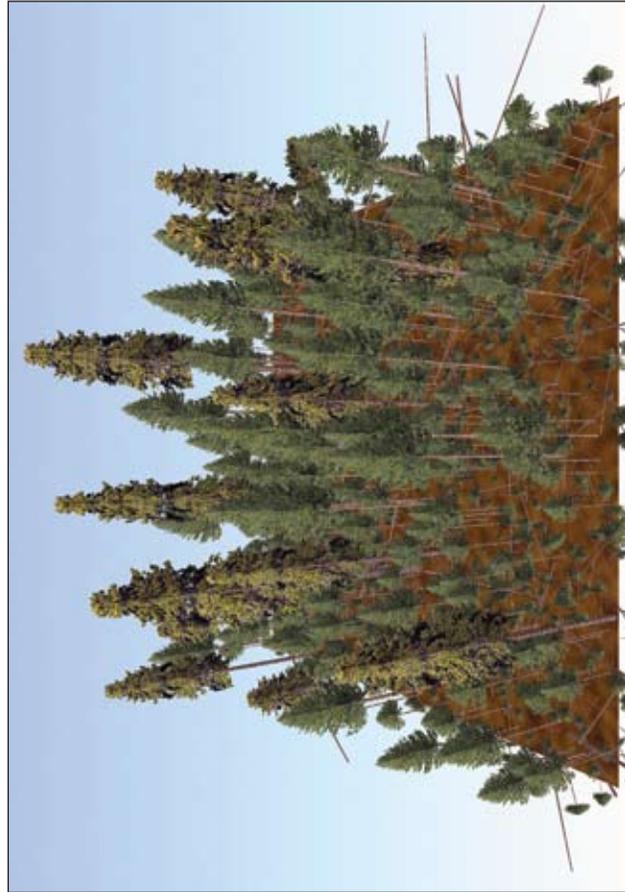
Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This is a dense stand with 2,514 trees per acre (tpa) composed of primarily understory Douglas-fir with overstory ponderosa pine. Canopy base height is 7 ft and canopy bulk density is 0.52 kg/m³ (0.0325 lb/ft³), so initial conditions have low potential for passive crown fire but high potential for active crown fire spread (conditional crown fire) under severe fire weather. Potential tree mortality is 34 percent, and flame lengths are only 2 ft. Woody fuel loading is 11 tons/ac, and litter and duff loading is 12 tons/ac. With no action, canopy base height remains constant, canopy bulk density decreases, and flame lengths increase, so the potential for crown fire spread increases, but the potential for passive crown fire increases. In 40 years, passive crown fire is predicted for severe fire weather, but surface fire is predicted for moderate fire weather. Surface fuels accumulate over time, and flame lengths are 6 ft in 50 years for severe fire weather.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment does not affect canopy base height, but fire-caused mortality of small trees reduces canopy bulk density and increases snag density. Surface fuel loading is greatly reduced and potential flame lengths decrease initially. All thinning treatments increase canopy base height and reduce canopy bulk density; the greater the thinning, the greater the change in forest structure. Immediately after the thinning the predicted fire type changes to surface fire for all treatments, but extensive activity fuels cause higher potential flame lengths. Both the pile and burn and the prescribed fire surface fuel treatments reduce woody fuels, and the prescribed fire treatment also reduces litter and duff, but potential flame lengths decrease only slightly because fuel model 5 is assigned to the open stands with low woody fuel loading. Flame lengths remain above 4 ft for severe fire weather, but are 2 ft or less for moderate fire weather. Brush fuels are not tracked in FFE and may or may not be present following treatment.

Silvicultural and surface fuel treatments—long-term effects

All treatments reduce canopy bulk density sufficiently that active crown fire spread remains unlikely for the 50-year projection. In the prescribed fire only treatment, forest structure changes little over time, but surface fuels accumulate, and higher flame lengths cause a gradual increase in crown fire potential. In the 50 and 100 tpa treatments, regeneration causes an abrupt decline in canopy base height in 10 to 30 years depending on surface fuel treatment, but because flame lengths are low, the decline in canopy base height only temporarily increases crown fire potential. In the 200 and 300 tpa treatments, regeneration is minimal, so canopy base height continues to increase over time as the trees grow and the stand self-thins. In high-density treatments with prescribed fire, regeneration is greater and canopy base height decreases in 40 years, at which time surface fuels have accumulated and flame lengths are higher, so passive crown fire is predicted again for severe fire weather. Another treatment would be necessary to reduce surface fuels or increase canopy base height. Crown fire potential remains low in all treatments for moderate fire weather for the entire 50-year projection.

Table 26a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Initial condition	Prescribed fire only	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	3	1	14	14	12	10
	0–3 in	4	0	8	9	8	6
	3–6 in	4	2	2	3	3	4
	6–12 in	0	0	0	0	0	0
	>12 in	2	1	5	5	4	4
	Litter	10	7	7	8	9	10
	Duff	1	1	5	5	4	3
	Moderate	2	1	8	7	6	5
	Severe	197	232	38	43	45	53
	Severe	6	22	48	40	23	17
Pile and burn	Torching index	Surface	Surface	Surface	Surface	Surface	Surface
	Crowning index	Surface	Surface	Surface	Surface	Surface	Surface
	Type of fire	Conditional	23	8	12	18	22
	Potential basal area mortality (%)	34	23	29	28	36	35
	Severe	3	3	3	3	3	2
	0–3 in	2	1	1	1	2	2
	3–6 in	1	0	0	0	1	1
	6–12 in	0	5	5	4	0	0
	>12 in	5	6	6	7	4	4
	Litter	2	2	2	2	8	9
Prescribed fire	Duff	6	6	5	5	4	2
	Moderate	50	50	62	62	138	447
	Severe	48	48	40	40	23	17
	Severe	Surface	Surface	Surface	Surface	Surface	Surface
	Torching index	Surface	Surface	Surface	Surface	Surface	Surface
	Crowning index	8	8	12	12	18	22
	Type of fire	10	10	18	18	18	22
	Potential basal area mortality (%)	0	0	0	0	0	0
	Severe	2	2	2	2	2	2
	0–3 in	1	1	1	1	2	2
Pile and burn	3–6 in	0	0	0	0	0	0
	6–12 in	0	0	0	0	0	0
	>12 in	0	0	0	1	1	1
	Litter	5	5	6	6	6	7
	Duff	2	2	1	1	1	1
	Moderate	6	6	6	6	5	4
	Severe	43	43	53	53	50	81
	Severe	51	51	51	51	36	29
	Torching index	Surface	Surface	Surface	Surface	Surface	Surface
	Crowning index	Surface	Surface	Surface	Surface	Surface	Surface
Type of fire	7	9	10	10	14	17	
Potential basal area mortality (%)	9	9	18	18	24	22	
Severe	0	0	0	0	0	0	

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 26b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	3	6	8	10	10	10	1	7	5	5	6	6
	0–3 in	4	4	5	6	7	8	0	6	6	6	6	7
	3–6 in	4	3	4	4	6	7	2	3	3	4	5	6
	6–12 in	0	1	2	3	5	6	0	1	2	4	6	7
	>12 in	2	6	6	6	6	5	1	3	3	3	4	4
	Litter	10	10	11	12	12	13	7	7	8	8	9	9
	Duff	1	2	3	3	4	4	1	2	2	2	3	3
	Moderate	2	3	4	5	5	6	1	4	3	4	4	5
	Severe	197	45	22	15	11	8	232	28	35	29	19	17
	Severe	6	10	13	16	18	19	22	23	23	24	25	25
Flame length (ft)	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Cond.	Cond.	Cond.	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	159	295	474	353	314	229	536	18	39	59	70	
	18–29.9 in	4	4	5	5	5	5	5	5	5	6	5	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	
	Torching index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Cond.	Cond.	Cond.	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
		0–17.9 in	159	295	474	353	314	229	536	18	39	59	70
		18–29.9 in	4	4	5	5	5	5	5	5	5	6	5
		30–36 in	0	0	0	0	0	0	0	0	0	0	0
Crowning index		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Cond.	Cond.	Cond.	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
		0–17.9 in	159	295	474	353	314	229	536	18	39	59	70
		18–29.9 in	4	4	5	5	5	5	5	5	5	6	5
		30–36 in	0	0	0	0	0	0	0	0	0	0	0
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Cond.	Cond.	Cond.	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
		0–17.9 in	159	295	474	353	314	229	536	18	39	59	70
		18–29.9 in	4	4	5	5	5	5	5	5	5	6	5
		30–36 in	0	0	0	0	0	0	0	0	0	0	0
Thin from below to 50 tpa, 18-in d.b.h. limit		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Cond.	Cond.	Cond.	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
		0–17.9 in	159	295	474	353	314	229	536	18	39	59	70
		18–29.9 in	4	4	5	5	5	5	5	5	5	6	5
		30–36 in	0	0	0	0	0	0	0	0	0	0	0
	Thin from below to 100 tpa, 18-in d.b.h. limit	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Cond.	Cond.	Cond.	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
		0–17.9 in	159	295	474	353	314	229	536	18	39	59	70
		18–29.9 in	4	4	5	5	5	5	5	5	5	6	5
		30–36 in	0	0	0	0	0	0	0	0	0	0	0
None		Surface fuel loadings (tons/ac)	14	8	5	4	3	3	14	8	5	4	4
		0–3 in	8	8	7	7	7	7	9	8	8	8	7
		3–6 in	2	2	3	3	4	4	3	3	3	3	4
		6–12 in	0	1	2	3	5	7	0	1	2	3	5
		>12 in	5	1	2	2	2	2	5	2	2	2	2
	Litter	7	7	8	8	8	8	8	8	9	9	9	
	Duff	5	3	3	3	3	3	5	3	2	2	3	
	Moderate	8	5	6	4	4	4	7	5	5	5	5	
	Severe	38	73	79	9	17	22	43	87	78	83	10	17
	Severe	48	47	45	45	47	49	40	41	40	37	34	35
Flame length (ft)	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Cond.	Cond.	Cond.	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	
	0–17.9 in	159	295	474	353	314	229	536	18	39	59	70	
	18–29.9 in	4	4	5	5	5	5	5	5	5	6	5	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	
	Torching index	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Cond.	Cond.	Cond.	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
		0–17.9 in	159	295	474	353	314	229	536	18	39	59	70
		18–29.9 in	4	4	5	5	5	5	5	5	5	6	5
		30–36 in	0	0	0	0	0	0	0	0	0	0	0
Crowning index		Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Cond.	Cond.	Cond.	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
		0–17.9 in	159	295	474	353	314	229	536	18	39	59	70
		18–29.9 in	4	4	5	5	5	5	5	5	5	6	5
		30–36 in	0	0	0	0	0	0	0	0	0	0	0
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Cond.	Cond.	Cond.	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
		0–17.9 in	159	295	474	353	314	229	536	18	39	59	70
		18–29.9 in	4	4	5	5	5	5	5	5	5	6	5
		30–36 in	0	0	0	0	0	0	0	0	0	0	0

Table 26b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
Pile and burn	Surface fuel loadings (tons/ac)	3	3	3	3	3	3	3	3	3	3	3	3	4
	3–6 in	2	2	2	3	3	3	3	2	3	3	3	3	4
	6–12 in	1	1	1	2	2	3	1	1	1	2	3	3	4
	>12 in	0	1	2	3	5	6	0	1	2	3	3	5	6
	Litter	5	1	2	2	2	2	4	2	2	2	2	2	2
	Duff	6	6	7	7	7	7	7	7	8	8	8	8	8
	Moderate	2	2	4	2	2	2	2	1	2	2	2	2	2
	Severe	6	6	6	3	3	4	5	5	5	5	5	5	4
	Severe	50	51	65	16	23	26	62	70	72	86	11	38	38
	Severe	48	47	45	45	46	40	40	39	39	36	33	34	34
Prescribed fire	Surface fuel loadings (tons/ac)	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	0–3 in	6	7	12	19	24	24	6	8	13	18	22	26	
	3–6 in	4	4	5	5	6	5	4	4	5	5	5	5	
	6–12 in	0	0	0	0	0	0	0	0	0	0	0	0	
	>12 in	0	1	2	4	6	7	0	1	3	4	6	7	
	Litter	0	1	2	2	2	2	4	2	2	2	2	2	
	Duff	5	5	5	5	5	6	7	6	6	6	6	6	
	Moderate	2	2	2	2	2	2	1	1	2	2	2	2	
	Severe	6	3	3	3	3	4	6	6	5	3	4	4	
	Severe	43	4	17	24	31	35	53	61	67	31	18	19	
Pile and burn	Surface fuel loadings (tons/ac)	51	50	33	24	22	20	51	49	47	42	40	40	
	3–6 in	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	6–12 in	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	>12 in	10	10	15	24	32	34	16	10	14	18	23	27	
	Litter	5	5	5	5	5	5	5	5	5	5	5	5	
	Duff	0	0	0	0	0	0	0	0	0	0	0	0	
	Moderate	0	0	0	0	0	0	0	0	0	0	0	0	
	Severe	0	0	0	0	0	0	0	0	0	0	0	0	
	Severe	0	0	0	0	0	0	0	0	0	0	0	0	
	Severe	0	0	0	0	0	0	0	0	0	0	0	0	

Table 26b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	12	7	5	5	5	5	10	6	5	6	6	7
	0–3 in												
	3–6 in	8	7	7	7	7	8	6	6	6	6	7	7
	6–12 in	3	3	3	4	5	6	4	3	3	4	5	7
	>12 in	0	1	2	3	5	6	0	1	2	3	5	6
	Litter	4	3	3	3	3	3	4	3	3	4	4	4
	Duff	9	10	10	10	11	11	10	11	11	11	12	12
	Moderate	4	3	2	2	3	3	3	2	2	2	3	3
	Severe	6	4	4	4	4	5	5	4	3	4	4	5
	Severe	45	95	120	124	111	96	53	120	147	128	102	87
Pile and burn	Torching index	23	25	26	26	26	26	17	20	19	20	21	21
	Crowning index												
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	0–17.9 in	4	7	14	22	29	33	7	13	25	37	48	54
	18–29.9 in	4	4	5	5	5	5	4	4	5	5	5	5
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
	Surface fuel loadings (tons/ac)	3	3	3	4	5	5	2	3	4	5	6	7
	0–3 in												
	3–6 in	2	2	3	3	3	4	2	2	2	3	4	5
6–12 in	1	1	1	2	3	5	1	1	1	2	4	6	
>12 in	0	1	2	3	5	6	0	1	2	3	5	6	
Litter	4	3	3	3	3	3	4	3	3	4	4	4	
Duff	8	9	9	9	9	10	9	9	10	10	10	11	
Moderate	2	1	1	2	2	3	1	1	1	2	2	3	
Severe	4	3	3	3	4	4	2	2	2	3	4	5	
Severe	138	270	264	208	156	133	447	545	360	218	145	105	
None	Torching index	23	25	26	26	26	25	17	19	19	20	22	22
	Crowning index												
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	0–17.9 in	7	10	18	27	33	36	7	13	25	36	48	55
	18–29.9 in	4	4	5	5	5	5	4	4	5	5	5	5
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
	Surface fuel loadings (tons/ac)	3	3	3	4	5	5	2	3	4	5	6	7
	0–3 in												
	3–6 in	2	2	3	3	3	4	2	2	2	3	4	5
6–12 in	1	1	1	2	3	5	1	1	1	2	4	6	
>12 in	0	1	2	3	5	6	0	1	2	3	5	6	
Litter	4	3	3	3	3	3	4	3	3	4	4	4	
Duff	8	9	9	9	9	10	9	9	10	10	10	11	
Moderate	2	1	1	2	2	3	1	1	1	2	2	3	
Severe	4	3	3	3	4	4	2	2	2	3	4	5	
Severe	138	270	264	208	156	133	447	545	360	218	145	105	

Table 26b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	3	3	3	3	4	0	4	3	4	4	5
	0–3 in												
	3–6 in	2	5	5	5	5	5	2	5	5	5	6	6
	6–12 in	2	3	4	4	5	6	2	4	4	4	5	6
	>12 in	0	1	3	4	6	7	0	1	3	4	6	7
Flame length (ft)	Litter	1	2	2	2	2	2	1	2	2	3	3	3
	Duff	6	7	7	7	7	8	7	7	7	8	8	8
	Moderate	1	2	2	2	2	3	1	2	2	2	3	3
Torching index	Severe	5	5	5	5	4	4	4	4	4	4	4	5
	Severe	50	69	76	86	13	23	81	88	90	92	14	11
Crowning index	Severe	36	37	38	38	35	33	29	31	30	32	32	31
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Type of fire	Severe	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Passive	Passive
	Severe	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Passive	Passive
	Severe	29	11	16	21	25	29	43	12	20	26	33	36
Hard snags (stems/ac)	0–17.9 in	5	5	5	5	5	5	5	5	5	6	5	5
	18–29.9 in												
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

tpa = trees per acre; d.b.h. = diameter at breast height; cond. = conditional.

Table 26c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,514	2,182	1,773	1,532	1,277	1,126	544	534	505	461	411	361
	Quadratic mean diameter (in)	3.7	4.1	4.6	5.1	5.7	6.1	3.7	6.9	7.5	8.1	8.8	9.5
	Total volume (ft ³)	4,651	5,145	5,504	5,977	6,340	6,818	4,049	4,273	4,691	5,049	5,435	5,805
	Merchantable volume (ft ³)	3,579	3,884	4,497	5,166	5,691	6,264	3,400	3,550	4,115	4,550	5,025	5,417
	Basal area (ft ²)	188	202	208	219	224	231	132	140	154	164	172	177
	Stand density index	510	525	517	522	513	514	284	297	317	327	332	331
	Canopy closure (percent)	88	88	86	85	83	82	63	65	67	67	66	65
	Crown competition factor	369	365	349	345	334	331	189	197	211	217	219	218
	Canopy base height (ft)	7	7	7	7	7	7	7	7	7	7	7	8
	Canopy bulk density (kg/m ³)	0.52	0.31	0.25	0.18	0.16	0.15	0.12	0.12	0.12	0.11	0.11	0.10

Table 26c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,514	50	148	144	136	127	118	100	147	142	135	127	118
	Quadratic mean diameter (in)	3.7	18.0	10.7	11.1	11.7	12.3	13.1	13.8	11.8	12.3	12.9	13.7	14.4
	Total volume (ft ³)	4,651	3,562	3,653	3,792	3,944	4,055	4,216	3,894	4,034	4,281	4,573	4,887	5,130
	Merchantable volume (ft ³)	3,579	3,387	3,437	3,572	3,725	3,796	3,881	3,701	3,803	4,028	4,334	4,654	4,848
	Basal area (ft ²)	188	89	93	96	101	105	110	103	111	117	123	129	133
	Stand density index	510	129	166	169	175	178	182	167	191	198	204	210	211
	Canopy cover (percent)	88	28	28	30	32	33	34	38	39	40	41	42	42
	Crown competition factor	369	86	89	92	100	103	106	110	117	121	127	133	135
	Canopy base height (ft)	7	31	35	40	5	8	10	28	32	32	33	6	8
	Canopy bulk density (kg/m ³)	0.52	0.04	0.04	0.05	0.05	0.04	0.04	0.06	0.05	0.05	0.06	0.07	0.07
Pile and burn	Trees per acre	2,514	50	148	144	136	127	118	100	173	168	160	151	140
	Quadratic mean diameter (in)	3.7	18.0	10.7	11.1	11.7	12.3	13.1	13.8	10.8	11.3	11.9	12.6	13.3
	Total volume (ft ³)	4,651	3,562	3,653	3,792	3,944	4,055	4,216	3,894	4,034	4,279	4,576	4,900	5,146
	Merchantable volume (ft ³)	3,579	3,387	3,437	3,572	3,725	3,796	3,881	3,701	3,803	4,026	4,337	4,663	4,858
	Basal area (ft ²)	188	89	93	96	101	105	110	103	111	117	123	130	135
	Stand density index	510	129	166	169	175	178	182	167	197	204	211	219	221
	Canopy cover (percent)	88	28	28	30	34	36	37	38	39	40	41	43	43
	Crown competition factor	369	86	89	92	100	103	106	110	117	121	128	135	138
	Canopy base height (ft)	7	31	35	40	5	8	10	28	32	32	33	6	8
	Canopy bulk density (kg/m ³)	0.52	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.07	0.07
Prescribed fire	Trees per acre	2,514	50	341	334	319	299	278	100	220	215	206	195	181
	Quadratic mean diameter (in)	3.7	18.0	7.0	7.6	8.3	9.1	9.9	13.8	9.0	9.3	9.9	10.5	11.2
	Total volume (ft ³)	4,651	3,361	3,438	3,624	3,836	4,203	4,524	3,560	3,665	3,838	4,074	4,300	4,517
	Merchantable volume (ft ³)	3,579	3,187	3,230	3,338	3,470	3,619	4,075	3,375	3,452	3,600	3,835	4,041	4,192
	Basal area (ft ²)	188	89	90	105	120	134	147	103	97	101	110	117	124
	Stand density index	510	129	190	214	237	255	271	167	186	191	202	211	217
	Canopy cover (percent)	88	28	33	41	47	50	52	38	33	34	38	40	42
	Crown competition factor	369	86	94	119	134	144	153	110	98	101	117	123	128
	Canopy base height (ft)	7	42	2	4	7	10	13	29	32	33	4	7	9
	Canopy bulk density (kg/m ³)	0.52	0.04	0.04	0.07	0.11	0.12	0.14	0.04	0.04	0.04	0.05	0.06	0.05

Table 26c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,514	200	220	211	197	181	166	300	317	301	278	250	221
	Quadratic mean diameter (in)	3.7	10.6	10.7	11.4	12.1	13.0	13.7	9.2	9.5	10.2	11.0	11.8	12.6
	Total volume (ft ³)	4,651	4,302	4,515	4,913	5,346	5,814	6,157	4,583	4,837	5,320	5,814	6,247	6,630
	Merchantable volume (ft ³)	3,579	3,770	4,008	4,618	5,099	5,577	5,914	3,763	4,000	4,808	5,527	5,973	6,338
	Basal area (ft ²)	188	124	137	149	158	166	171	139	157	172	183	189	192
	Stand density index	510	221	245	259	269	274	276	263	293	313	324	325	321
	Canopy cover (percent)	88	51	54	55	56	56	55	60	64	65	65	64	63
	Crown competition factor	369	148	161	172	179	183	186	179	198	212	220	221	219
	Canopy base height (ft)	7	23	26	27	29	31	35	19	22	24	26	29	32
	Canopy bulk density (kg/m ³)	0.52	0.12	0.10	0.10	0.10	0.10	0.10	0.17	0.14	0.15	0.14	0.13	0.13
Pile and burn	Trees per acre	2,514	200	233	224	209	193	176	300	330	314	291	262	230
	Quadratic mean diameter (in)	3.7	10.6	10.4	11.0	11.8	12.6	13.4	9.2	9.3	10.0	10.7	11.5	12.4
	Total volume (ft ³)	4,651	4,302	4,515	4,913	5,345	5,813	6,163	4,583	4,837	5,320	5,809	6,254	6,600
	Merchantable volume (ft ³)	3,579	3,770	4,008	4,617	5,098	5,576	5,915	3,763	4,000	4,808	5,521	5,975	6,321
	Basal area (ft ²)	188	124	137	149	158	166	171	139	157	172	183	189	191
	Stand density index	510	221	248	262	272	278	280	263	296	315	327	328	323
	Canopy cover (percent)	88	51	54	55	56	56	55	60	64	65	65	65	63
	Crown competition factor	369	148	161	172	179	183	186	179	198	212	220	222	218
	Canopy base height (ft)	7	23	26	27	29	31	35	19	22	24	26	29	32
	Canopy bulk density (kg/m ³)	0.52	0.12	0.10	0.10	0.10	0.10	0.10	0.17	0.15	0.15	0.14	0.13	0.13
Prescribed fire	Trees per acre	2,514	200	197	190	180	168	154	300	242	231	217	199	181
	Quadratic mean diameter (in)	3.7	10.6	10.2	10.7	11.3	12.0	12.8	9.2	9.5	10.1	10.7	11.4	12.2
	Total volume (ft ³)	4,651	3,777	3,925	4,184	4,480	4,808	5,091	3,908	4,072	4,370	4,687	5,014	5,298
	Merchantable volume (ft ³)	3,579	3,419	3,582	3,930	4,254	4,585	4,843	3,414	3,571	4,032	4,448	4,777	5,027
	Basal area (ft ²)	188	124	111	118	125	132	138	139	120	129	136	142	146
	Stand density index	510	221	202	211	219	225	229	263	225	235	243	247	248
	Canopy cover (percent)	88	51	42	43	44	45	45	60	48	49	50	50	49
	Crown competition factor	369	148	121	127	135	142	145	179	139	146	152	156	158
	Canopy base height (ft)	7	24	26	27	29	6	8	19	23	23	25	6	6
	Canopy bulk density (kg/m ³)	0.52	0.06	0.06	0.06	0.06	0.07	0.07	0.09	0.08	0.08	0.08	0.07	0.08

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 26d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None			Percent			Percent			Percent				Percent
	1	8	89	10	11			8	100				
	10	10	71	8	29			10	85	8	15		
	20	10	92	12	8			10	74	8	26		
	30	10	72	12	28			10	86	8	14		
40	10	56	12	44			10	95	12	5			
50	12	57	10	43			10	81	12	19			

Thin from below to 50 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
None			Percent			Percent			Percent				Percent
	1	12	62	10	38			12	57	10	43		
	10	10	89	5	10	1	1	10	95	5	5		
	20	10	60	6	40			10	68	5	32		
	30	10	53	9	47			10	65	5	34	8	2
40	10	60	9	40			10	74	5	24	8	2	
50	10	72	9	28			10	90	5	10	8	1	
Pile and burn	1	5	56	10	38	1	6	5	67	10	33		
	10	5	92	1	8			5	98	10	2		
	20	6	98	2	2	10	1	5	92	10	8		
	30	9	89	10	11			5	74	10	20	8	6
	40	9	73	10	27			5	55	10	37	8	8
50	9	57	10	43			10	57	8	43			
Prescribed fire	1	5	77	1	23			5	100				
	10	9	100					5	99	10	1		
	20	9	98	10	2			5	87	10	13		
	30	9	78	10	22			8	72	10	28		
	40	9	56	10	44			9	56	10	44		
50	10	66	9	34			10	63	9	37			

Table 26d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit										Thin from below to 300 tpa, 18-in. d.b.h. limit									
	Years					Fuel models					Years					Fuel models				
	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent	Model	Weight	Model	Weight	Percent
None	1	10	61	12	39						10	85	12	15						
	10	10	90	8	7	5	3				10	76	8	24						
	20	10	72	8	21	5	7				10	71	8	29						
	30	10	79	8	17	5	4				10	88	8	12						
	40	10	100	8	5						10	90	12	10						
50	10	87	12	13						10	73	12	27							
Pile and burn	1	8	45	5	35	10	21				8	92	10	8						
	10	8	65	5	29	10	6				8	92	10	8						
	20	8	64	5	20	10	16				8	75	10	25						
	30	8	51	10	36	5	13				10	52	8	48						
	40	10	62	8	30	5	8				10	86	8	14						
50	10	92	8	6	2					10	88	12	12							
Prescribed fire	1	5	100								5	74	8	26						
	10	5	71	10	22	8	7				10	39	5	37						24
	20	5	59	10	31	8	10				10	45	5	30						25
	30	10	46	5	43	8	12				10	62	5	20						18
	40	10	64	5	26	8	9				10	84	5	8						8
50	10	86	8	14						10	95	12	5							

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 26e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			1-hr (0-0.25 in)	10-hr (0.25-1 in)	100-hr (1-3 in)	1,000-hr (3+ in)	Duff	Live
Severe—98 th percentile	14	81	3	5	10	15	50	100
Moderate—75 th percentile	8	64	6	8	15	18	125	150

Table 26f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).



Initial stand conditions

Site: Elevation = 3,400 ft, slope = 36 percent, aspect = 266°.

Species (based on trees per acre): Grand fir (*Abies grandis*) = 53 percent, Douglas-fir (*Pseudotsuga menziesii*) = 38 percent, lodgepole pine (*Pinus contorta*) = 1 percent, ponderosa pine (*Pinus ponderosa*) = 8 percent.

Stand attributes: Stem density = 2,092 tpa, basal area = 166 ft²/ac, top height = 92 ft, stand density index = 445, quadratic mean diameter = 3.8 in, crown competition factor = 217, canopy cover = 66 percent.



Thin from below to 50 tpa, 18-in d.b.h. limit



Thin from below to 100 tpa, 18-in d.b.h. limit



Thin from below to 200 tpa, 18-in d.b.h. limit



Thin from below to 300 tpa, 18-in d.b.h. limit

Initial conditions/no-action trajectory

This is a dense stand with 2,092 trees per acre (tpa) composed of grand fir, Douglas-fir, lodgepole pine, and ponderosa pine. Canopy base height is 2 ft, and canopy bulk density is 0.08 kg/m³ (0.005 lb/ft³) so initial conditions have high potential for passive crown fire and tree mortality, but low potential for active crown fire spread under severe fire weather. Initial woody fuel loading is 9 tons/ac, and litter and duff loading is 7 tons/ac. With no action, canopy base height will increase and canopy bulk density will decrease over time as trees grow and the stand self-thins, but surface fuels accumulate and potential flame lengths increase, so crown fire potential remains similar. Passive crown fire is predicted for the entire 50-year trajectory for severe fire weather, but surface fire is predicted for moderate fire weather.

Silvicultural and surface fuel treatments—immediate effects

The prescribed fire only treatment increases canopy base height and reduces canopy bulk density and surface fuels enough to change the predicted fire type to surface fire for severe and moderate fire weather; however, many snags are created and surface fuels accumulate rapidly. Potential flame lengths increase immediately after treatment despite the reduction in woody surface fuels, because the more open stand is characterized by fuel model 6 suggesting that brush fuels are an important contributor to fire behavior following prescribed fire; this may or may not be a factor, depending on the site. All thinning treatments effectively reduce canopy bulk density and increase canopy base height enough to reduce crown fire potential and tree mortality, but the 100 to 300 tpa treatments similarly affect stand structure. The thinning treatments also increase surface fuels and potential flame lengths; the greater the thinning, the greater the change in surface fuels and flame lengths. These activity fuels are reduced by the pile and burn treatment and to a greater extent by prescribed fire, but this change in surface fuels does not reduce flame lengths, because the more open stands with low surface fuels are characterized by fuel model 6. The 300 tpa treatment with a prescribed burn surface fuel treatment is still predicted to be passive crown fire immediately after treatment because canopy base height is relatively low and fuel model 6 is the primary model used. Brush fuels are not tracked in FFE, so these results should be interpreted with caution.

Silvicultural and surface fuel treatments—long-term effects

Crown fire potential decreases over time in the prescribed fire only treatment as canopy base height continues to increase, but surface fuels accumulate and flame lengths are predicted to be 5 ft in 50 years. Regeneration in the 50 tpa treatment causes an abrupt decline in canopy base height, and passive crown fire becomes likely again in 30 years. At this time, a second treatment would be necessary to prevent passive crown fire. Regeneration plays an important role in crown fire potential over time, but the decrease in canopy base height may not be as extreme or abrupt in reality. Canopy base height continues to increase in all other thinning treatments, so crown fire potential remains low for both moderate and severe fire weather for the entire 50-year projection.

Table 27a—Projected treatment effects on fuels and fire first cycle after treatments implemented

Surface fuel treatment	Fuel/fire attribute	Prescribed fire only	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit	Thin from below to 100 tpa, 18-in d.b.h. limit	Thin from below to 200 tpa, 18-in d.b.h. limit	Thin from below to 300 tpa, 18-in d.b.h. limit
None	Surface fuel loadings (tons/ac)	1	3	7	6	5	4
		0	3	4	5	3	3
		1	3	1	2	2	2
		0	0	0	0	0	0
		1	2	4	3	3	3
		4	5	2	4	4	5
		4	2	4	4	3	2
		5	3	6	5	4	3
		19	0	63	22	26	34
		43	31	53	40	34	31
Pile and burn	Flame length (ft)	Surface	Surface	Surface	Surface	Surface	Surface
	Torching index	Surface	Passive	Surface	Surface	Surface	Surface
	Crowning index	Surface	Passive	Surface	Surface	Surface	Surface
	Type of fire	Surface	Passive	Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	16	21	7	11	16	19
		30	75	11	25	26	23
Prescribed fire	Surface fuel loadings (tons/ac)	2	2	2	2	1	1
		1	3-6 in	1	1	1	1
		0	6-12 in	0	1	1	1
		0	>12 in	0	0	0	0
		3	Litter	3	3	3	3
		2	Duff	2	3	4	4
		4	Moderate	4	4	3	2
		7	Severe	7	6	4	3
		41	Severe	41	18	26	37
		53	Severe	53	40	34	31
Pile and burn	Flame length (ft)	Surface	Surface	Surface	Surface	Surface	Surface
	Torching index	Surface	Surface	Surface	Surface	Surface	Surface
	Crowning index	Surface	Surface	Surface	Surface	Surface	Surface
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	7	12	7	12	16	19
		24	31	24	31	25	21
Prescribed fire	Surface fuel loadings (tons/ac)	0	0	0	0	0	0
		1	0-3 in	1	1	1	1
		1	3-6 in	1	1	1	1
		0	6-12 in	0	0	0	0
		1	>12 in	1	1	1	1
		2	Litter	2	3	3	3
		4	Duff	4	4	4	3
		7	Moderate	7	6	6	8
		31	Severe	31	22	22	7
		56	Severe	56	43	42	42
Pile and burn	Flame length (ft)	Surface	Surface	Surface	Surface	Surface	Surface
	Torching index	Surface	Surface	Surface	Surface	Surface	Surface
	Crowning index	Surface	Surface	Surface	Surface	Surface	Surface
	Type of fire	Surface	Surface	Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	7	11	7	11	15	16
		23	31	23	31	32	56

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 27b—Treatment effect on fuels and fire behavior, 50-year projection

Surface fuel treatment	Fuel/fire attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	3	6	9	10	9	8	1	5	6	6	7	7
	3–6 in	3	3	5	6	7	8	0	4	4	4	5	5
	6–12 in	3	3	4	6	8	9	1	4	4	4	5	5
	>12 in	0	0	1	2	4	6	0	1	1	2	3	4
	Litter	2	4	4	3	3	3	1	3	3	3	3	3
	Duff	5	5	6	6	7	7	4	4	4	5	5	5
	Moderate	2	2	3	4	4	4	4	3	3	3	3	3
	Severe	3	4	4	5	6	6	5	5	4	4	4	5
	Severe	0	8	5	5	7	9	19	41	102	132	155	155
	Severe	31	33	36	36	36	37	43	40	36	35	35	34
	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Passive	Passive	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	189	407	395	229	166	127	520	9	11	21	21	20
	0–17.9 in	1	2	3	4	4	4	1	1	1	1	1	1
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Surface fuel loadings (tons/ac)	7	5	4	3	4	4	6	5	5	5	6	6
	3–6 in	4	4	4	4	4	5	5	4	5	5	5	6
	6–12 in	1	1	1	1	1	1	2	2	2	2	2	3
	>12 in	0	0	0	0	0	1	0	0	0	0	1	2
	Litter	4	2	2	2	3	3	3	3	3	3	3	3
	Duff	2	3	3	3	4	4	4	4	4	5	5	5
	Moderate	4	4	4	4	4	2	4	3	3	3	3	3
	Severe	6	6	6	6	6	4	5	5	5	5	5	5
	Severe	63	82	103	0	7	22	22	60	99	124	145	177
	Severe	53	51	50	50	49	48	40	37	35	34	35	35
	Moderate	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	1	1	3	3	3	4	1	2	4	10	17	18
	0–17.9 in	0	0	0	0	1	1	0	0	0	1	1	2
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

Table 27b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Pile and burn	Surface fuel loadings (tons/ac)	2	2	3	3	4	4	2	3	4	5	6	6
	3–6 in	1	1	2	2	3	3	1	2	2	3	3	4
	6–12 in	0	0	1	1	1	1	1	1	1	1	1	2
	>12 in	0	0	0	0	0	0	0	0	0	0	0	2
	Litter	3	2	2	2	3	3	3	3	3	3	3	3
	Duff	2	2	3	3	3	4	3	4	4	4	5	5
	Moderate	4	4	4	4	2	2	4	4	3	3	3	3
	Severe	7	7	7	6	3	4	6	5	5	5	5	5
	Torching index	41	62	78	0	21	21	18	55	88	117	138	162
	Crowning index	53	51	50	50	49	49	40	37	34	34	35	35
Type of fire	Moderate	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
Hard snags (stems/ac)	0–17.9 in	1	1	4	4	4	9	1	2	3	15	18	19
	18–29.9 in	0	0	0	0	1	1	0	0	0	1	1	2
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
Prescribed fire	Surface fuel loadings (tons/ac)	0	2	2	3	3	4	0	3	3	4	5	5
	3–6 in	1	2	2	2	3	4	1	2	3	3	4	4
	6–12 in	1	1	2	2	2	2	1	3	4	4	4	4
	>12 in	0	1	1	1	2	2	0	1	1	2	2	3
	Litter	1	2	2	2	3	3	3	2	3	3	3	3
	Duff	2	2	2	2	3	3	3	3	3	3	4	4
	Moderate	4	4	4	2	2	2	4	4	4	3	3	3
	Severe	7	7	7	3	3	4	6	6	6	5	5	5
	Torching index	31	51	77	12	18	19	22	52	92	116	132	162
	Crowning index	56	54	54	44	35	33	43	40	38	37	38	38
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Passive
Hard snags (stems/ac)	0–17.9 in	9	8	8	7	12	18	16	9	7	10	17	20
	18–29.9 in	1	1	1	0	1	1	1	1	1	1	1	2
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

Table 27b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit							
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	
None	Surface fuel loadings (tons/ac)	0–3 in	5	5	7	7	7	8	4	5	8	9	9	9
		3–6 in	3	3	4	5	5	6	3	3	4	5	6	7
	6–12 in	2	2	2	3	4	5	2	2	3	4	5	7	
		0	0	0	1	2	3	0	0	0	1	2	4	
	Litter	3	3	3	3	3	3	3	3	3	4	4	4	4
		4	5	5	6	6	7	5	5	6	6	7	7	7
	Flame length (ft)	Moderate	3	3	3	3	3	3	3	2	3	3	3	4
		Severe	4	4	4	4	4	5	3	3	4	4	5	5
	Torching index	Severe	26	72	102	123	150	150	150	34	66	121	118	103
		Crowning index	34	35	33	32	32	32	32	31	33	32	34	34
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	1	10	21	23	23	35	11	26	37	30	46	59	
Hard snags (stems/ac)	0–17.9 in	0	0	1	1	1	3	0	0	1	1	1	4	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in	1	3	6	7	7	8	1	4	7	8	8	9
		3–6 in	1	1	2	3	4	5	1	1	2	4	4	6
	6–12 in	1	1	1	2	3	4	1	1	1	2	3	6	
		0	0	0	1	2	3	0	0	0	1	2	4	
	Litter	3	3	3	3	3	3	3	3	4	4	4	4	4
		4	4	5	5	6	6	6	4	5	5	6	7	7
	Flame length (ft)	Moderate	3	2	3	3	3	3	2	2	3	3	3	4
		Severe	4	4	4	4	4	4	3	3	4	4	4	5
	Torching index	Severe	26	70	100	119	142	174	37	71	67	114	139	107
		Crowning index	34	35	33	32	32	30	31	35	33	32	33	34
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	
	Severe	1	10	22	23	22	36	11	26	36	29	49	68	
Hard snags (stems/ac)	0–17.9 in	0	0	1	1	1	3	0	0	1	1	2	2	
	18–29.9 in	0	0	0	0	0	0	0	0	0	0	0	0	
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0	

Table 27b—Treatment effect on fuels and fire behavior, 50-year projection (continued)

Surface fuel treatment	Fuel/fire attribute	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
Prescribed fire	Surface fuel loadings (tons/ac)	0	4	4	5	6	6	0	4	5	6	6	7
		1	3	4	4	5	6	1	4	4	5	5	6
		1	4	4	4	5	5	1	4	4	5	5	6
		0	1	1	2	2	3	0	1	1	2	3	4
		1	3	3	3	3	3	1	3	3	3	3	3
		3	3	4	4	5	5	3	4	4	4	5	5
		4	3	3	3	3	3	3	3	3	3	4	4
		6	5	5	5	4	5	8	4	4	4	5	6
		22	46	80	101	132	170	7	26	52	96	93	101
		42	39	36	35	35	35	42	38	36	36	36	36
Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Severe	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface
Hard snags (stems/ac)	0–17.9 in	30	9	10	20	22	20	48	9	17	25	23	21
	18–29.9 in	1	1	1	1	2	2	1	1	1	1	1	1
	30–36 in	0	0	0	0	0	0	0	0	0	0	0	0

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 27c—Treatment effect on forest stand attributes, 50-year trajectory

Surface fuel treatment	Stand attribute	No action					Prescribed fire only						
		1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,092	1,630	1,318	1,139	984	876	194	193	187	172	162	153
	Quadratic mean diameter (in)	3.8	4.5	5.1	5.7	6.2	6.7	3.8	12.2	13.3	14.4	15.4	16.5
	Total volume (ft ³)	4,896	5,758	6,373	7,074	7,695	8,232	4,759	5,312	6,395	7,266	8,168	9,043
	Merchantable volume (ft ³)	4,328	5,236	5,887	6,689	7,290	7,841	4,379	4,967	6,012	6,922	7,752	8,607
	Basal area (ft ²)	166	181	188	199	206	212	144	157	180	196	211	226
	Stand density index	445	454	449	456	456	457	248	265	295	310	326	341
	Canopy closure (percent)	66	66	65	62	62	61	49	51	54	56	57	58
	Crown competition factor	217	217	214	218	219	220	145	158	179	191	203	215
	Canopy base height (ft)	2	4	5	6	7	8	10	16	17	31	36	41
	Canopy bulk density (kg/m ³)	0.08	0.07	0.07	0.07	0.07	0.06	0.05	0.06	0.07	0.07	0.07	0.07

Table 27c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 50 tpa, 18-in d.b.h. limit					Thin from below to 100 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,092	50	149	147	145	142	140	100	149	147	141	133	125
	Quadratic mean diameter (in)	3.8	19.3	11.9	12.7	13.6	14.3	15.1	15.5	13.8	14.8	15.8	16.8	17.9
	Total volume (ft ³)	4,896	4,120	4,516	5,294	6,169	6,944	7,786	4,980	5,554	6,658	7,629	8,463	9,317
	Merchantable volume (ft ³)	4,328	3,955	4,355	5,076	5,961	6,679	7,506	4,741	5,362	6,378	7,378	8,161	9,014
	Basal area (ft ²)	166	102	116	130	146	159	173	131	155	177	193	205	219
	Stand density index	445	144	198	216	237	253	270	202	250	277	295	306	319
	Canopy cover (percent)	66	29	31	33	37	39	40	42	46	49	50	51	51
	Crown competition factor	217	84	95	105	120	133	144	124	146	164	177	186	196
	Canopy base height (ft)	2	31	38	44	4	6	8	11	25	39	47	51	56
	Canopy bulk density (kg/m ³)	0.08	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.07	0.07	0.07	0.07
Pile and burn	Trees per acre	2,092	50	199	196	193	190	183	100	175	173	162	153	144
	Quadratic mean diameter (in)	3.8	19.3	10.3	11.0	11.8	12.4	13.1	15.5	12.7	13.7	14.7	15.6	16.6
	Total volume (ft ³)	4,896	4,120	4,516	5,293	6,166	6,935	7,697	4,980	5,554	6,657	7,534	8,418	9,238
	Merchantable volume (ft ³)	4,328	3,955	4,355	5,076	5,960	6,665	7,417	4,741	5,362	6,378	7,287	8,118	8,926
	Basal area (ft ²)	166	102	116	130	146	159	172	131	155	177	191	204	217
	Stand density index	445	144	210	229	251	268	283	202	259	286	300	313	326
	Canopy cover (percent)	66	29	31	34	37	40	41	42	46	49	50	50	51
	Crown competition factor	217	84	95	105	121	137	146	124	146	164	175	185	195
	Canopy base height (ft)	2	31	38	44	4	6	7	11	25	38	47	52	56
	Canopy bulk density (kg/m ³)	0.08	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.07	0.07	0.07	0.07
Prescribed fire	Trees per acre	2,092	50	344	339	334	324	310	100	230	227	221	208	195
	Quadratic mean diameter (in)	3.8	19.3	7.6	8.1	8.7	9.2	9.7	15.5	10.4	11.2	11.9	12.8	13.6
	Total volume (ft ³)	4,896	3,834	4,199	4,920	5,733	6,429	7,057	4,467	4,968	5,942	6,851	7,701	8,470
	Merchantable volume (ft ³)	4,328	3,678	4,047	4,715	5,533	6,166	6,770	4,258	4,794	5,697	6,620	7,406	8,196
	Basal area (ft ²)	166	102	108	120	136	149	159	131	136	155	171	184	197
	Stand density index	445	144	220	240	265	282	295	202	246	272	292	307	319
	Canopy cover (percent)	66	29	29	33	39	42	43	42	40	43	45	47	48
	Crown competition factor	217	84	87	98	122	138	146	124	124	140	153	164	174
	Canopy base height (ft)	2	31	39	44	4	6	8	15	23	37	46	50	4
	Canopy bulk density (kg/m ³)	0.08	0.04	0.04	0.04	0.05	0.07	0.08	0.05	0.06	0.06	0.06	0.06	0.06

Table 27c—Treatment effect on forest stand attributes, 50-year trajectory (continued)

Surface fuel treatment	Stand attribute	Initial condition	Thin from below to 200 tpa, 18-in d.b.h. limit					Thin from below to 300 tpa, 18-in d.b.h. limit						
			1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs	1 yr	10 yrs	20 yrs	30 yrs	40 yrs	50 yrs
None	Trees per acre	2,092	200	217	202	190	179	161	300	300	273	255	226	185
	Quadratic mean diameter (in)	3.8	11.8	12.4	13.5	14.6	15.6	16.7	9.9	10.8	11.9	13.0	14.1	15.5
	Total volume (ft ³)	4,896	5,462	6,036	7,097	8,148	9,149	9,704	5,508	6,093	7,188	8,307	9,083	9,373
	Merchantable volume (ft ³)	4,328	4,968	5,637	6,702	7,768	8,703	9,266	4,902	5,536	6,609	7,874	8,605	8,931
	Basal area (ft ²)	166	151	181	202	221	238	243	159	189	212	235	245	244
	Stand density index	445	260	305	328	348	366	364	293	337	363	388	391	376
	Canopy cover (percent)	66	53	57	58	60	61	60	58	62	64	66	65	64
	Crown competition factor	217	157	184	201	216	230	234	176	203	222	242	245	244
	Canopy base height (ft)	2	11	24	30	33	37	42	10	14	17	27	31	37
	Canopy bulk density (kg/m ³)	0.08	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.07	0.07	0.08	0.07	0.07
Pile and burn	Trees per acre	2,092	200	230	213	200	189	169	300	313	286	267	234	198
	Quadratic mean diameter (in)	3.8	11.8	12.0	13.2	14.2	15.2	16.2	9.9	10.5	11.7	12.7	13.8	15.0
	Total volume (ft ³)	4,896	5,462	6,036	7,093	8,142	9,147	9,722	5,508	6,093	7,205	8,322	9,067	9,531
	Merchantable volume (ft ³)	4,328	4,968	5,637	6,700	7,762	8,699	9,286	4,902	5,536	6,623	7,890	8,593	9,085
	Basal area (ft ²)	166	151	181	202	220	237	243	159	189	213	236	245	244
	Stand density index	445	260	308	332	352	369	368	293	340	367	393	395	381
	Canopy cover (percent)	66	53	57	58	60	61	60	58	62	64	66	65	62
	Crown competition factor	217	157	184	201	215	230	234	176	203	223	243	248	237
	Canopy base height (ft)	2	11	24	30	33	37	42	10	14	17	27	31	35
	Canopy bulk density (kg/m ³)	0.08	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.07	0.07	0.08	0.07	0.07
Prescribed fire	Trees per acre	2,092	200	203	198	183	172	163	300	236	224	206	195	183
	Quadratic mean diameter (in)	3.8	11.8	11.7	12.7	13.7	14.7	15.6	9.9	11.0	12.0	13.1	14.0	15.0
	Total volume (ft ³)	4,896	4,708	5,269	6,365	7,253	8,143	9,004	4,754	5,322	6,326	7,238	8,190	9,129
	Merchantable volume (ft ³)	4,328	4,380	5,005	6,051	6,940	7,759	8,641	4,380	4,986	5,928	6,895	7,786	8,756
	Basal area (ft ²)	166	151	151	174	189	204	217	159	156	177	193	209	226
	Stand density index	445	260	261	291	305	320	334	293	275	301	318	336	353
	Canopy cover (percent)	66	53	47	50	51	52	53	58	50	53	54	55	57
	Crown competition factor	217	157	146	165	176	188	198	176	155	173	186	199	212
	Canopy base height (ft)	2	12	20	31	35	40	46	10	17	22	27	31	36
	Canopy bulk density (kg/m ³)	0.08	0.05	0.06	0.07	0.07	0.07	0.07	0.05	0.06	0.07	0.07	0.07	0.07

tpa = trees per acre; d.b.h. = diameter at breast height.

Table 27d—Forest Vegetation Simulator fuel model selection

Surface fuel treatment	No action						Prescribed fire only						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent
None	1	9	96	10	4	6	68	9	32	6	68	9	32
	10	10	52	9	48	10	51	9	28	10	51	9	28
	20	10	97	12	3	10	57	9	31	10	57	9	31
	30	10	75	12	25	10	74	9	20	10	74	9	20
	40	10	65	12	35	10	90	9	9	10	90	9	9
50	10	60	12	40	10	98	12	2	10	98	12	2	

Thin from below to 50 tpa, 18-in. d.b.h. limit

Surface fuel treatment	Thin from below to 50 tpa, 18-in. d.b.h. limit						Thin from below to 100 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent
None	1	10	77	6	21	10	61	6	35	10	61	6	35
	10	6	70	10	30	6	44	10	38	6	44	10	38
	20	6	78	10	22	10	42	6	33	10	42	6	33
	30	6	82	10	18	10	48	9	26	10	48	9	26
	40	6	76	10	24	10	61	9	21	10	61	9	21
50	9	65	10	35	10	78	9	13	10	78	9	13	

Pile and burn

1	6	95	2	5	6	88	9	12	6	88	9	12
10	6	100			6	70	9	30		6	70	9
20	6	100			6	48	9	37		6	48	9
30	6	99	10	1	6	34	10	33	10	33	9	33
40	9	89	10	11	10	47	9	28	6	47	9	28
50	9	74	10	26	10	63	9	21	6	63	9	21

Prescribed fire

1	6	83	2	17	6	100			6	100		
10	6	93	2	7	6	89	10	9	9	89	10	9
20	6	100			6	61	10	27	9	61	10	27
30	9	92	10	8	6	45	10	38	9	45	10	38
40	9	80	10	20	10	54	6	30	9	54	6	30
50	9	65	10	35	10	69	6	19	9	69	6	19

Table 27d—Forest Vegetation Simulator fuel model selection (continued)

Surface fuel treatment	Thin from below to 200 tpa, 18-in. d.b.h. limit						Thin from below to 300 tpa, 18-in. d.b.h. limit						
	Fuel models			Fuel models			Fuel models			Fuel models			
	Years	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent	Model	Weight Percent
None	1	9	44	10	31	6	26	9	73	10	19	6	7
	10	9	55	10	34	6	11	9	60	10	40		
	20	10	58	9	39	6	3	10	75	9	25		
	30	10	78	9	22			10	99	9	1		
	40	10	93	9	7			10	92	12	8		
50	10	93	12	7			10	75	12	25			
Pile and burn	1	9	63	6	37			9	91	6	9		
	10	9	80	6	16			9	88	10	12		
	20	9	57	10	38	10	3	10	54	9	46		
	30	10	62	9	37	6	1	10	81	9	19		
	40	10	77	9	23			10	98	9	2		
50	10	98	9	2			10	78	12	22			
Prescribed fire	1	6	85	9	15			6	60	9	40		
	10	6	45	10	30	9	25	9	41	10	32	6	27
	20	10	45	9	28	6	27	10	66	9	23	6	11
	30	10	66	9	19	6	15	10	99	9	1		
	40	10	85	9	9	6	6	10	84	12	16		
50	10	100	12				10	67	12	33			

tpa = trees per acre, d.b.h. = diameter at breast height.

Table 27e—FVS fuel model selection

Fire weather conditions	Windspeed Miles/hour	Temperature °F	Fuel moisture					
			1-hr (0–0.25 in)	10-hr (0.25–1 in)	100-hr (1–3 in)	1,000-hr (3+ in)	Duff Live	
Severe—98 th percentile	14	81	3	5	8	15	50	100
Moderate—75 th percentile	8	61	6	8	11	18	125	150

Table 27f—Prescribed fire weather conditions used in models

Windspeed (mph)	10
Moisture category*	3 = Moist
Temperature (°F)	70

*Moisture categories correspond to variant-specific percentage moisture values from Reinhardt and Crookston (2003).

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Web site	http://www.fs.fed.us/pnw
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Publication requests	(503) 808-2138
FAX	(503) 808-2130
E-mail	pnw_pnwpubs@fs.fed.us
Mailing address	Publications Distribution Pacific Northwest Research Station P.O. Box 3890 Portland, OR 97208-3890