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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.

Contents

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 Oracle[1] 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

[1] The 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.

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

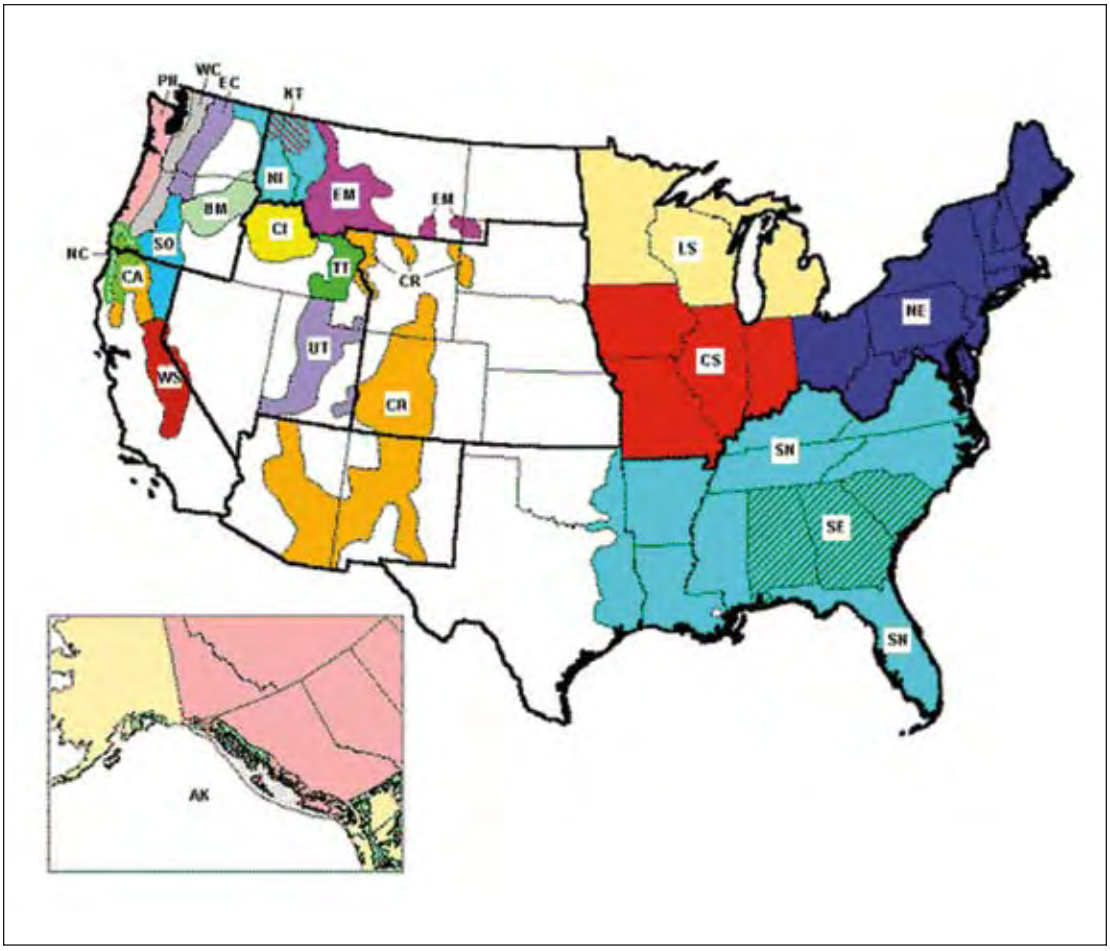

Figure 1—Geographic variants of the Forest Vegetation Simulator. These variants account for tree growth rates and structures associated with specific geographic locations, and are described in detail in Dixon (2002).

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

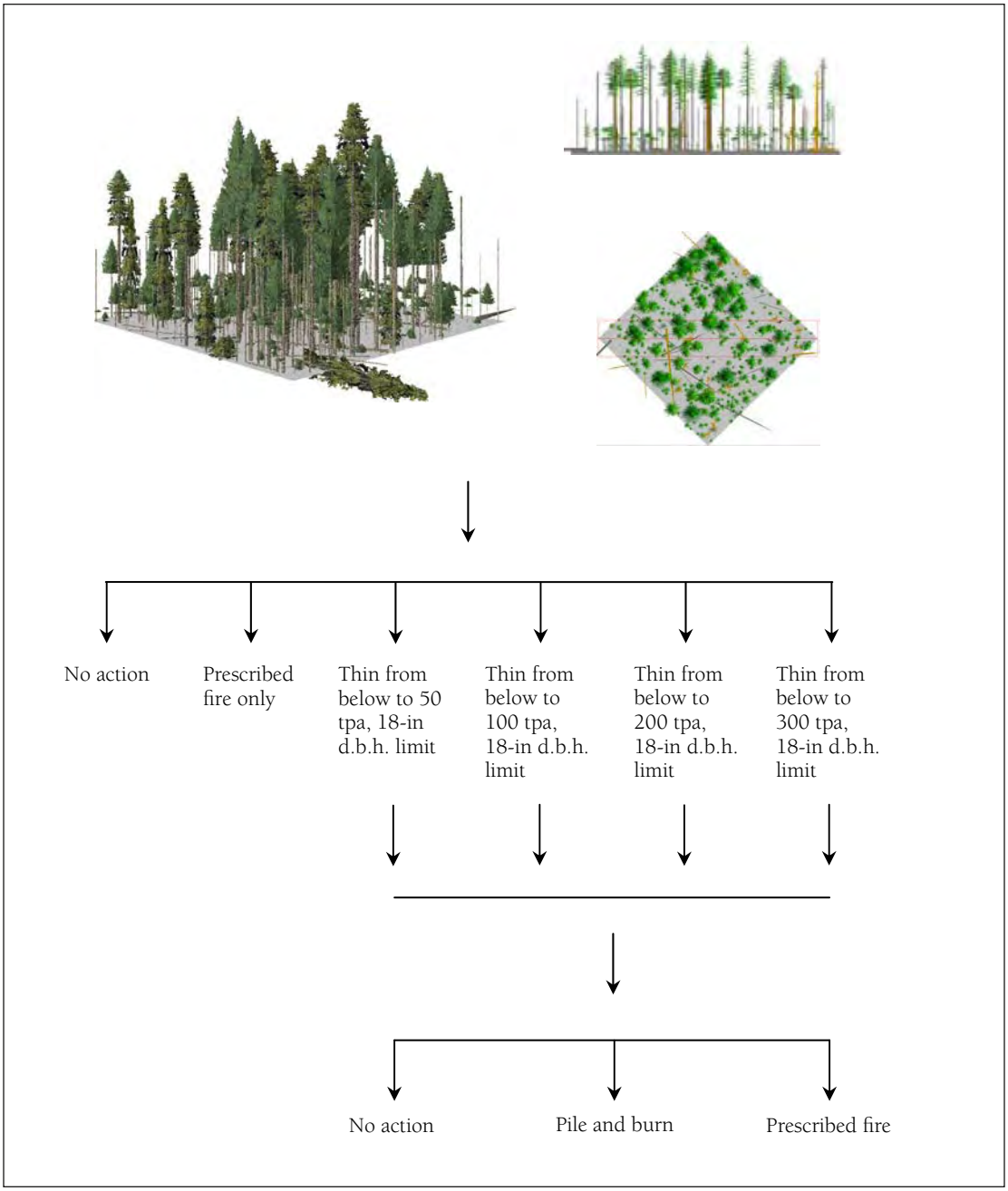

Figure 2—Conceptual diagram of the process used to simulate the effects of fuel treatments for a forest stand in FFE-FVS. Note: tpa = trees per acre; d.b.h.= diameter at breast height.

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
		Trees per acre		
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 loadings 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 ft^2/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 $lb\ ac^{-1}\ ft^{-1}$ 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/m^3) (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

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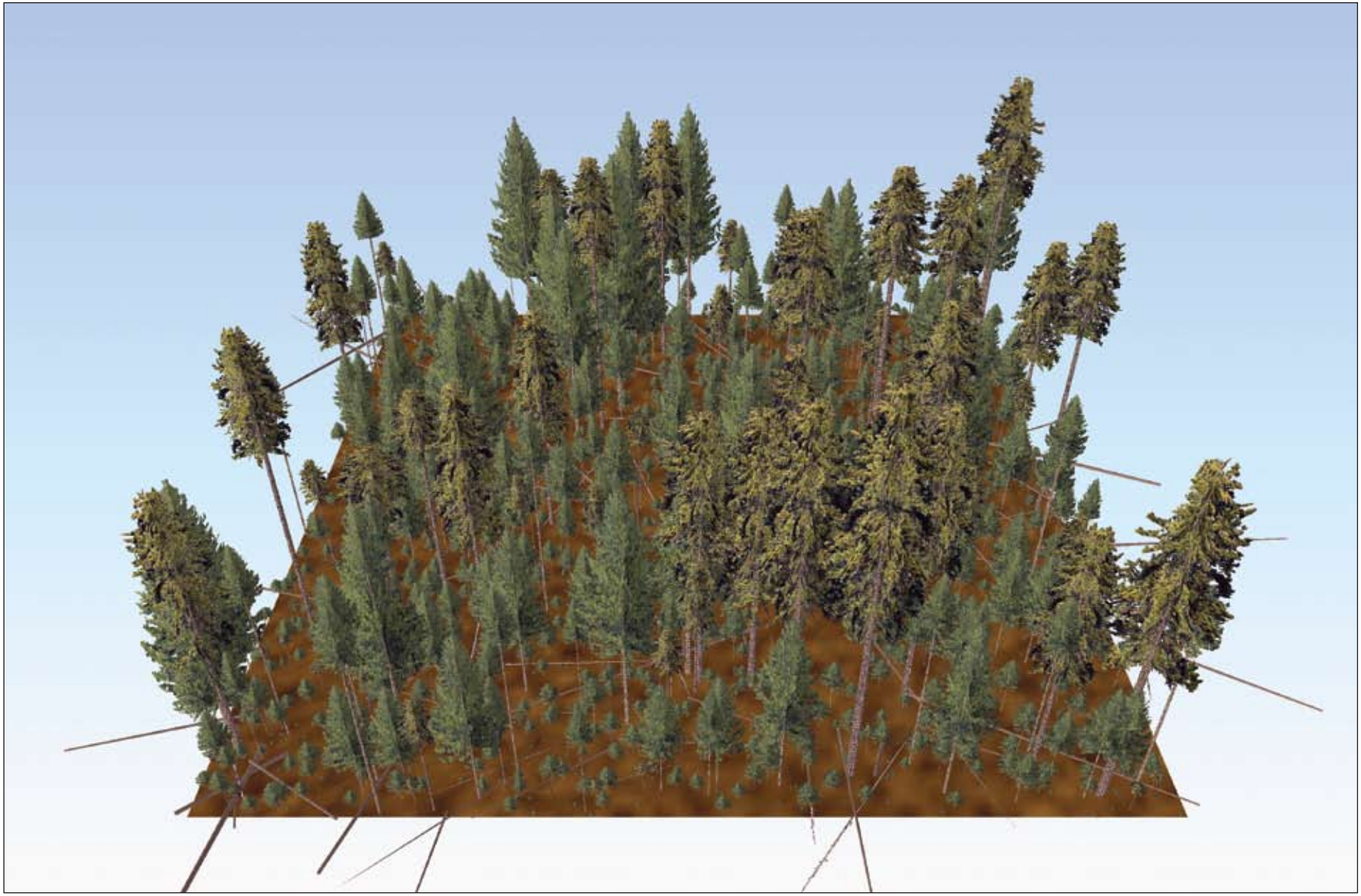
Appendix 1—Keywords used in FFE-FVS for Simulations Represented in the *Guide*

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

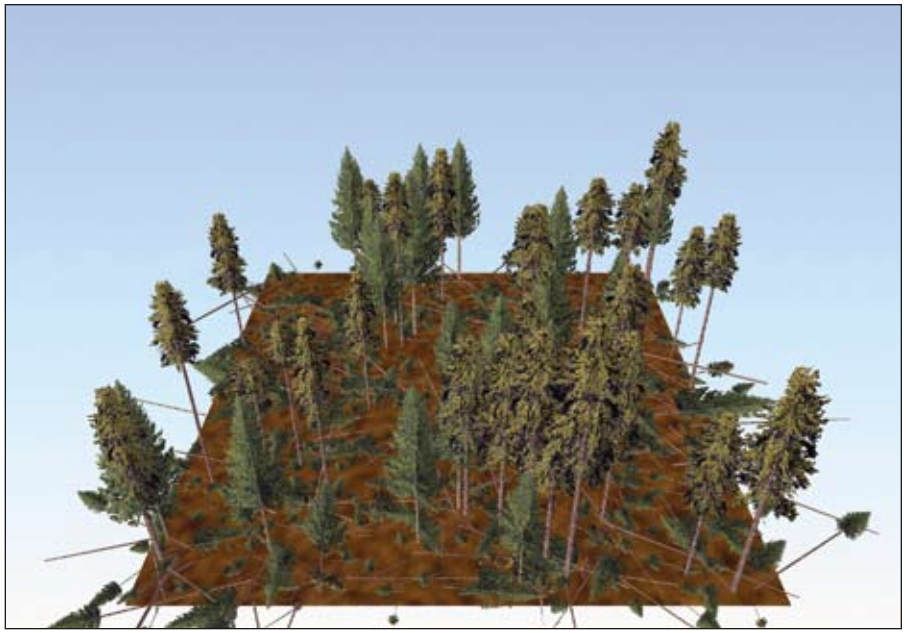


Initial stand conditions

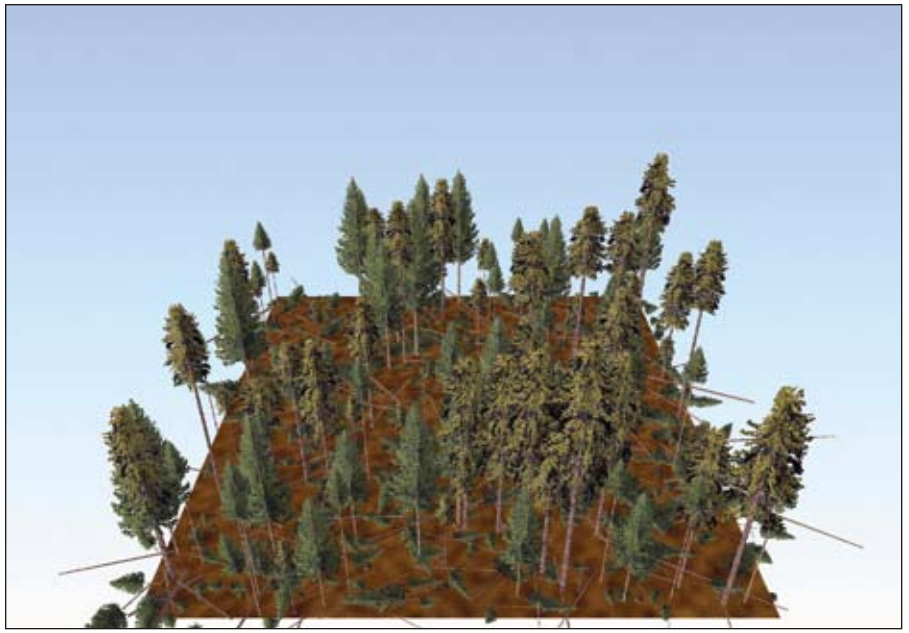
Site: Elevation = 4,400 ft, slope = 24 percent, aspect = 90 percent.

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

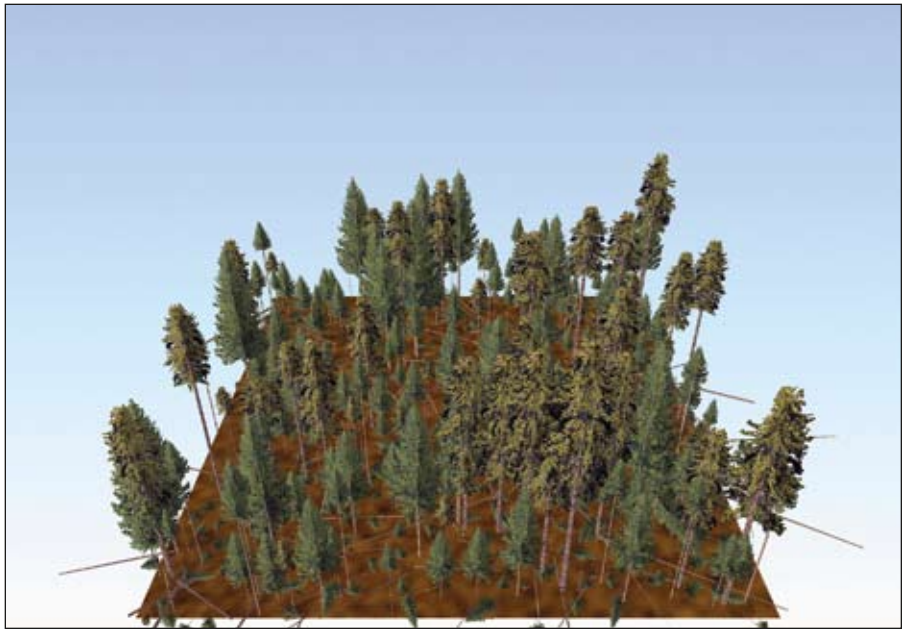
Stand attributes: Stem density = 2,345 tpa, basal area = 114 ft^2/ac, top height = 78 ft, stand density index = 338, quadratic mean diameter = 3.0 in, crown competition factor = 116, canopy cover = 65 percent.



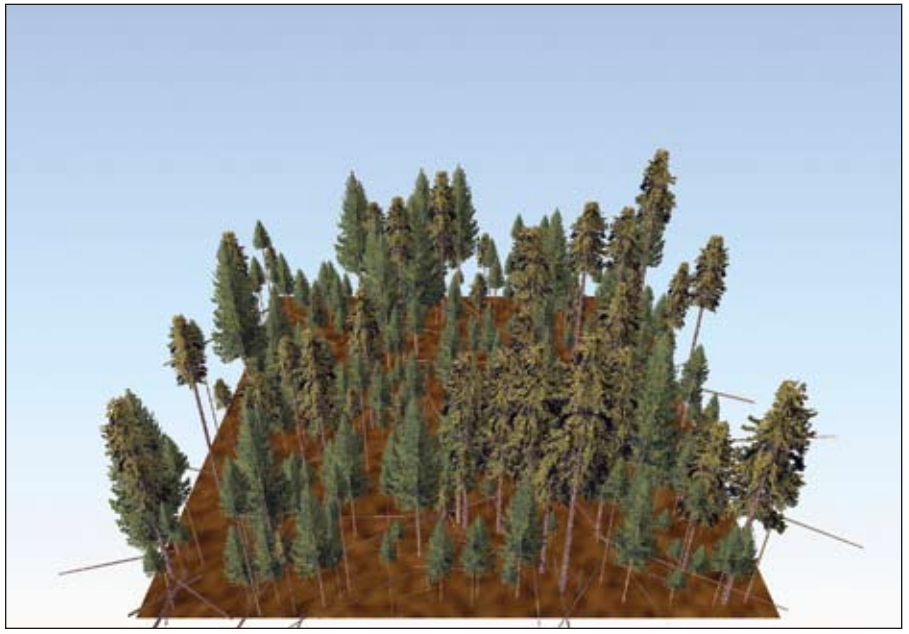
Thin from below to 50 tpa, 18-in d.b.h. limit



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/m^3 (0.0087 lb/ft^3), 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	3	1	5	5	4	4
		3–6 in	3	0	3	3	2	2
		6–12 in	3	1	1	2	2	2
		>12 in	0	0	0	0	0	0
		Litter	2	1	2	2	2	2
		Duff	5	4	3	3	4	4
	Flame length (ft)	Moderate	2	3	4	3	2	2
		Severe	3	5	7	6	4	3
	Torching index	Severe	15	8	32	38	35	27
	Crowning index	Severe	19	51	49	45	38	38
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Passive	Passive	Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Moderate	25	15	9	15	19	21
		Severe	97	72	68	53	29	24
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in			1	1	1	1
		3–6 in			1	1	1	1
		6–12 in			0	0	1	1
		>12 in			0	0	0	0
		Litter			2	2	2	2
		Duff			2	3	3	4
	Flame length (ft)	Moderate			4	3	2	2
		Severe			7	6	4	3
	Torching index	Severe			32	47	45	34
	Crowning index	Severe			49	45	38	38
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Moderate			9	15	19	21
		Severe			80	56	28	23
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in			0	0	0	0
		3–6 in			1	1	1	1
		6–12 in			1	1	1	1
		>12 in			0	0	0	0
		Litter			0	0	1	1
		Duff			2	2	3	3
	Flame length (ft)	Moderate			4	4	3	3
		Severe			7	7	6	6
	Torching index	Severe			30	31	32	26
	Crowning index	Severe			53	52	51	51
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Moderate			9	11	14	14
		Severe			88	81	61	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)	0–3 in	3	3	3	4	4	4	1	3	2	2	2	3
		3–6 in	3	2	3	3	3	4	0	2	2	3	3	3
		6–12 in	3	2	2	2	2	3	1	2	2	2	2	2
		>12 in	0	0	0	1	2	2	0	1	1	2	2	2
		Litter	2	2	2	3	3	3	1	1	1	2	2	2
		Duff	5	5	5	6	6	6	4	4	4	4	4	4
	Flame length (ft)	Moderate	2	2	2	2	2	2	3	3	2	2	2	2
		Severe	3	3	3	3	3	3	5	5	4	4	3	3
	Torching index	Severe	15	17	24	20	9	7	8	19	30	42	53	54
	Crowning index	Severe	19	19	19	19	19	20	51	46	43	41	41	40
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Passive	Passive	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	195	316	374	330	286	241	608	17	22	19	18	16
		18–29.9 in	0	1	2	2	3	4	1	1	1	2	2	3
		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)	0–3 in	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
	Flame length (ft)	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
	Torching index	Severe	32	39	48	1	0	16	38	59	68	84	97	111
	Crowning index	Severe	49	48	47	47	46	46	45	42	39	38	38	38
	Type of fire	Moderate	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	1	3	4	21	20	17	2	5	7	26	27	24
		18–29.9 in	0	0	1	1	2	2	0	0	1	1	2	3
		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)	0–3 in	1	1	1	2	2	2	1	1	2	2	2	2
		3–6 in	1	1	1	1	1	2	1	1	1	1	2	2
		6–12 in	0	0	0	0	1	1	0	0	1	1	1	1
		>12 in	0	0	0	0	1	1	0	0	0	1	1	1
		Litter	2	1	1	1	1	2	2	1	1	2	2	2
		Duff	2	2	3	3	3	3	3	3	3	3	3	3
	Flame length (ft)	Moderate	4	3	3	3	3	2	3	3	3	2	2	2
		Severe	7	7	6	5	5	4	6	5	5	4	4	4
	Torching index	Severe	32	39	48	2	0	13	47	59	69	85	14	114
	Crowning index	Severe	49	48	47	47	46	46	45	42	39	37	37	37
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Passive	Surface
	Hard snags (stems/ac)	0–17.9 in	1	3	4	22	21	18	2	5	7	28	29	25
		18–29.9 in	0	0	1	1	2	2	0	0	1	1	2	3
		30–36 in	0	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	2	2	0	1	1	2	2	2
		3–6 in	1	1	1	1	2	2	1	2	2	2	2	2
		6–12 in	1	1	1	1	1	1	1	2	2	2	2	2
		>12 in	0	1	1	1	2	2	0	1	1	1	2	2
		Litter	0	1	1	1	1	2	2	1	1	1	1	2
		Duff	2	2	2	2	2	2	3	2	2	3	3	3
	Flame length (ft)	Moderate	4	4	3	3	3	2	3	3	3	3	3	2
		Severe	7	7	7	6	5	4	6	6	6	5	4	4
	Torching index	Severe	32	32	42	0	0	6	38	41	52	0	0	7
	Crowning index	Severe	49	51	51	50	50	50	45	49	46	44	43	43
	Type of fire	Moderate	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Passive	Passive	Surface
		Severe	Surface	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface	Passive	Passive	Passive
	Hard snags (stems/ac)	0–17.9 in	9	9	7	22	21	18	17	9	8	25	24	21
		18–29.9 in	1	1	1	1	1	2	1	1	1	1	2	2
		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	3	4	2	3	3	3	3
		3–6 in	2	2	2	2	3	3	2	2	2	3	3	3
		6–12 in	2	2	2	2	2	2	2	2	2	2	2	3
		>12 in	0	0	0	1	1	2	0	0	0	1	2	2
		Litter	2	1	2	2	2	2	2	2	2	2	2	2
		Duff	4	4	4	4	4	5	4	4	5	5	5	5
	Flame length (ft)	Moderate	2	2	2	2	2	2	2	2	2	2	2	2
		Severe	4	3	3	3	3	3	3	3	3	3	3	3
	Torching index	Severe	35	73	83	99	102	95	27	47	60	62	10	8
	Crowning index	Severe	38	37	35	33	32	32	38	32	30	29	29	28
	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	Passive	Passive
	Hard snags (stems/ac)	0–17.9 in	7	11	15	36	36	33	9	19	27	61	60	52
		18–29.9 in	0	1	1	2	3	3	0	1	2	2	3	4
		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	1	2	2	3	3	1	2	2	3	3	3
		3–6 in	1	1	1	2	2	2	1	1	1	2	2	3
		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
		Litter	2	1	2	2	2	2	2	2	2	2	2	2
		Duff	3	4	4	4	4	4	4	4	4	4	4	5
	Flame length (ft)	Moderate	2	2	2	2	2	2	2	2	2	2	2	2
		Severe	4	3	3	3	3	3	3	3	3	3	3	3
	Torching index	Severe	45	73	83	95	103	105	34	46	48	60	13	10
	Crowning index	Severe	38	37	35	33	32	31	38	34	33	32	31	31
	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	Passive	Passive
	Hard snags (stems/ac)	0–17.9 in	7	11	15	38	38	34	12	21	26	63	62	53
		18–29.9 in	0	1	1	2	3	3	0	1	1	2	3	4
		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
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	2	2	2	2	2	0	2	2	2	2	2
		3–6 in	1	3	3	3	3	3	1	3	3	3	3	3
		6–12 in	1	2	2	2	2	2	1	2	2	2	2	2
		>12 in	0	1	1	1	2	2	0	1	1	1	2	2
		Litter	1	1	1	2	2	2	1	1	1	2	2	2
		Duff	3	3	3	3	3	3	3	3	3	3	4	4
	Flame length (ft)	Moderate	3	3	3	2	2	2	3	3	3	2	2	2
		Severe	6	5	5	4	3	3	6	5	4	4	3	3
	Torching index	Severe	32	44	57	75	10	22	26	41	54	72	11	49
	Crowning index	Severe	51	45	42	40	39	39	51	45	42	40	39	39
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Passive	Surface
	Hard snags (stems/ac)	0–17.9 in	34	10	9	28	28	25	55	11	12	30	29	26
		18–29.9 in	1	1	1	2	2	3	1	1	1	2	2	3
		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	Years	No action								Prescribed fire only							
		Fuel models								Fuel models							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*		*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				

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	Model	Weight	Model	Weight
			Percent		*Percent*		*Percent*				*Percent*		*Percent*		*Percent*		
None	1	2	61	10	37	9	3			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	Years	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							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*		*Percent*				*Percent*		*Percent*				
None	1	9	67	2	18	10	15			9	90	10	10				
	10	9	94	2	6					9	100						
	20	9	100							9	100						
	30	9	100							9	96	10	4				
	40	9	98	10	2					9	87	10	13				
	50	9	91	10	9					9	76	10	24				
Pile and burn	1	9	79	2	21					9	100						
	10	9	94	2	6					9	100						
	20	9	100							9	100						
	30	9	100							9	100						
	40	9	100							9	99	10	1				
	50	9	96	10	4					9	90	10	10				
Prescribed fire	1	2	74	9	26					2	68	9	32				
	10	2	56	9	44					9	52	2	48				
	20	9	59	2	41					9	67	2	33				
	30	9	76	2	24					9	85	2	15				
	40	9	92	2	8					9	100	2					
	50	9	98	10	2					9	96	10	4				

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

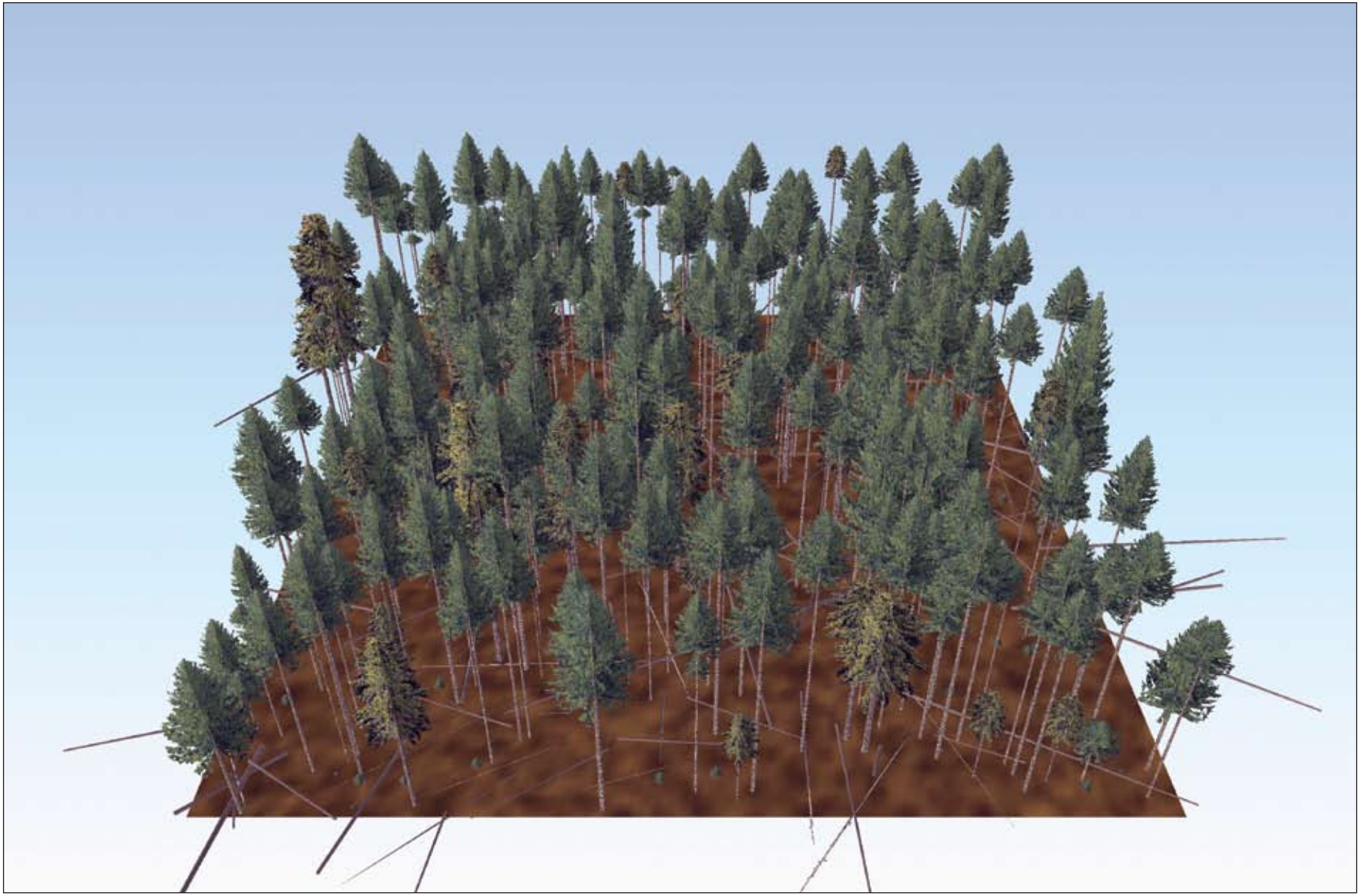
Table 3e—FVS fuel model selection

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
	Miles/hour	*°F*	*Percent*					
Severe—98th percentile	17	96	2	4	10	15	50	100
Moderate—75th 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).

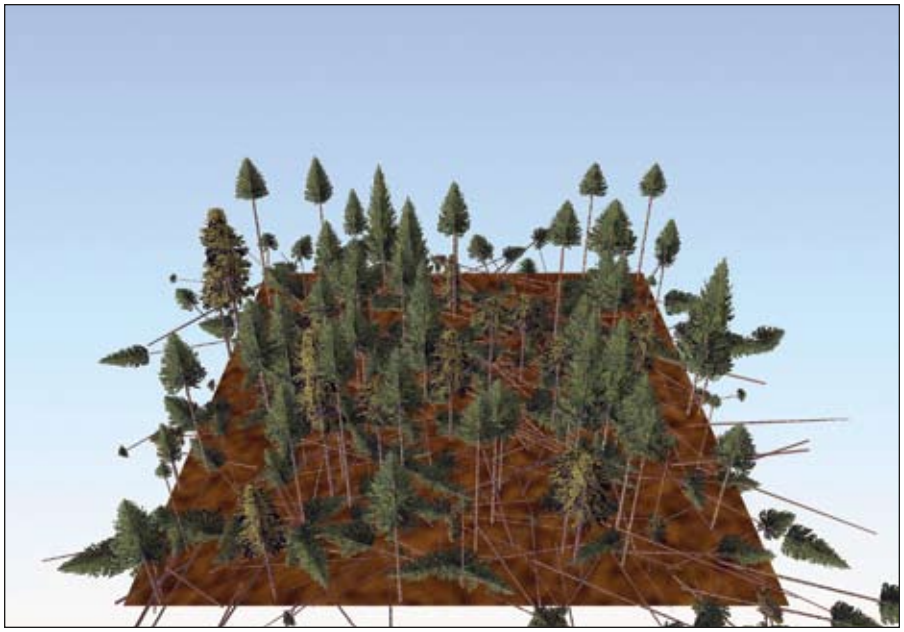


Initial stand conditions

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

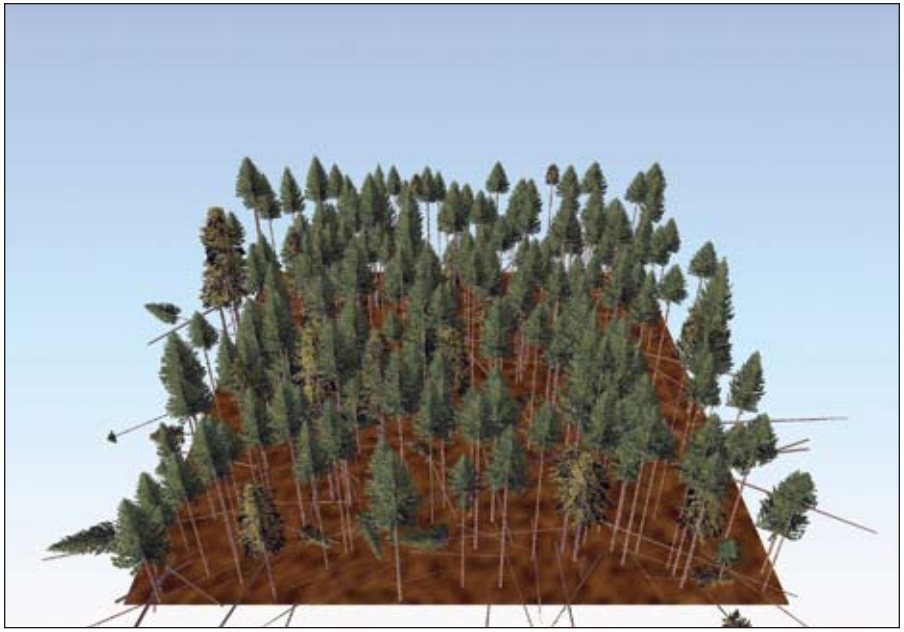
Species (based on trees per acre): Douglas-fir (*Pseudotsuga menziesii*) = 91 percent, ponderosa pine (*Pinus ponderosa*) = 6 percent.

Stand attributes: Stem density = 452 tpa, basal area = 123 ft^2/ac, top height = 63 ft, stand density index = 258, quadratic mean diameter = 7.1 in, crown competition factor = 134, canopy cover = 57 percent.

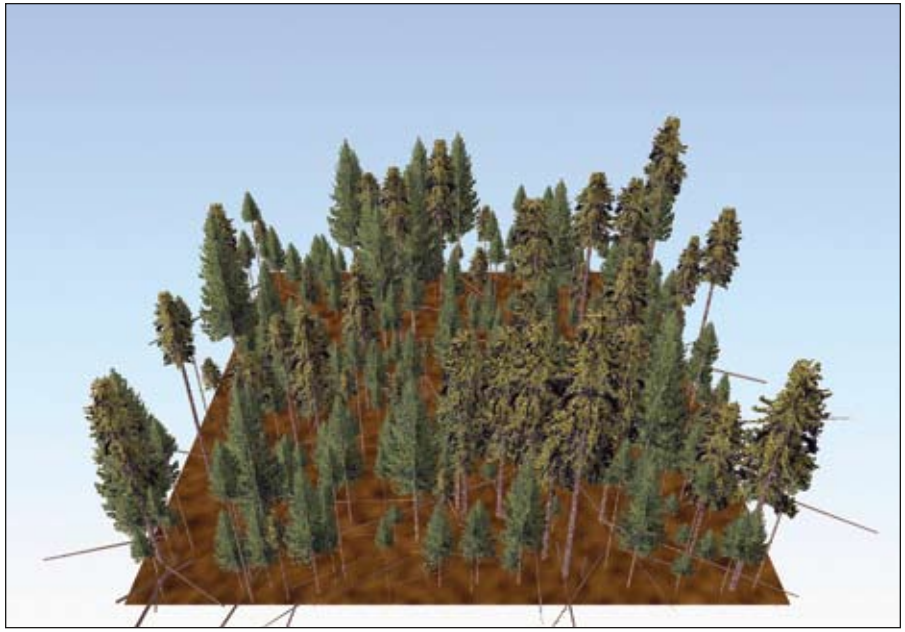


Thin from below to 50 tpa, 18-in d.b.h. limit

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 liter and duff loading is 12 tons/ac. Canopy base height is 13 ft and canopy bulk density is 0.17 kg/m^3 (0.0106 lb/ft^3), 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	3	1	9	7	4	3
		3–6 in	3	0	5	5	5	3
		6–12 in	3	1	3	3	3	3
		>12 in	0	0	0	0	0	0
		Litter	2	1	3	2	2	2
		Duff	10	7	10	10	10	10
	Flame length (ft)	Moderate	2	3	3	3	2	2
		Severe	3	5	5	5	3	3
	Torching index	Severe	57	51	120	45	26	57
	Crowning index	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
		6–12 in			1	1	1	1
		>12 in			0	0	0	0
		Litter			2	2	2	2
		Duff			9	9	9	9
	Flame length (ft)	Moderate			4	3	2	2
		Severe			8	6	3	3
	Torching index	Severe			29	47	63	67
	Crowning index	Severe			50	29	18	15
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			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
		6–12 in			2	2	2	2
		>12 in			0	0	0	0
		Litter			0	0	1	1
		Duff			7	7	7	7
	Flame length (ft)	Moderate			4	4	3	3
		Severe			8	7	5	5
	Torching index	Severe			31	31	49	51
	Crowning index	Severe			57	34	24	22
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Surface	Surface
	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)	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
	Flame length (ft)	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	Severe	57	18	20	66	21	27	51	41	51	57	63	67
	Crowning index	Severe	15	16	16	16	17	18	22	23	23	23	24	24
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Cond.	Cond.	Cond.	Cond.	Cond.	Surface	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	78	82	68	59	53	48	116	20	20	16	15	16
		18–29.9 in	2	2	1	1	2	2	2	2	1	1	1	1
		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)	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	4
		>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
	Flame length (ft)	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	Severe	120	25	30	0	0	15	45	45	57	70	70	88
	Crowning index	Severe	50	44	42	41	41	40	29	28	27	26	26	26
	Type of fire	Moderate	Surface	Surface	Surface	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	48	32	7	16	15	14	49	34	10	25	25	24
		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

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)	0–3 in	2	1	1	1	1	2	2	1	2	2	2	2
		3–6 in	1	2	2	2	2	2	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	1	0	0	1	1	1	1
		Litter	2	1	1	1	1	1	2	1	1	1	2	2
		Duff	9	9	9	9	9	9	9	9	9	9	9	9
	Flame length (ft)	Moderate	4	4	4	4	3	3	3	3	3	3	3	2
		Severe	8	8	8	7	6	5	6	6	5	5	4	4
	Torching index	Severe	29	26	30	0	4	8	47	54	64	77	91	103
	Crowning index	Severe	50	44	42	41	41	40	29	28	26	26	26	26
	Type of fire	Moderate	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	48	32	7	17	16	14	49	34	11	26	27	25
		18–29.9 in	2	2	1	1	1	2	2	2	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)	0–3 in	0	1	1	1	1	1	0	1	1	2	2	2
		3–6 in	1	2	2	2	2	2	1	2	2	2	2	2
		6–12 in	2	3	3	3	3	2	2	4	4	4	4	4
		>12 in	0	1	1	1	1	1	0	1	1	1	1	2
		Litter	0	1	1	1	1	1	2	1	1	1	1	1
		Duff	7	7	7	7	7	7	9	7	7	7	7	7
	Flame length (ft)	Moderate	4	4	4	4	3	3	4	4	3	3	3	3
		Severe	8	8	8	7	6	5	7	7	6	5	5	4
	Torching index	Severe	31	24	29	0	4	0	31	39	49	0	8	86
	Crowning index	Severe	57	49	46	45	44	44	34	33	31	30	30	29
	Type of fire	Moderate	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface
		Severe	Surface	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface	Passive	Passive	Surface
	Hard snags (stems/ac)	0–17.9 in	32	15	9	15	14	13	36	16	12	23	23	21
		18–29.9 in	2	2	1	1	1	1	2	2	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
None	Surface fuel loadings (tons/ac)	0–3 in	4	3	3	3	3	3	3	3	4	4	4	4
		3–6 in	5	5	5	5	4	4	3	3	4	4	4	4
		6–12 in	3	3	4	4	5	6	3	3	4	4	5	6
		>12 in	0	0	1	1	1	2	0	0	1	1	1	2
		Litter	2	2	2	2	2	2	2	2	2	2	2	2
		Duff	10	10	10	10	10	10	10	10	10	10	10	10
	Flame length (ft)	Moderate	2	2	2	2	2	2	2	2	2	2	2	3
		Severe	3	4	4	4	4	4	3	3	4	4	4	4
	Torching index	Severe	26	53	59	64	64	69	57	65	65	72	72	78
	Crowning index	Severe	18	18	18	18	18	19	15	16	15	15	15	16
	Type of fire	Moderate	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.
	Hard snags (stems/ac)	0–17.9 in	53	41	21	40	41	37	60	53	37	51	52	49
		18–29.9 in	2	2	1	1	1	2	2	2	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	1	2	3	3	3	3	1	3	3	4	4	4
		3–6 in	1	2	2	2	2	3	1	1	2	2	3	3
		6–12 in	1	1	2	3	3	4	1	1	2	3	4	5
		>12 in	0	0	1	1	1	2	0	0	1	1	1	2
		Litter	2	2	2	2	2	2	2	2	2	2	2	2
		Duff	9	9	9	9	9	9	9	9	9	9	9	9
	Flame length (ft)	Moderate	2	2	2	2	2	2	2	2	2	2	2	2
		Severe	3	3	3	3	3	4	3	3	3	3	4	4
	Torching index	Severe	63	73	83	80	79	80	67	77	79	79	76	77
	Crowning index	Severe	18	18	18	18	18	19	15	16	16	16	17	18
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Surface	Surface	Cond.	Cond.	Cond.	Cond.	Cond.	Surface
	Hard snags (stems/ac)	0–17.9 in	53	41	21	41	42	38	62	55	39	53	53	48
		18–29.9 in	2	2	1	1	1	2	2	2	1	1	2	2
		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)	0–3 in	0	2	2	3	3	3	0	3	3	3	3	3
		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
	Flame length (ft)	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	Severe	49	42	49	58	8	74	51	43	50	58	69	72
	Crowning index	Severe	24	23	22	22	22	22	22	21	21	21	22	22
	Type of fire	Moderate	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)	0–17.9 in	48	19	17	33	34	31	68	21	21	37	37	33
		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	50 yrs
None	Trees per acre	452	45	154	152	138	129	122	90	197	192	171	156	142
	Quadratic mean diameter (in)	7.1	14.8	8.5	9.1	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	1,746	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	1,552	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	68	76	85	95	80	88	95	103	110	117
	Stand density index	258	86	119	130	139	150	162	133	167	178	185	192	198
	Canopy cover (percent)	57	25	28	30	34	38	42	37	40	41	43	44	46
	Crown competition factor	134	49	53	58	64	71	79	79	86	91	95	100	103
	Canopy base height (ft)	13	28	23	25	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	0.05	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	90	208	203	181	164	151
	Quadratic mean diameter (in)	7.1	14.8	8.2	8.8	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	1,740	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	1,550	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	68	76	85	96	80	88	96	103	111	118
	Stand density index	258	86	121	131	141	153	165	133	169	181	188	195	201
	Canopy cover (percent)	57	25	28	30	35	39	43	37	40	41	43	45	47
	Crown competition factor	134	49	53	58	64	72	80	79	86	91	96	100	105
	Canopy base height (ft)	13	28	23	25	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	0.05	0.08	0.08	0.09	0.09	0.09	0.09
Prescribed fire	Trees per acre	452	45	170	167	154	145	138	90	202	198	177	163	151
	Quadratic mean diameter (in)	7.1	14.8	7.6	8.2	9.1	10.1	11.1	12.7	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	2,605	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	2,253	1,443	1,576	1,839	2,123	2,363	2,627
	Basal area (ft^2)	123	55	54	61	70	81	93	80	74	82	90	98	107
	Stand density index	258	86	110	121	133	147	163	133	147	158	167	177	186
	Canopy cover (percent)	57	25	25	28	34	39	44	37	35	37	40	43	46
	Crown competition factor	134	49	47	52	59	68	78	79	71	76	82	88	94
	Canopy base height (ft)	13	32	23	26	2	4	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	0.05	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	Years	No action								Prescribed fire only							
		Fuel models								Fuel models							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*		*Percent*		
None	1	9	93	10	7					9	73	2	27				
	10	9	88	10	12					9	59	10	29	2	13		
	20	9	78	10	22					9	63	10	26	2	11		
	30	9	71	10	29					9	64	10	27	2	10		
	40	9	65	10	35					9	64	10	27	2	9		
	50	9	58	10	42					9	63	10	29	2	8		

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	Model	Weight	Model	Weight
			Percent		*Percent*		*Percent*				*Percent*		*Percent*		*Percent*		*Percent*
None	1	11	65	2	18	10	17			11	49	2	25	9	14	10	12
	10	2	83	10	17					2	44	9	41	10	15		
	20	2	99	9	1					9	51	2	43	10	6		
	30	2	79	9	21					9	61	2	35	10	3		
	40	2	59	9	41					9	69	2	27	10	4		
	50	9	58	2	42					9	74	2	19	10	6		
Pile and burn	1	2	100							2	63	9	37				
	10	2	100							2	52	9	48				
	20	2	98	9	2					9	56	2	44				
	30	2	77	9	23					9	65	2	35				
	40	2	55	9	45					9	75	2	25				
	50	9	64	2	36					9	83	2	17				
Prescribed fire	1	2	100							2	92	9	8				
	10	2	100							2	76	9	24				
	20	2	100							2	66	9	34				
	30	2	81	9	19					2	51	9	49				
	40	2	54	9	46					9	65	2	35				
	50	9	69	2	31					9	78	2	22				

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

Surface fuel treatment	Years	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							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*		*Percent*				*Percent*		*Percent*		*Percent*		
None	1	9	64	11	36					9	93	10	7				
	10	9	82	10	18					9	87	10	13				
	20	9	79	10	21					9	75	10	25				
	30	9	75	10	25					9	67	10	33				
	40	9	71	10	29					9	59	10	41				
	50	9	65	10	35					9	50	10	50				
Pile and burn	1	9	100							9	100						
	10	9	100							9	100						
	20	9	100							9	96	10	4				
	30	9	93	10	7					9	85	10	15				
	40	9	86	10	14					9	78	10	22				
	50	9	79	10	21					9	69	10	31				
Prescribed fire	1	9	64	2	36					9	73	2	27				
	10	9	63	10	20	2	18			9	61	10	29	2	10		
	20	9	65	10	21	2	13			9	64	10	29	2	7		
	30	9	71	10	22	2	7			9	68	10	30	2	2		
	40	9	75	10	23	2	2			9	70	10	30				
	50	9	74	10	26					9	69	10	31				

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

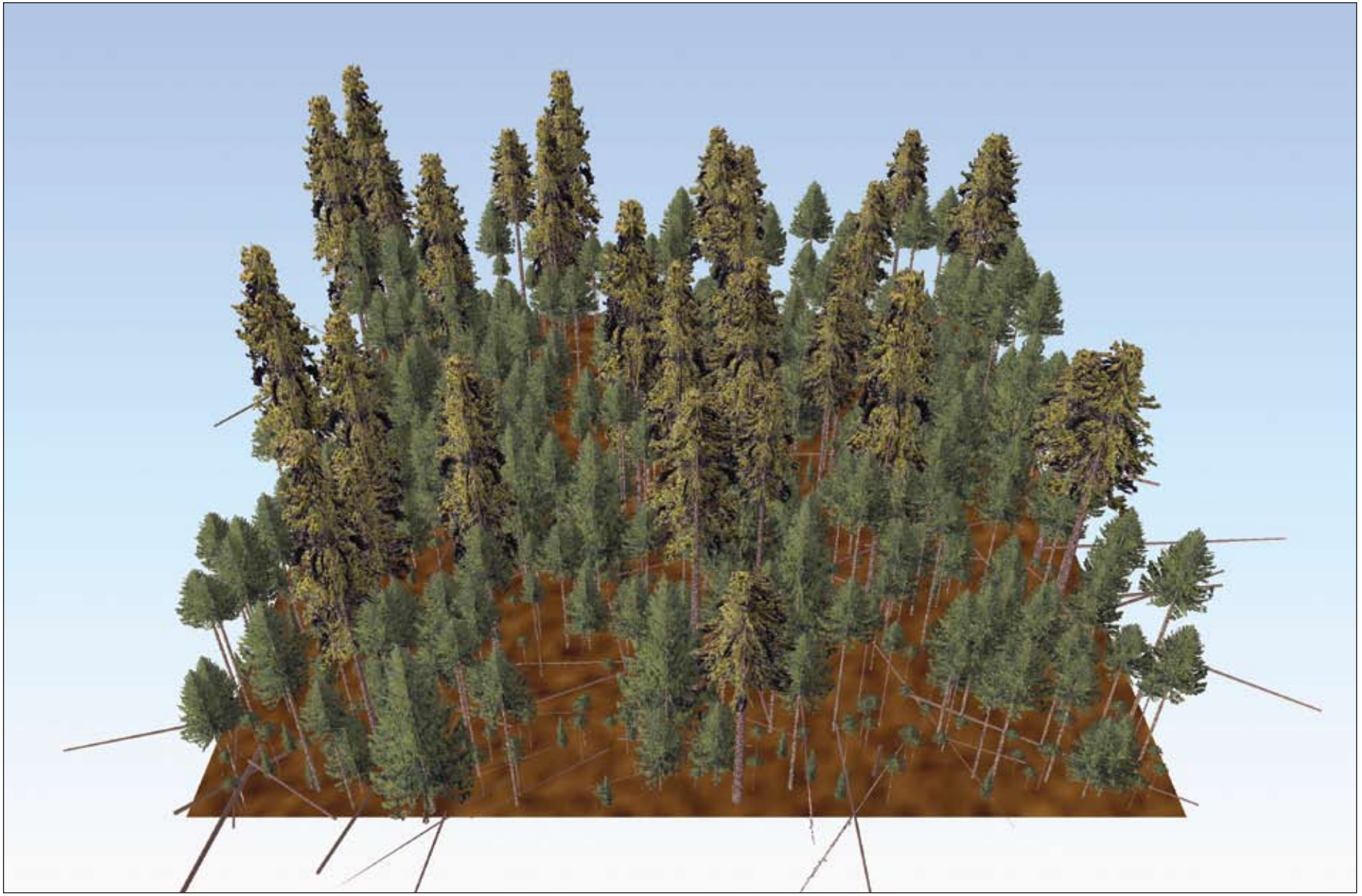
Table 4e—FVS fuel model selection

Fire weather conditions	Windspeed	Temperature	Fuel moisture					
			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—98th percentile	17	96	2	4	10	15	50	100
Moderate—75th 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).

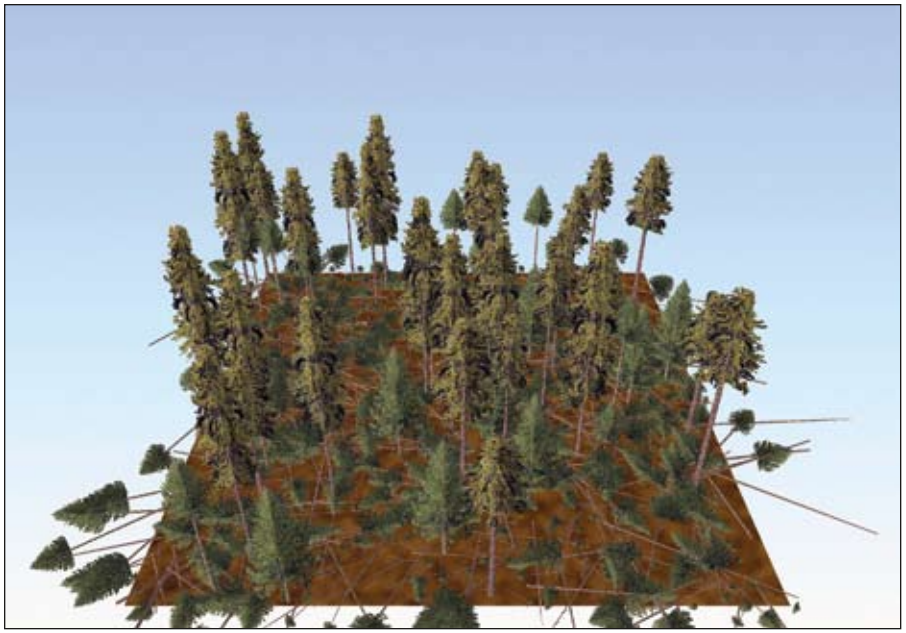


Initial stand conditions

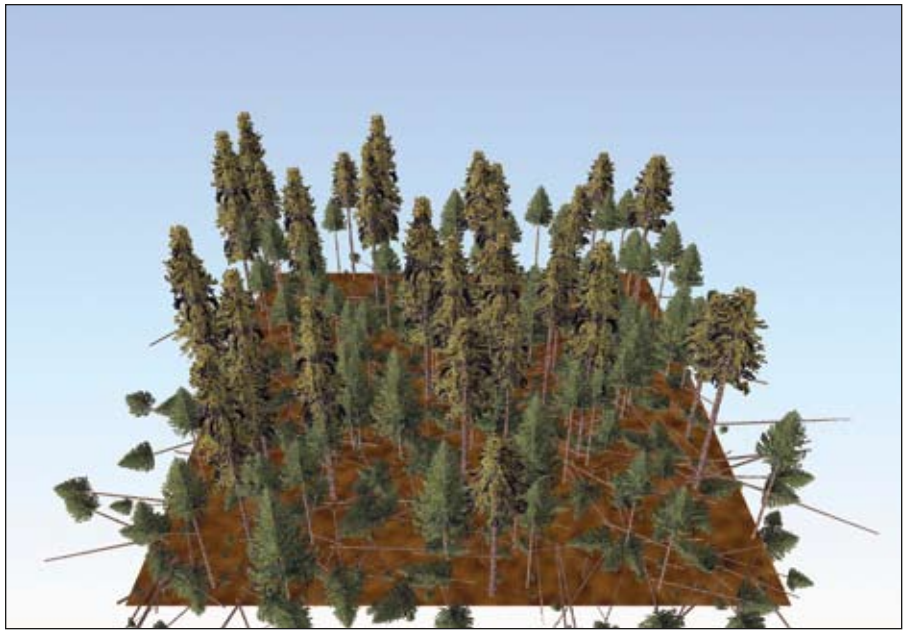
Site: Elevation = 5,200 ft, slope = 40 percent, aspect = 225°.

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

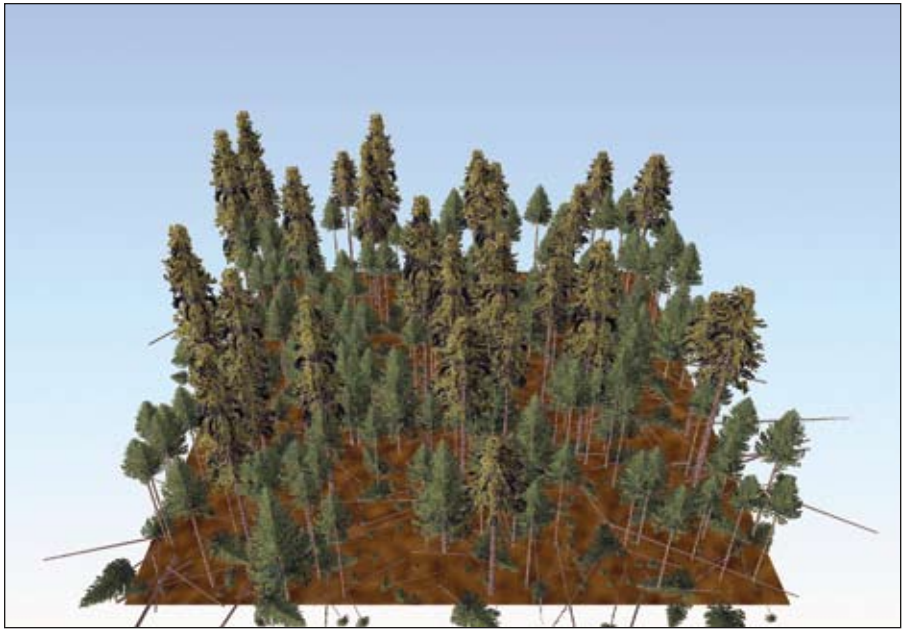
Stand attributes: Stem density = 873 tpa, basal area = 197 ft^2/ac, top height = 75 ft, stand density index = 430, quadratic mean diameter = 6.4 in, crown competition factor = 280, canopy cover = 71 percent.



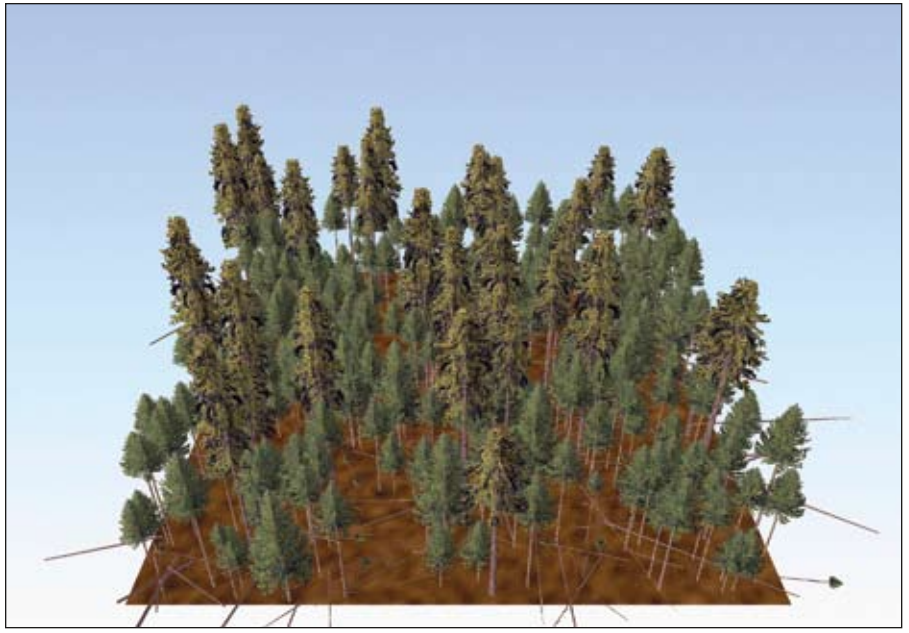
Thin from below to 50 tpa, 18-in d.b.h. limit



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 liter and duff loading is 12 tons/ac. Canopy bulk density is 0.21 kg/m^3 (0.0131 lb/ft^3), 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	3	1	12	10	7	5
		3–6 in	4	0	6	6	6	5
		6–12 in	3	2	3	3	3	3
		>12 in	0	0	0	0	0	0
		Litter	2	1	4	3	3	3
		Duff	10	7	10	10	10	10
	Flame length (ft)	Moderate	2	1	4	4	3	2
		Severe	2	1	6	5	3	3
	Torching index	Severe	163	234	116	163	262	105
	Crowning index	Severe	13	17	45	24	13	13
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Conditional	Conditional	Surface	Surface	Conditional	Conditional
	Potential basal area mortality (%)	Moderate	26	20	13	13	17	21
		Severe	27	20	33	25	19	24
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in			3	2	2	2
		3–6 in			2	2	2	1
		6–12 in			1	1	1	1
		>12 in			0	0	0	0
		Litter			3	3	3	2
		Duff			9	9	9	9
	Flame length (ft)	Moderate			5	3	1	1
		Severe			8	5	1	1
	Torching index	Severe			36	147	782	315
	Crowning index	Severe			45	24	13	13
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Conditional	Conditional
	Potential basal area mortality (%)	Moderate			18	12	17	21
		Severe			92	31	17	21
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in			0	0	0	0
		3–6 in			2	2	2	1
		6–12 in			2	2	2	2
		>12 in			0	0	0	0
		Litter			1	1	1	1
		Duff			7	7	7	7
	Flame length (ft)	Moderate			5	4	2	1
		Severe			9	6	3	1
	Torching index	Severe			36	80	362	255
	Crowning index	Severe			48	28	17	17
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Conditional	Conditional
	Potential basal area mortality (%)	Moderate			18	14	16	18
		Severe			93	58	16	18

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
		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
		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
	Torching index	Severe	163	128	91	77	56	48	234	70	95	111	82	85
	Crowning index	Severe	13	13	13	13	14	14	17	20	20	20	19	19
	Type of fire	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.
	Hard snags (stems/ac)	0–17.9 in	146	98	38	40	34	34	187	16	14	12	11	9
		18–29.9 in	0	1	2	2	3	3	1	1	1	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)	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
		>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
		Duff	10	10	10	10	10	10	10	10	10	10	10	11
	Flame length (ft)	Moderate	4	5	5	4	4	4	4	3	3	2	2	2
		Severe	6	7	7	7	7	6	5	5	4	3	3	3
	Torching index	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
	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)	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
		30–36 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 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	2	2	2	2	2	2	2	3	3	3
		3–6 in	2	2	2	2	2	3	2	2	2	2	2	3
		6–12 in	1	1	1	1	1	1	1	1	1	1	1	2
		>12 in	0	0	0	1	1	2	0	0	0	1	1	2
		Litter	3	1	1	1	2	2	3	2	2	2	2	2
		Duff	9	9	9	9	9	9	9	9	9	9	9	9
	Flame length (ft)	Moderate	5	5	5	4	4	4	3	3	2	2	1	1
		Severe	8	8	7	7	7	6	5	4	3	3	2	2
	Torching index	Severe	36	34	48	65	84	103	147	213	377	613	838	773
	Crowning index	Severe	45	43	42	43	44	45	24	26	26	27	27	27
	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)	0–17.9 in	132	74	5	6	6	6	133	75	7	9	9	9
		18–29.9 in	0	1	1	2	2	2	0	1	1	1	2	2
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	2	2	2	2	2	0	2	2	2	2	3
		3–6 in	2	2	2	2	2	3	2	2	2	2	3	3
		6–12 in	2	2	2	2	2	2	2	3	3	3	3	3
		>12 in	0	1	1	2	2	2	0	1	1	2	2	2
		Litter	1	1	1	1	1	2	3	1	2	2	2	2
		Duff	7	7	7	7	7	7	9	7	7	7	7	7
	Flame length (ft)	Moderate	5	5	5	5	5	4	4	4	3	3	3	3
		Severe	9	8	8	8	7	7	6	5	5	4	4	4
	Torching index	Severe	36	41	45	58	68	76	80	120	180	258	317	307
	Crowning index	Severe	48	47	46	47	48	48	28	29	30	30	31	31
	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)	0–17.9 in	58	10	8	7	6	6	66	15	11	9	8	9
		18–29.9 in	1	1	1	2	2	2	1	1	1	2	2	2
		30–36 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	5	4	4	5	6	5
		3–6 in	6	5	5	5	5	5	5	5	5	5	5	5
		6–12 in	3	3	3	3	3	3	3	3	3	3	4	4
		>12 in	0	0	0	1	1	2	0	0	0	1	1	2
		Litter	3	2	2	2	2	3	3	3	3	3	3	3
		Duff	10	10	10	11	11	11	10	10	10	11	11	11
	Flame length (ft)	Moderate	3	2	2	2	2	2	2	2	2	3	3	3
		Severe	3	3	3	3	3	4	3	3	3	4	4	4
	Torching index	Severe	262	225	428	435	412	389	105	185	263	238	235	224
	Crowning index	Severe	13	17	18	18	18	18	13	15	16	16	16	16
	Type of fire	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.
	Hard snags (stems/ac)	0–17.9 in	134	77	10	11	12	12	135	79	14	23	25	23
		18–29.9 in	0	1	1	1	2	2	0	1	1	2	3	4
		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	3	3	4	4	4	2	3	4	5	6	5
		3–6 in	2	2	2	2	3	3	1	2	2	2	3	3
		6–12 in	1	1	1	1	2	2	1	1	1	2	2	3
		>12 in	0	0	0	1	1	2	0	0	0	1	1	2
		Litter	3	2	2	2	2	3	2	3	3	3	3	3
		Duff	9	9	9	9	10	10	9	9	9	10	10	10
	Flame length (ft)	Moderate	1	1	1	1	2	2	1	1	1	2	2	3
		Severe	1	1	1	2	3	3	1	1	2	3	3	4
	Torching index	Severe	782	702	1038	775	612	554	315	562	498	361	320	294
	Crowning index	Severe	13	17	18	17	17	17	13	15	16	16	16	16
	Type of fire	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.
	Hard snags (stems/ac)	0–17.9 in	134	77	10	11	12	12	135	79	15	23	25	24
		18–29.9 in	0	1	1	1	2	2	0	1	1	2	3	4
		30–36 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
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	3	3	3	3	4	0	4	3	3	4	4
		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
		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
	Flame length (ft)	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	Severe	362	367	456	469	436	404	255	153	231	274	269	266
	Crowning index	Severe	17	20	21	22	22	22	17	20	21	21	21	21
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Cond.	Cond.	Surface	Surface	Surface	Surface	Cond.	Cond.	Cond.	Surface	Cond.	Cond.
	Hard snags (stems/ac)	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
		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	9.9	10.4	11.0	11.5	12.0
	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
	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)	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)	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
	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
	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
Prescribed fire	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
	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
	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	Years	No action								Prescribed fire only							
		Fuel models								Fuel models							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*				
None	1	8	87	10	13					8	100						
	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				

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	Model	Weight	Model	Weight
			Percent		*Percent*		*Percent*				*Percent*		*Percent*		*Percent*		
None	1	11	73	14	27					11	92	14	8				
	10	2	62	10	36	8	3			8	46	10	35	2	18		
	20	2	80	8	11	10	9			8	69	10	16	2	15		
	30	2	78	8	20	10	1			8	82	10	10	2	8		
	40	2	72	8	27	10	1			8	84	10	14	2	2		
	50	2	63	8	31	10	6			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	Years	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							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*		*Percent*		*Percent*		*Percent*		*Percent*		*Percent*		*Percent*
None	1	11	73	8	27					8	52	11	48				
	10	8	65	10	35					8	67	10	33				
	20	8	75	10	25					8	69	10	31				
	30	8	71	10	29					8	53	10	47				
	40	8	63	10	37					10	56	8	44				
	50	8	58	10	42					10	64	8	36				
Pile and burn	1	8	100							8	100						
	10	8	100							8	100						
	20	8	100							8	92	10	8				
	30	8	91	10	9					8	72	10	28				
	40	8	79	10	21					8	61	10	39				
	50	8	72	10	28					8	51	10	49				
Prescribed fire	1	8	84	2	16					8	100						
	10	8	83	10	17					8	68	10	32				
	20	8	83	10	17					8	70	10	30				
	30	8	80	10	20					8	67	10	33				
	40	8	73	10	27					8	60	10	40				
	50	8	64	10	36					8	53	10	47				

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

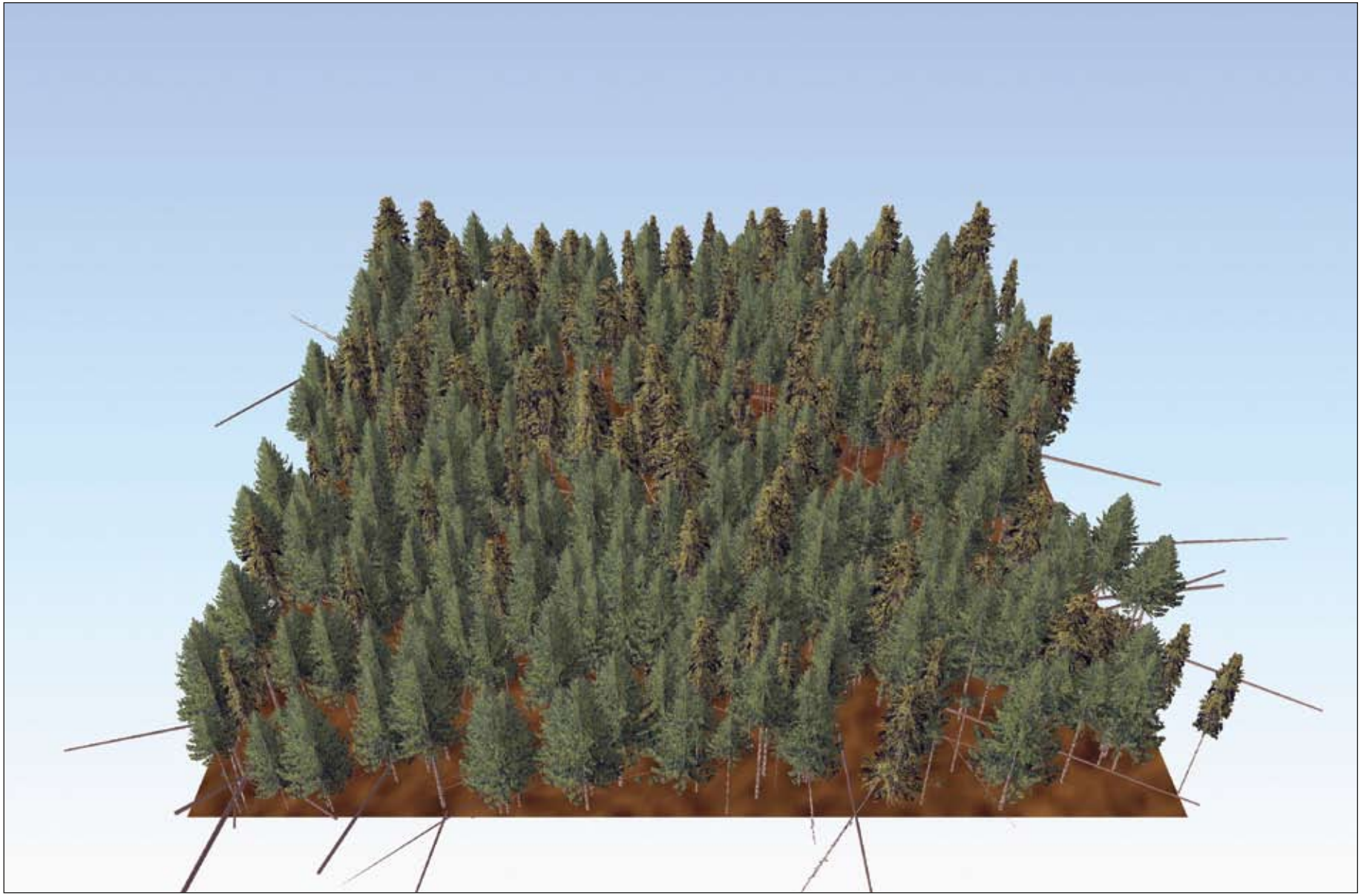
Table 5e—FVS fuel model selection

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—98th percentile	21	94	3	5	8	16	50	100
Moderate—75th 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).

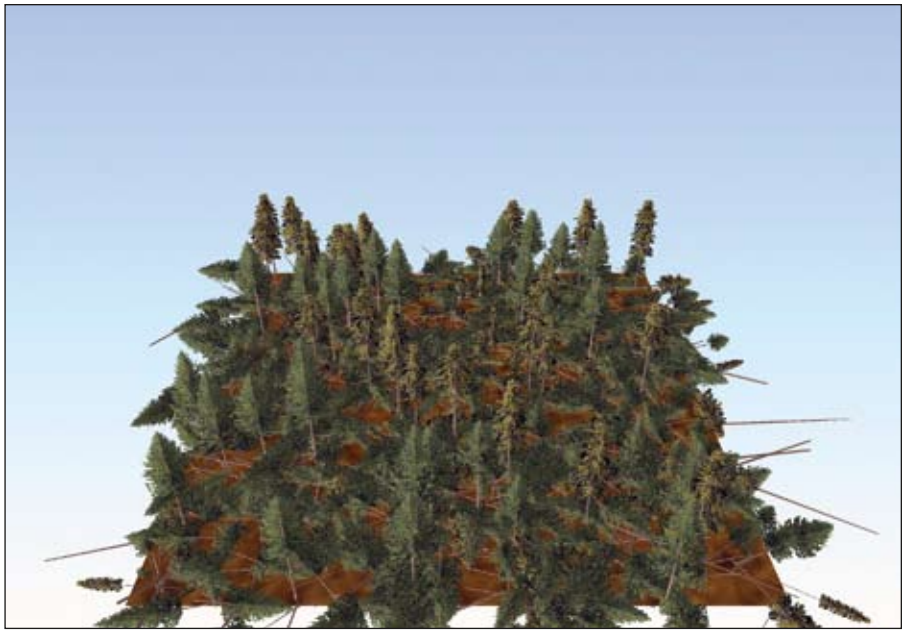


Initial stand conditions

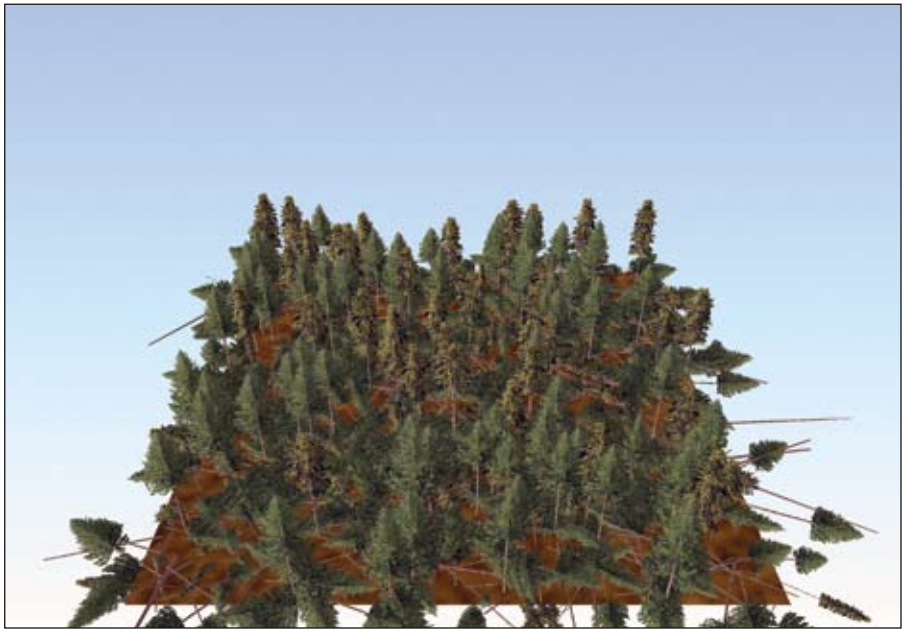
Site: Elevation = 6,200 ft, slope = 27 percent, aspect = 90°.

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 ft^2/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 liter and duff loading is 13 tons/ac. Canopy bulk density is 0.29 kg/m^3 (0.0181 lb/ft^3), 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)	0–3 in	3	1	14	12	9	7
		3–6 in	3	0	7	7	7	7
		6–12 in	3	2	4	4	4	4
		>12 in	0	0	0	0	0	0
		Litter	3	1	5	4	4	3
		Duff	10	7	10	10	10	10
	Flame length (ft)	Moderate	3	3	5	4	3	2
		Severe	4	4	6	5	4	3
	Torching index	Severe	18	35	37	52	82	82
	Crowning index	Severe	11	16	45	28	19	14
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Conditional	Conditional	Surface	Surface	Surface	Conditional
	Potential basal area mortality (%)	Moderate	34	32	22	21	25	27
		Severe	57	65	94	60	30	29
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in			3	3	2	2
		3–6 in			2	2	2	2
		6–12 in			1	1	1	1
		>12 in			0	0	0	0
		Litter			4	4	4	3
		Duff			9	9	9	9
	Flame length (ft)	Moderate			3	3	3	3
		Severe			5	5	5	4
	Torching index	Severe			22	26	30	40
	Crowning index	Severe			45	28	19	14
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Surface	Conditional
	Potential basal area mortality (%)	Moderate			18	21	25	28
		Severe			48	45	67	57
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in			0	0	0	0
		3–6 in			2	2	2	2
		6–12 in			2	2	2	2
		>12 in			0	0	0	0
		Litter			0	1	1	1
		Duff			7	7	7	7
	Flame length (ft)	Moderate			4	3	3	3
		Severe			5	4	5	5
	Torching index	Severe			29	34	27	31
	Crowning index	Severe			51	34	23	19
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Moderate			18	21	24	27
		Severe			42	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)	0–3 in	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
		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
		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
	Flame length (ft)	Moderate	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
	Torching index	Severe	18	28	14	25	38	54	35	60	73	79	92	101
	Crowning index	Severe	11	11	11	11	11	12	16	16	15	15	15	15
	Type of fire	Moderate	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.
	Hard snags (stems/ac)	0–17.9 in	214	131	31	32	28	28	178	19	14	11	11	11
		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)	0–3 in	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
		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
		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
	Flame length (ft)	Moderate	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
	Torching index	Severe	37	24	36	45	47	47	52	121	303	624	694	793
	Crowning index	Severe	45	49	51	53	55	57	28	31	33	34	35	36
	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)	0–17.9 in	201	111	5	6	5	5	202	112	7	7	8	8
		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	1	3	2	2	2	2	2
		3–6 in	2	2	2	2	2	1	2	2	2	2	2	2
		6–12 in	1	1	1	1	1	1	1	1	1	2	2	2
		>12 in	0	0	0	0	0	0	0	0	0	0	0	1
		Litter	4	1	1	1	1	1	4	1	1	1	2	2
		Duff	9	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	3
		Severe	5	5	5	4	4	4	5	5	5	5	5	5
	Torching index	Severe	22	34	39	45	47	48	26	38	40	47	47	53
	Crowning index	Severe	45	49	51	53	55	57	28	31	33	34	35	35
	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)	0–17.9 in	201	111	6	6	6	6	202	112	7	8	8	9
		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
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	1	1	1	1	1	0	2	1	1	1	1
		3–6 in	2	2	2	2	2	1	2	2	2	2	2	2
		6–12 in	2	3	3	3	3	2	2	4	4	4	4	4
		>12 in	0	0	0	0	1	1	0	0	0	0	1	1
		Litter	0	1	1	1	1	1	4	1	1	1	1	1
		Duff	7	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	3
		Severe	5	5	5	5	5	4	4	4	5	5	5	5
	Torching index	Severe	29	33	37	42	45	47	34	39	40	45	47	49
	Crowning index	Severe	51	55	59	61	63	64	34	36	38	40	41	41
	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)	0–17.9 in	86	12	8	6	5	5	95	18	10	7	7	7
		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
None	Surface fuel loadings (tons/ac)	0–3 in	9	5	4	3	3	4	7	5	5	5	5	5
		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
	Flame length (ft)	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
	Torching index	Severe	82	159	302	450	535	562	82	63	76	89	103	106
	Crowning index	Severe	19	21	21	22	22	22	14	15	15	14	15	15
	Type of fire	Moderate	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.
	Hard snags (stems/ac)	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)	0–3 in	2	3	3	3	3	3	2	4	4	4	5	4
		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
	Flame length (ft)	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
	Torching index	Severe	30	48	58	69	76	85	40	57	69	83	95	103
	Crowning index	Severe	19	21	21	21	22	22	14	15	15	14	15	15
	Type of fire	Moderate	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.
	Hard snags (stems/ac)	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 in	0	3	2	2	2	3	0	4	3	3	3	3
		3–6 in	2	3	3	3	3	3	2	4	4	4	3	3
		6–12 in	2	5	6	5	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
	Flame length (ft)	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	Severe	27	35	44	49	59	68	31	47	55	64	75	84
	Crowning index	Severe	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)	0–17.9 in	103	19	12	9	9	10	114	20	13	10	11	12
		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 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	Years	No action								Prescribed fire only							
		Fuel models								Fuel models							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*				
None	1	2	84	10	16					2	100						
	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				

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	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*				
None	1	14	57	11	43					11	61	14	39				
	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					1	50	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	Years	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							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*		*Percent*				*Percent*		*Percent*				
None	1	11	86	14	14					11	90	2	10				
	10	8	50	10	50					10	53	2	47				
	20	8	70	10	30					2	55	10	45				
	30	8	77	10	23					2	62	10	38				
	40	8	78	10	22					2	59	10	41				
	50	8	76	10	24					2	58	10	42				
Pile and burn	1	2	100							2	100						
	10	2	100							2	95	10	5				
	20	2	100							2	86	10	14				
	30	2	100							2	84	10	16				
	40	2	96	10	4					2	78	10	22				
	50	2	92	10	8					2	74	10	26				
Prescribed fire	1	2	75	1	25					2	100						
	10	2	74	10	17	1	9			2	59	10	41				
	20	2	90	10	10					2	71	10	29				
	30	2	93	10	7					2	75	10	25				
	40	2	92	10	8					2	77	10	23				
	50	2	90	10	10					2	76	10	24				

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

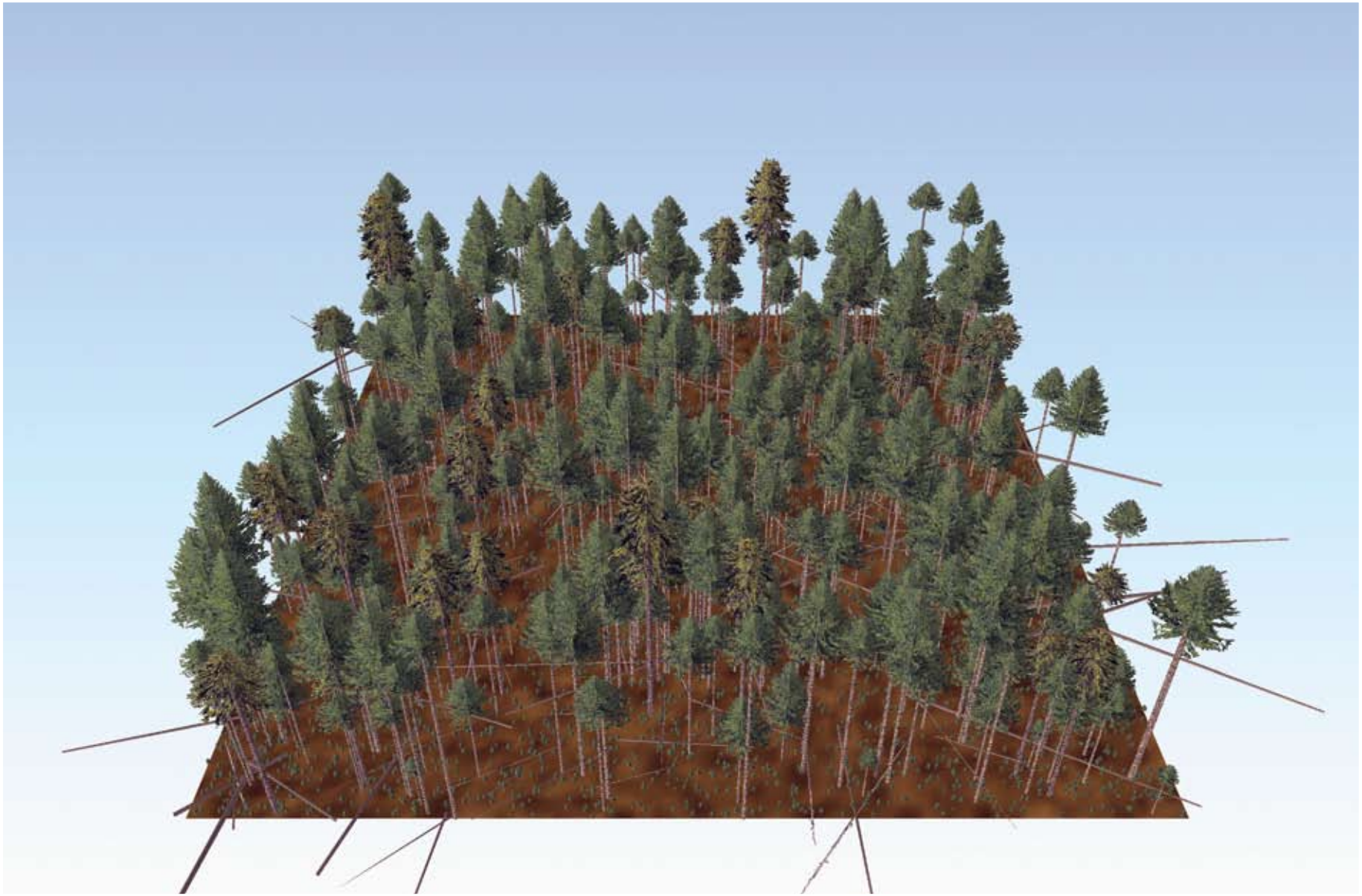
Table 6e—FVS fuel model selection

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
	Miles/hour	*°F*	*Percent*					
Severe—98th percentile	16	80	4	6	15	16	50	100
Moderate—75th 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).

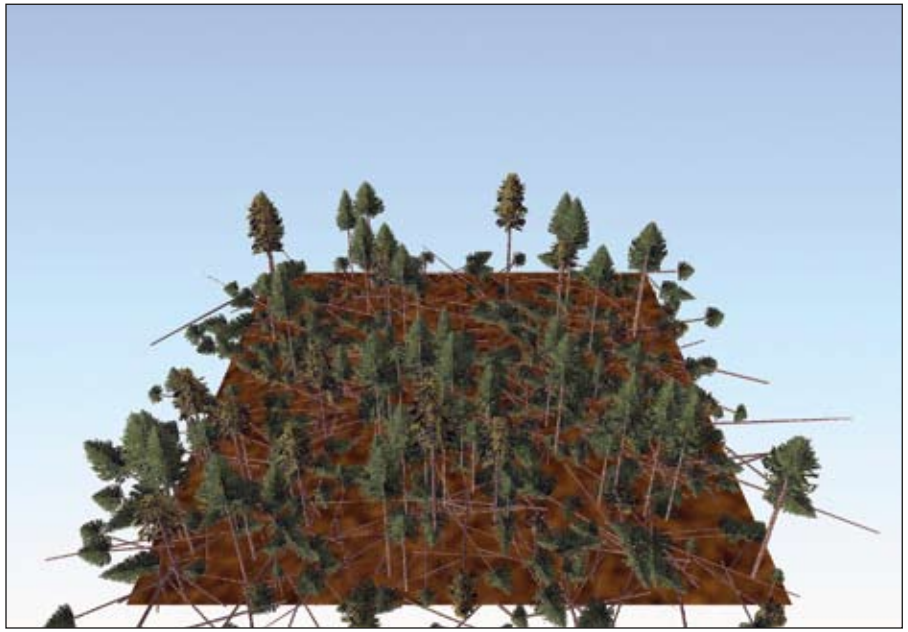


Initial stand conditions

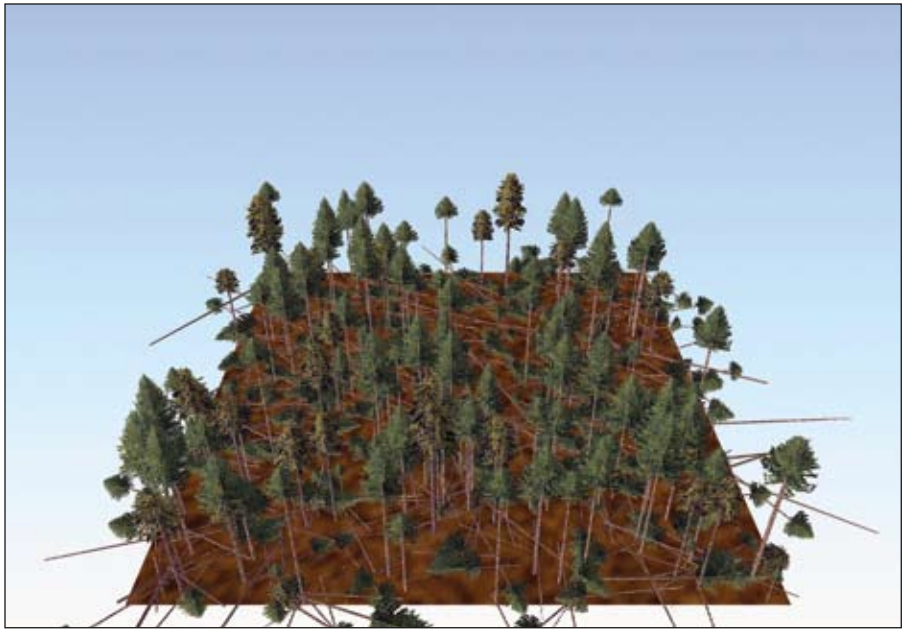
Site: Elevation = 5,600 ft, slope = 25 percent, aspect = 360°.

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.

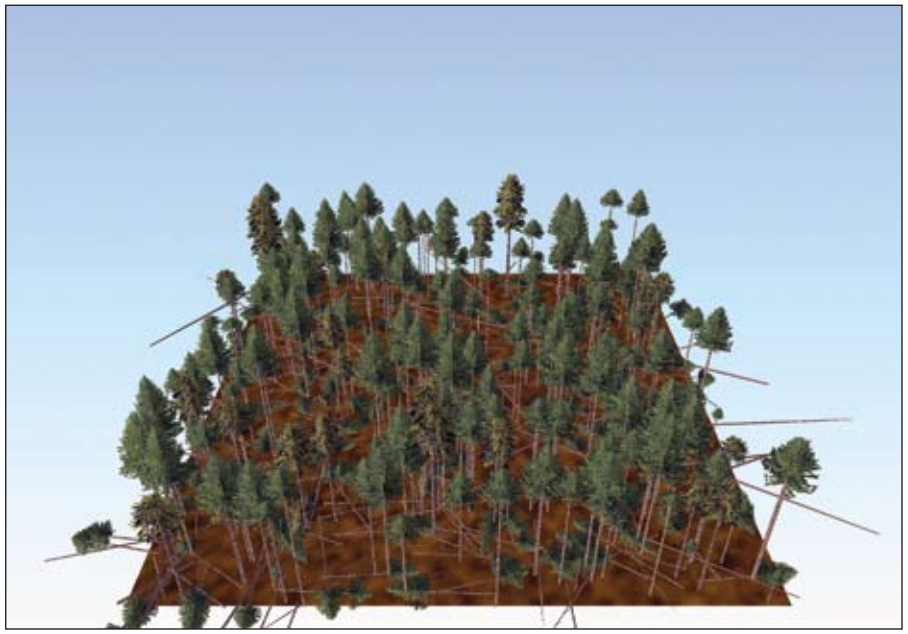
Stand attributes: Stem density = 6,573 tpa, basal area = 172 ft^2/ac, top height = 54 ft, stand density index = 575, quadratic mean diameter = 2.2 in, crown competition factor = 243, canopy cover = 69 percent.



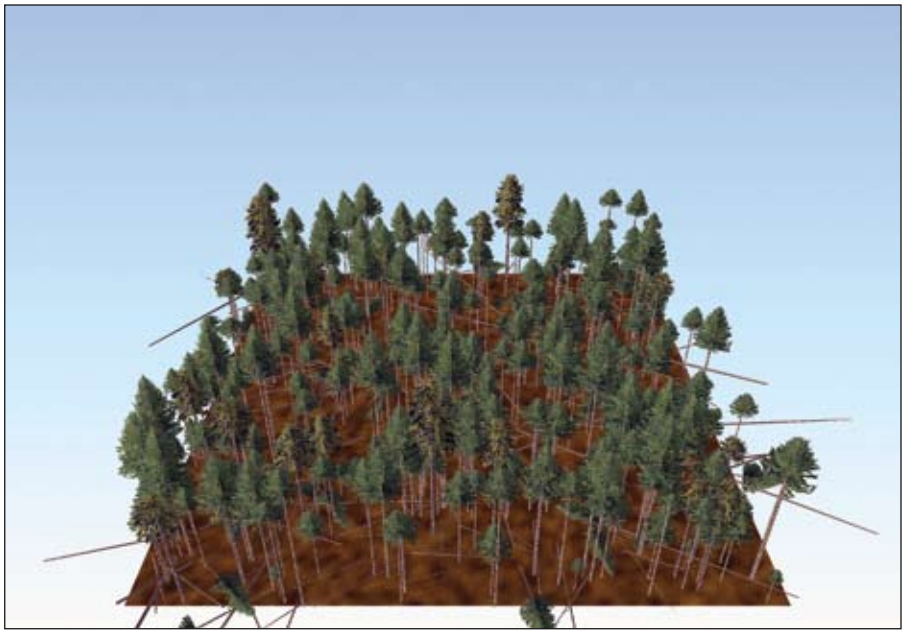
Thin from below to 50 tpa, 18-in d.b.h. limit



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/m^3 (0.0131 lb/ft^3), 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	3	1	10	8	6	4
		3–6 in	3	0	4	4	4	4
		6–12 in	3	2	3	3	3	3
		>12 in	0	0	0	0	0	0
		Litter	3	1	4	4	3	3
		Duff	10	7	10	10	10	10
	Flame length (ft)	Moderate	3	3	4	3	3	3
		Severe	4	5	5	4	4	4
	Torching index	Severe	42	44	117	196	51	27
	Crowning index	Severe	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
		6–12 in			1	1	1	1
		>12 in			0	0	0	0
		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	Severe			48	28	17	16
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Surface	Conditional
	Potential basal area mortality (%)	Moderate			19	20	25	27
		Severe			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
		6–12 in			2	2	2	2
		>12 in			0	0	0	0
		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	Severe			55	32	21	20
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Moderate			16	18	22	25
		Severe			18	18	24	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)	0–3 in	3	5	6	6	6	7	1	5	3	2	2	3
		3–6 in	3	4	4	4	5	5	0	4	4	4	3	3
		6–12 in	3	4	5	6	8	9	2	7	8	8	7	7
		>12 in	0	0	0	1	1	2	0	0	1	1	1	1
		Litter	3	3	3	3	4	4	1	2	2	2	2	2
		Duff	10	10	10	11	11	11	7	7	7	8	8	8
	Flame length (ft)	Moderate	3	3	3	3	3	3	3	3	3	3	3	3
		Severe	4	4	4	4	4	4	5	5	4	4	4	4
	Torching index	Severe	42	0	9	10	10	13	44	54	55	60	11	11
	Crowning index	Severe	15	16	16	16	7	5	20	19	19	19	19	19
	Type of fire	Moderate	Surface	Passive	Surface	Surface	Cond.	Cond.	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Cond.	Active	Passive	Passive	Active	Active	Surface	Surface	Surface	Surface	Passive	Passive
	Hard snags (stems/ac)	0–17.9 in	287	436	551	560	519	484	1,629	28	18	14	15	15
		18–29.9 in	0	0	0	1	1	1	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)	0–3 in	10	4	2	1	1	1	8	4	2	1	1	2
		3–6 in	4	4	4	4	3	3	4	4	4	4	3	3
		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
	Flame length (ft)	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
	Torching index	Severe	117	36	52	54	18	19	196	44	56	15	15	19
	Crowning index	Severe	48	49	50	52	54	57	28	29	30	32	33	35
	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	Passive	Passive	Surface
	Hard snags (stems/ac)	0–17.9 in	37	25	7	6	6	6	38	26	9	9	9	9
		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 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	1	2	2	1	1	1	1
		3–6 in	1	2	2	2	1	1	1	2	2	2	2	2
		6–12 in	1	1	2	2	2	2	1	2	2	2	2	2
		>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	2	2
		Duff	9	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	3
		Severe	5	5	5	4	4	4	4	4	5	5	5	5
	Torching index	Severe	36	47	52	17	18	19	49	53	56	15	15	17
	Crowning index	Severe	48	49	50	52	54	57	28	28	30	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	Passive	Passive	Surface
	Hard snags (stems/ac)	0–17.9 in	37	25	7	7	6	6	38	26	9	9	9	9
		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
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	1	1	1	1	1	0	2	1	1	1	1
		3–6 in	1	2	2	2	2	2	1	2	2	2	2	2
		6–12 in	2	3	4	4	3	3	2	4	5	5	5	4
		>12 in	0	0	1	1	1	1	0	0	1	1	1	1
		Litter	0	1	1	1	1	1	4	1	1	1	1	1
		Duff	7	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	3
		Severe	5	5	5	5	4	4	5	4	4	4	5	5
	Torching index	Severe	40	44	49	14	17	17	49	54	56	14	16	18
	Crowning index	Severe	55	56	56	58	61	62	32	33	35	36	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	Passive	Passive	Surface
	Hard snags (stems/ac)	0–17.9 in	30	17	10	7	6	6	39	24	14	9	9	9
		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 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
		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
		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
	Flame length (ft)	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
	Torching index	Severe	51	55	61	73	80	84	27	57	67	76	85	92
	Crowning index	Severe	17	18	19	19	20	20	16	16	16	15	15	16
	Type of fire	Moderate	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.
	Hard snags (stems/ac)	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
		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	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
		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
		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
	Flame length (ft)	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
	Torching index	Severe	50	60	65	76	20	20	51	61	71	78	84	94
	Crowning index	Severe	17	18	18	19	20	21	16	16	15	15	15	16
	Type of fire	Moderate	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.
	Hard snags (stems/ac)	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
		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 in	0	3	2	2	2	2	0	4	3	2	2	3
		3–6 in	1	3	3	3	3	3	1	4	4	4	3	3
		6–12 in	2	6	7	7	6	6	2	7	8	8	7	7
		>12 in	0	0	1	1	1	1	0	0	1	1	1	1
		Litter	1	1	1	2	2	2	1	2	2	2	2	2
		Duff	7	7	7	7	7	7	7	7	7	7	8	8
	Flame length (ft)	Moderate	3	3	3	3	3	3	3	3	3	3	3	3
		Severe	4	5	5	5	5	5	5	5	5	4	4	4
	Torching index	Severe	51	48	52	59	14	15	42	47	55	63	71	16
	Crowning index	Severe	21	21	23	23	24	26	20	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	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	51	27	16	10	10	10	62	28	17	12	12	12
		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 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	7	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	6	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	Years	No action								Prescribed fire only							
		Fuel models								Fuel models							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*				
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				

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	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*		*Percent*		*Percent*
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	Years	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							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*		*Percent*				*Percent*		*Percent*		*Percent*		
None	1	11	65	2	29	1	6			2	67	11	33				
	10	2	78	10	22					2	76	10	24				
	20	2	90	10	10					2	81	10	19				
	30	2	94	10	6					2	79	10	21				
	40	2	94	10	6					2	76	10	24				
	50	2	89	10	11					2	69	10	31				
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	1	1		
	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.

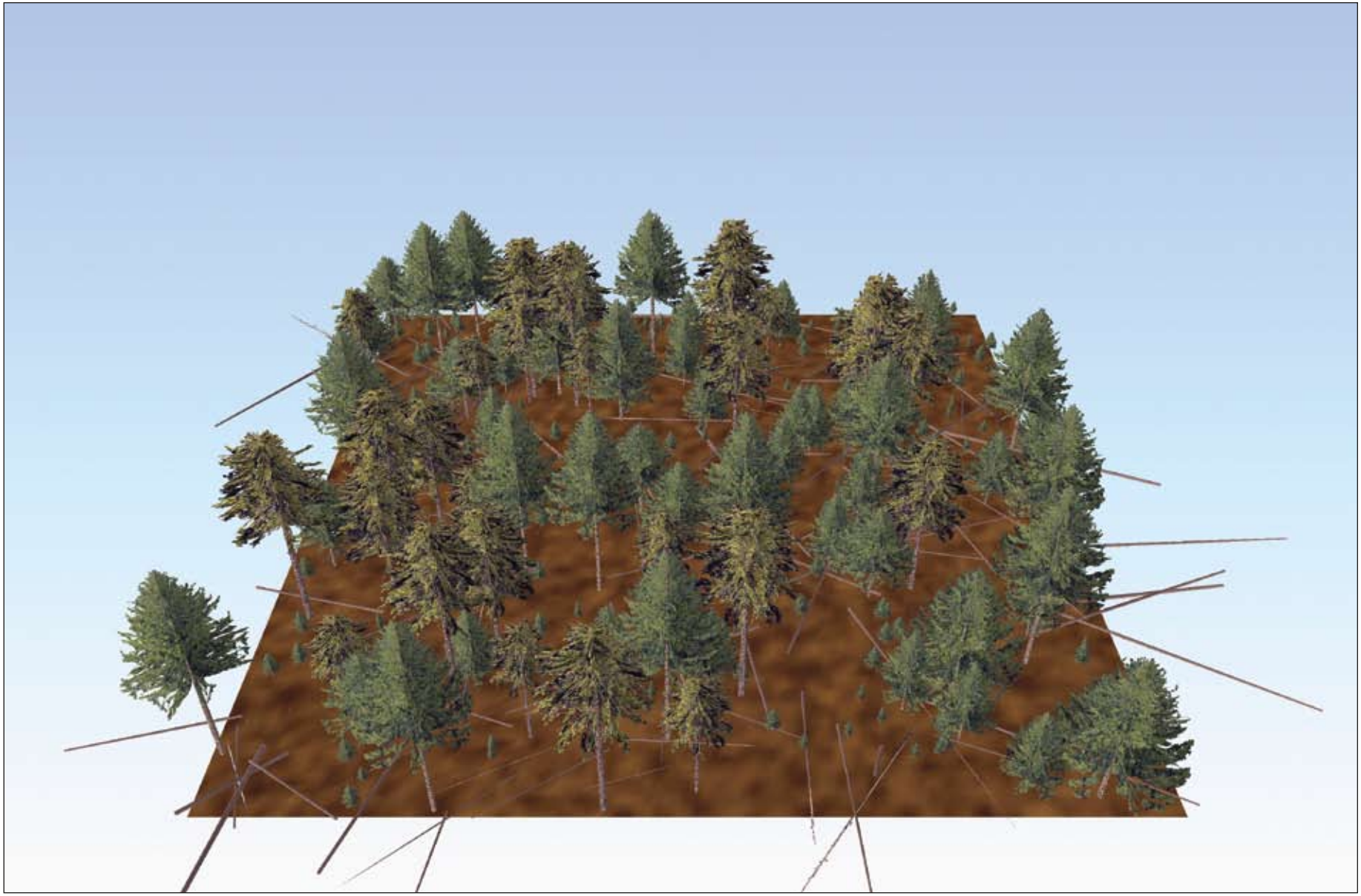
Table 7e—FVS fuel model selection

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
	Miles/hour	*°F*	*Percent*					
Severe—98th percentile	16	80	4	5	10	15	50	100
Moderate—75th 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).

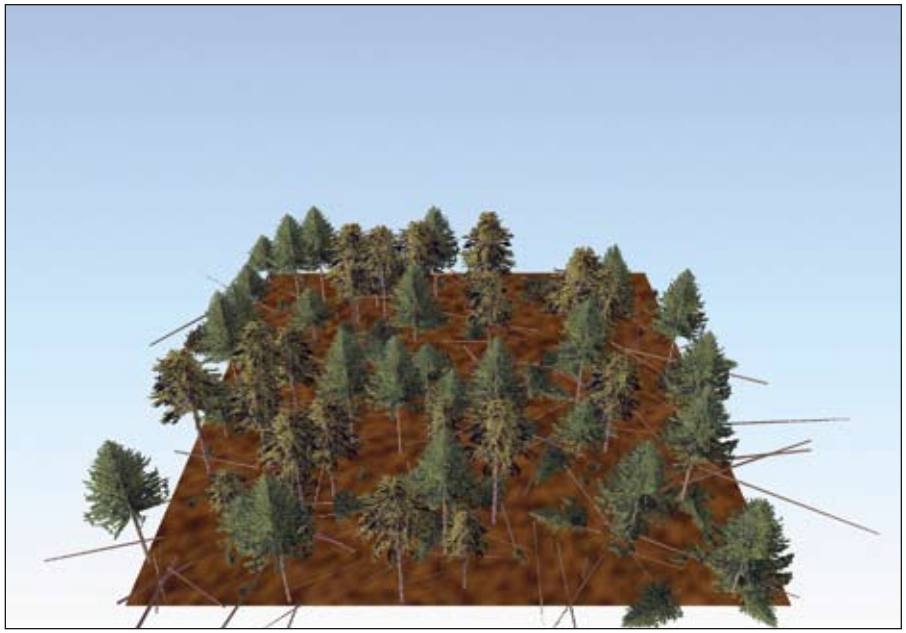


Initial stand conditions

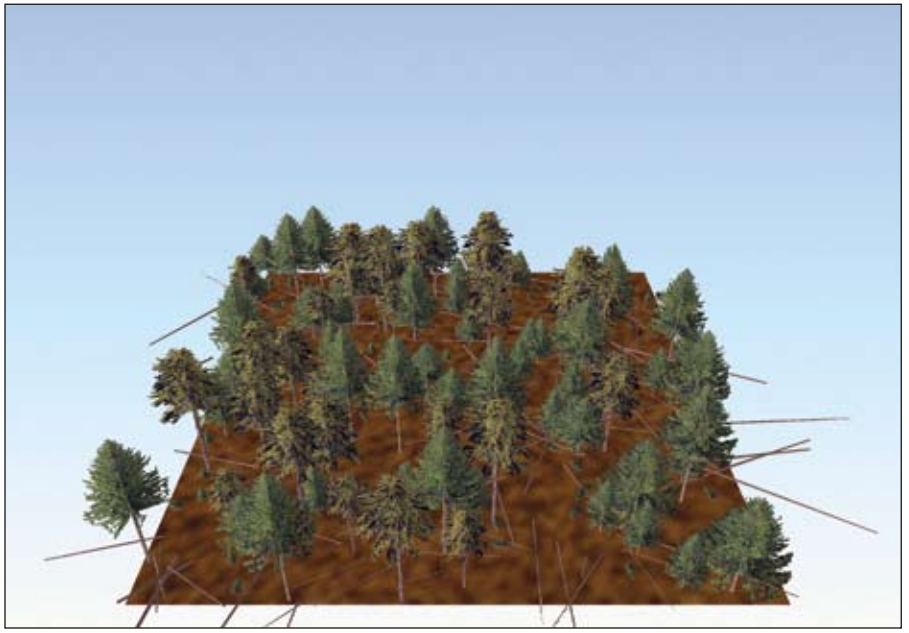
Site: Elevation = 9,200 ft, slope = 20 percent, aspect = 45°.

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

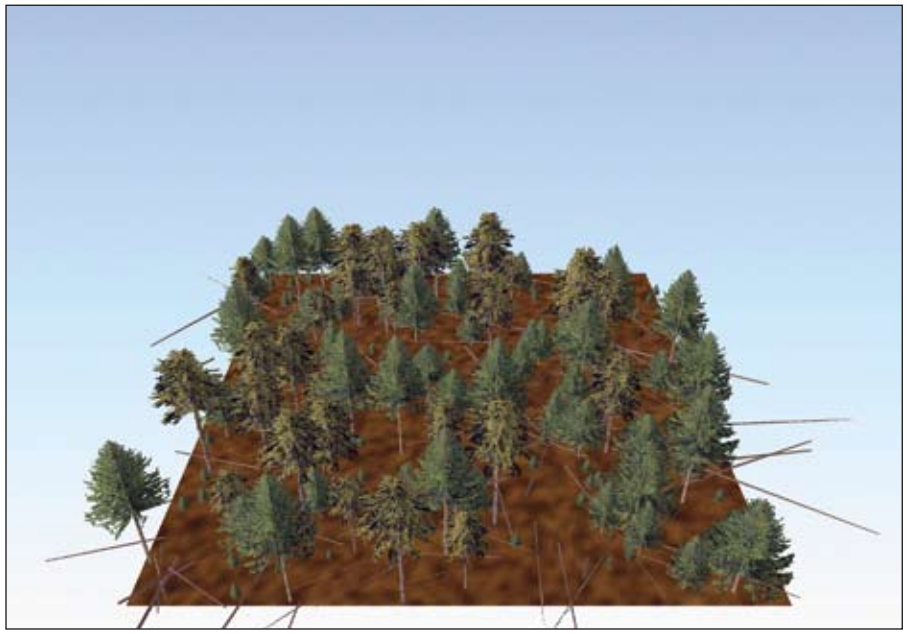
Stand attributes: Stem density = 384 tpa, basal area = 80 ft^2/ac, top height = 50 ft, stand density index = 177, quadratic mean diameter = 6.2 in, crown competition factor = 77, canopy cover = 54 percent.



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/m^3 (0.0044 lb/ft^3), 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	2	1	4	3	3	2
		3–6 in	2	0	2	2	2	2
		6–12 in	2	1	2	2	2	2
		>12 in	0	0	0	0	0	0
		Litter	2	0	3	2	2	2
		Duff	4	3	4	4	4	4
	Flame length (ft)	Moderate	2	1	2	2	2	2
		Severe	3	5	5	3	3	3
	Torching index	Severe	7	11	29	23	7	7
	Crowning index	Severe	37	43	43	37	37	37
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Passive	Passive	Surface	Surface	Passive	Passive
	Potential basal area mortality (%)	Moderate	18	15	12	17	18	18
		Severe	87	96	46	23	88	87
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in			1	1	1	1
		3–6 in			1	1	1	1
		6–12 in			1	1	1	1
		>12 in			0	0	0	0
		Litter			2	2	2	2
		Duff			4	4	4	4
	Flame length (ft)	Moderate			1	2	2	2
		Severe			5	3	3	3
	Torching index	Severe			24	28	8	8
	Crowning index	Severe			43	37	37	37
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Passive	Passive
	Potential basal area mortality (%)	Moderate			12	16	18	18
		Severe			60	21	83	83
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in			0	0	0	0
		3–6 in			0	0	0	0
		6–12 in			1	1	1	1
		>12 in			0	0	0	0
		Litter			0	0	0	0
		Duff			3	3	3	3
	Flame length (ft)	Moderate			1	1	1	1
		Severe			6	5	5	5
	Torching index	Severe			23	11	11	11
	Crowning index	Severe			48	43	43	43
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Passive	Passive	Passive
	Potential basal area mortality (%)	Moderate			12	15	15	15
		Severe			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)	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)	Moderate	2	2	2	2	2	2	1	1	1	2	2	2
		Severe	3	3	3	3	4	4	5	5	5	3	3	3
	Torching index	Severe	7	6	0	0	0	3	11	23	24	59	67	67
	Crowning index	Severe	37	34	29	25	22	19	43	44	41	41	39	37
	Type of fire	Moderate	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Passive	Passive	Passive	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	5	7	9	10	10	10	76	5	3	2	2	2
		18–29.9 in	0	0	0	0	1	1	1	1	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)	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)	Moderate	2	2	1	2	2	2	2	2	2	1	1	1
		Severe	5	5	5	3	3	3	3	3	3	2	2	2
	Torching index	Severe	29	26	30	69	71	66	23	37	43	196	213	218
	Crowning index	Severe	43	44	43	42	40	39	37	36	34	32	31	30
	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)	0–17.9 in	2	2	2	2	2	2	2	2	2	3	3	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 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)	0–3 in	1	1	2	2	2	2	1	1	2	2	2	3
		3–6 in	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
		>12 in	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
		Duff	4	4	4	4	4	4	4	4	4	4	4	4
	Flame length (ft)	Moderate	1	1	1	2	2	2	2	2	2	1	1	1
		Severe	5	5	5	3	3	3	3	3	3	1	1	1
	Torching index	Severe	24	25	29	72	75	72	28	43	51	307	349	318
	Crowning index	Severe	43	42	40	42	40	39	37	36	33	32	31	30
	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)	0–17.9 in	2	2	2	2	2	2	2	2	2	3	3	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
Prescribed fire	Surface fuel loadings (tons/ac)	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)	Moderate	1	1	1	1	1	2	1	1	1	2	2	2
		Severe	6	5	5	5	5	3	5	5	5	3	3	3
	Torching index	Severe	23	24	25	31	33	33	11	23	24	59	67	65
	Crowning index	Severe	48	45	42	41	40	40	43	41	39	36	36	35
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Surface	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	8	5	4	3	2	2	15	5	3	2	2	2
		18–29.9 in	1	1	0	0	0	0	1	1	0	0	0	0
		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
None	Surface fuel loadings (tons/ac)	0–3 in	3	2	3	3	3	3	2	2	3	3	3	4
		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	1	0	0	0	0	0	1
		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
	Flame length (ft)	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
	Torching index	Severe	7	6	6	13	10	17	7	6	5	4	11	18
	Crowning index	Severe	37	34	32	30	27	25	37	34	30	26	23	21
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Passive	Passive	Passive	Passive	Passive	Surface	Passive	Passive	Passive	Passive	Passive	Surface
	Hard snags (stems/ac)	0–17.9 in	3	4	6	7	7	6	5	6	7	9	9	8
		18–29.9 in	0	0	0	0	0	1	0	0	0	0	1	1
		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	1	2	2	3	3	1	1	2	2	3	3
		3–6 in	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
		>12 in	0	0	0	0	0	1	0	0	0	0	0	1
		Litter	2	3	3	4	4	4	2	3	3	4	4	5
		Duff	4	4	4	4	4	5	4	4	4	4	4	5
	Flame length (ft)	Moderate	2	2	2	2	3	2	2	2	2	2	2	2
		Severe	3	3	3	3	4	4	3	3	2	3	4	4
	Torching index	Severe	8	9	9	18	10	24	8	9	10	8	11	25
	Crowning index	Severe	37	34	32	30	27	24	37	34	30	26	23	20
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Passive	Passive	Passive	Surface	Passive	Surface	Passive	Passive	Passive	Passive	Passive	Surface
	Hard snags (stems/ac)	0–17.9 in	3	4	6	7	7	6	5	6	7	9	9	8
		18–29.9 in	0	0	0	0	0	1	0	0	0	0	1	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)	0–3 in	0	2	2	2	2	2	0	2	2	2	2	2
		3–6 in	0	1	1	1	1	1	0	1	1	1	1	1
		6–12 in	1	2	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	2	2	2	2	3	0	2	2	2	2	3
		Duff	3	3	3	3	3	4	3	3	3	3	3	4
	Flame length (ft)	Moderate	1	1	1	2	2	2	1	1	1	2	2	2
		Severe	5	5	5	3	3	3	5	5	5	3	3	3
	Torching index	Severe	11	23	24	59	67	71	11	23	24	59	67	70
	Crowning index	Severe	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	Surface	Passive	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	36	5	3	2	2	2	57	5	3	2	2	2
		18–29.9 in	1	1	0	0	0	0	1	1	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	0.09
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	Years	No action								Prescribed fire only							
		Fuel models								Fuel models							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*				
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				

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	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*				
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	Years	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							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*				
None	1	9	96	10	4					9	97	10	3				
	10	9	92	10	8					9	92	10	8				
	20	9	87	10	13					9	85	10	15				
	30	9	80	10	20					9	77	10	23				
	40	10	100							10	100						
	50	10	100							10	100						
Pile and burn	1	9	100							9	100						
	10	9	100							9	100						
	20	9	100							9	100						
	30	9	95	10	5					9	92	10	8				
	40	10	100							10	100						
	50	10	100							10	100						
Prescribed fire	1	5	100							5	100						
	10	5	100							5	100						
	20	5	100							5	100						
	30	9	100							9	100						
	40	9	100							9	100						
	50	9	97	10	3					9	96	10	4				

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

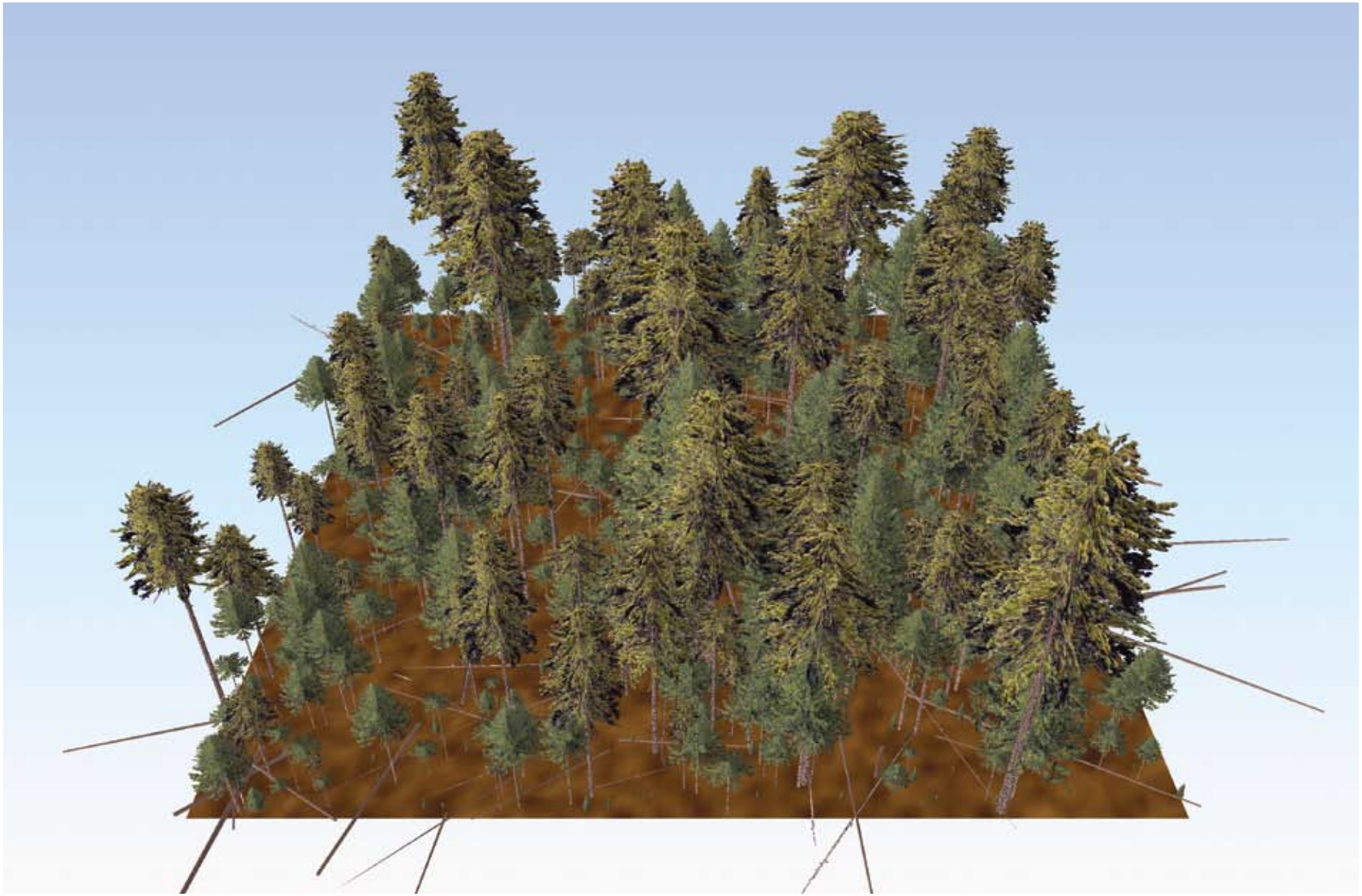
Table 8e—FVS fuel model selection

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
	Miles/hour	*°F*	*Percent*					
Severe—98th percentile	18	87	3	5	13	16	50	100
Moderate—75th percentile	10	69	5	7	16	19	125	150

Table 8f—Prescribed fire weather onditions 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).



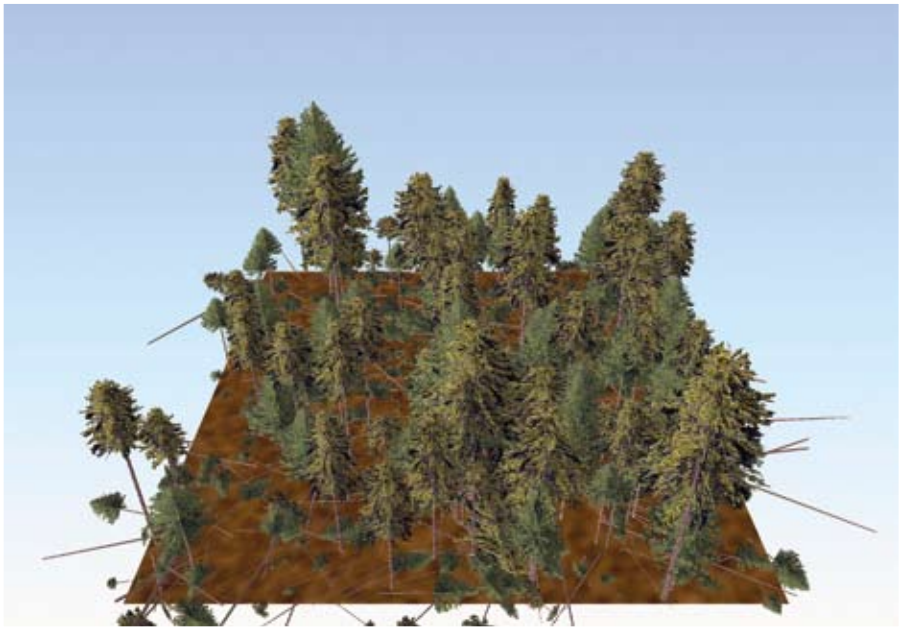
Initial stand conditions

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

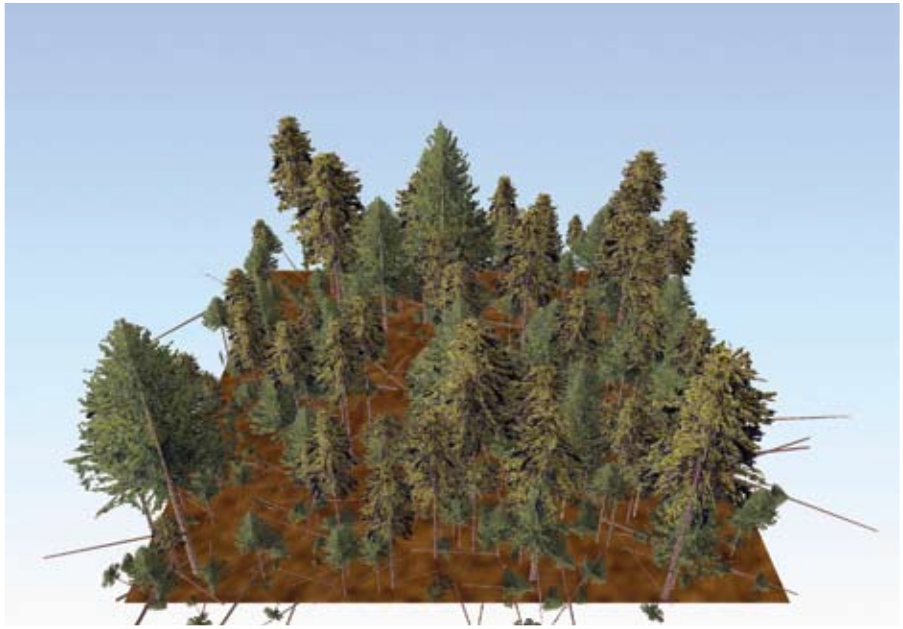
Species (based on trees per acre): White fir (*Abies concolor*) = 43 percent, Douglas-fir (*Pseudotsuga menziesii*) = 42 percent, ponderosa pine (*Pinus ponderosa*) = 12 percent.

Stand attributes: Stem density = 953 tpa, basal area = 157 ft^2/ac, top height = 65 ft, stand density index = 365, quadratic mean diameter = 5.5 in, crown competition factor = 174, canopy cover = 82 percent.

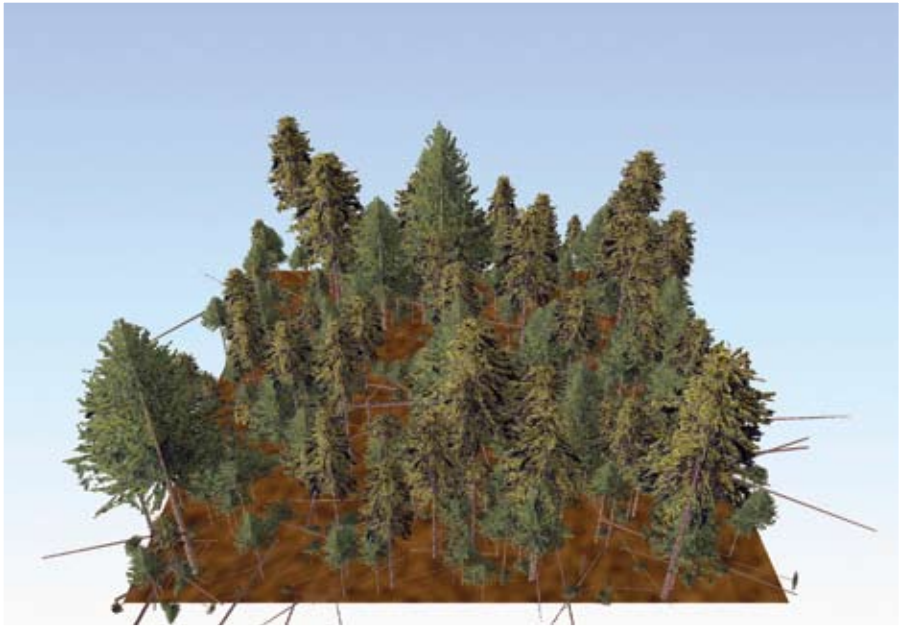
Thin from below to 50 tpa, 18-in d.b.h. limit



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/m^3 (0.015 lb/ft^3), 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)	0–3 in	3	1	10	8	7	5
		3–6 in	3	0	4	4	4	3
		6–12 in	3	1	2	3	3	3
		>12 in	0	0	0	0	0	0
		Litter	2	1	5	5	4	3
		Duff	5	4	4	5	5	5
	Flame length (ft)	Moderate	2	2	4	3	3	3
		Severe	3	3	6	5	4	4
	Torching index	Severe	14	49	45	62	46	25
	Crowning index	Severe	13	26	50	31	24	18
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Active	Surface	Surface	Surface	Surface	Conditional
	Potential basal area mortality (%)	Moderate	30	22	13	16	21	25
		Severe	100	23	33	34	33	32
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in			2	2	2	1
		3–6 in			1	1	1	1
		6–12 in			1	1	1	1
		>12 in			0	0	0	0
		Litter			5	4	4	3
		Duff			4	5	5	5
	Flame length (ft)	Moderate			4	2	2	2
		Severe			6	3	3	3
	Torching index	Severe			34	88	87	52
	Crowning index	Severe			50	31	24	18
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Surface	Conditional
	Potential basal area mortality (%)	Moderate			12	16	21	25
		Severe			35	16	21	25
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in			0	0	0	0
		3–6 in			0	0	0	0
		6–12 in			1	1	1	1
		>12 in			0	0	0	0
		Litter			0	1	1	1
		Duff			3	4	4	4
	Flame length (ft)	Moderate			4	4	2	2
		Severe			6	6	5	3
	Torching index	Severe			33	37	39	85
	Crowning index	Severe			57	40	35	29
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Moderate			11	15	18	20
		Severe			38	41	43	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)	0–3 in	3	4	6	8	8	9	1	5	5	5	5	6
		3–6 in	3	3	3	4	4	5	0	3	3	3	3	4
		6–12 in	3	3	3	4	4	5	1	4	4	4	4	4
		>12 in	0	0	1	1	2	2	0	1	1	2	2	2
		Litter	2	6	7	8	8	9	1	4	4	5	5	5
		Duff	5	5	6	6	6	7	4	4	4	4	4	5
	Flame length (ft)	Moderate	2	3	3	4	4	4	2	3	3	3	3	3
		Severe	3	4	4	5	5	6	3	4	4	4	4	4
	Torching index	Severe	14	0	0	0	0	0	49	33	41	46	45	51
	Crowning index	Severe	13	14	14	13	12	12	26	29	26	24	23	22
	Type of fire	Moderate	Surface	Passive	Passive	Passive	Passive	Passive	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Active	Active	Active	Active	Active	Active	Surface	Surface	Surface	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	43	46	53	51	49	62	189	12	10	10	10	12
		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

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)	0–3 in	10	7	5	5	4	4	8	6	5	5	5	5
		3–6 in	4	4	4	4	4	4	4	4	4	4	4	4
		6–12 in	2	2	2	3	3	3	3	3	3	3	3	3
		>12 in	0	0	1	1	2	2	0	0	1	1	1	2
		Litter	5	2	2	2	2	2	5	3	3	3	3	4
		Duff	4	4	4	4	5	5	5	5	5	6	6	6
	Flame length (ft)	Moderate	4	3	3	2	2	2	3	3	3	3	3	3
		Severe	6	5	5	5	5	5	5	4	4	4	4	4
	Torching index	Severe	45	51	52	58	60	58	62	71	81	85	94	104
	Crowning index	Severe	50	52	49	48	47	46	31	33	32	31	30	30
	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)	0–17.9 in	8	6	6	6	6	6	8	7	7	7	8	8
		18–29.9 in	1	1	2	2	3	3	1	1	2	2	2	3
		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 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	4	2	2	3	4	4	5
		3–6 in	1	1	1	2	2	2	1	1	2	2	2	2
		6–12 in	1	1	1	1	2	2	1	1	1	2	2	2
		>12 in	0	0	1	1	2	2	0	0	1	1	1	2
		Litter	5	2	2	2	2	3	4	3	3	3	3	4
		Duff	4	4	4	4	4	4	5	5	5	5	5	5
	Flame length (ft)	Moderate	4	2	2	2	2	2	2	2	2	2	2	3
		Severe	6	6	5	5	5	5	3	3	3	3	3	3
	Torching index	Severe	34	48	50	57	59	58	88	109	104	98	101	107
	Crowning index	Severe	50	50	47	46	44	44	31	33	32	31	30	30
	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)	0–17.9 in	8	6	6	6	6	6	8	7	7	8	8	8
		18–29.9 in	1	1	2	2	2	3	1	1	2	2	2	2
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	1	2	3	3	3	0	2	3	3	4	4
		3–6 in	0	1	1	1	2	2	1	1	1	2	2	2
		6–12 in	1	2	2	2	2	3	1	3	4	4	4	4
		>12 in	0	1	1	2	2	3	0	1	1	2	2	3
		Litter	0	2	2	2	2	2	4	2	3	3	3	3
		Duff	3	3	3	3	3	3	5	4	4	4	4	4
	Flame length (ft)	Moderate	4	2	2	2	2	2	4	2	2	2	3	3
		Severe	6	6	6	5	5	5	6	5	5	3	4	4
	Torching index	Severe	33	48	52	59	62	60	37	54	59	86	86	89
	Crowning index	Severe	57	54	52	50	48	48	40	41	39	37	36	36
	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)	0–17.9 in	18	11	8	7	7	7	24	11	8	7	7	7
		18–29.9 in	1	1	2	2	3	3	1	1	2	2	2	3
		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
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
		>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
	Flame length (ft)	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
	Torching index	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
	Type of fire	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
		>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
	Flame length (ft)	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
	Torching index	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
	Type of fire	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 in	0	3	3	4	4	5	0	4	4	4	5	5
		3–6 in	0	2	2	2	3	3	0	3	3	3	3	3
		6–12 in	1	4	4	4	4	4	1	4	4	4	4	4
		>12 in	0	1	1	2	2	3	0	1	1	2	2	3
		Litter	1	3	3	3	4	4	1	3	4	4	4	4
		Duff	4	4	4	4	4	4	4	4	4	4	4	4
	Flame length (ft)	Moderate	2	2	2	3	3	3	2	2	3	3	3	3
		Severe	5	3	3	4	4	4	3	3	4	4	4	4
	Torching index	Severe	39	67	75	81	91	96	85	60	62	70	80	86
	Crowning index	Severe	35	36	34	33	31	30	29	31	30	29	28	27
	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)	0–17.9 in	34	11	9	8	8	8	50	12	10	9	9	9
		18–29.9 in	1	1	2	2	2	2	1	2	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 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
	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	0.04	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
	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
Prescribed fire	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
	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
	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							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*				
None	1	9	93	10	7					9	100						
	10	10	60	9	40					10	58	9	42				
	20	10	95	9	5					10	69	9	31				
	30	10	87	12	13					10	75	9	25				
	40	10	74	12	26					10	83	9	17				
	50	10	62	12	38					10	92	9	8				

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	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*				
None	1	10	87	12	13					10	96	12	4				
	10	10	60	5	40					10	66	9	34				
	20	5	53	10	47					10	59	9	41				
	30	5	57	10	43					10	59	9	41				
	40	5	57	10	43					10	64	9	36				
	50	5	56	10	44					10	70	9	30				
Pile and burn	1	2	80	10	20					9	88	10	12				
	10	5	100							9	96	10	4				
	20	5	97	10	3					9	86	10	14				
	30	5	89	10	11					9	75	10	25				
	40	5	81	10	19					9	64	10	36				
	50	5	75	10	25					9	53	10	47				
Prescribed fire	1	2	100							2	100						
	10	5	100							5	99	10	1				
	20	5	100							5	83	10	17				
	30	5	91	10	9					9	72	10	28				
	40	5	83	10	17					9	62	10	38				
	50	5	76	10	24					9	54	10	46				

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

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

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

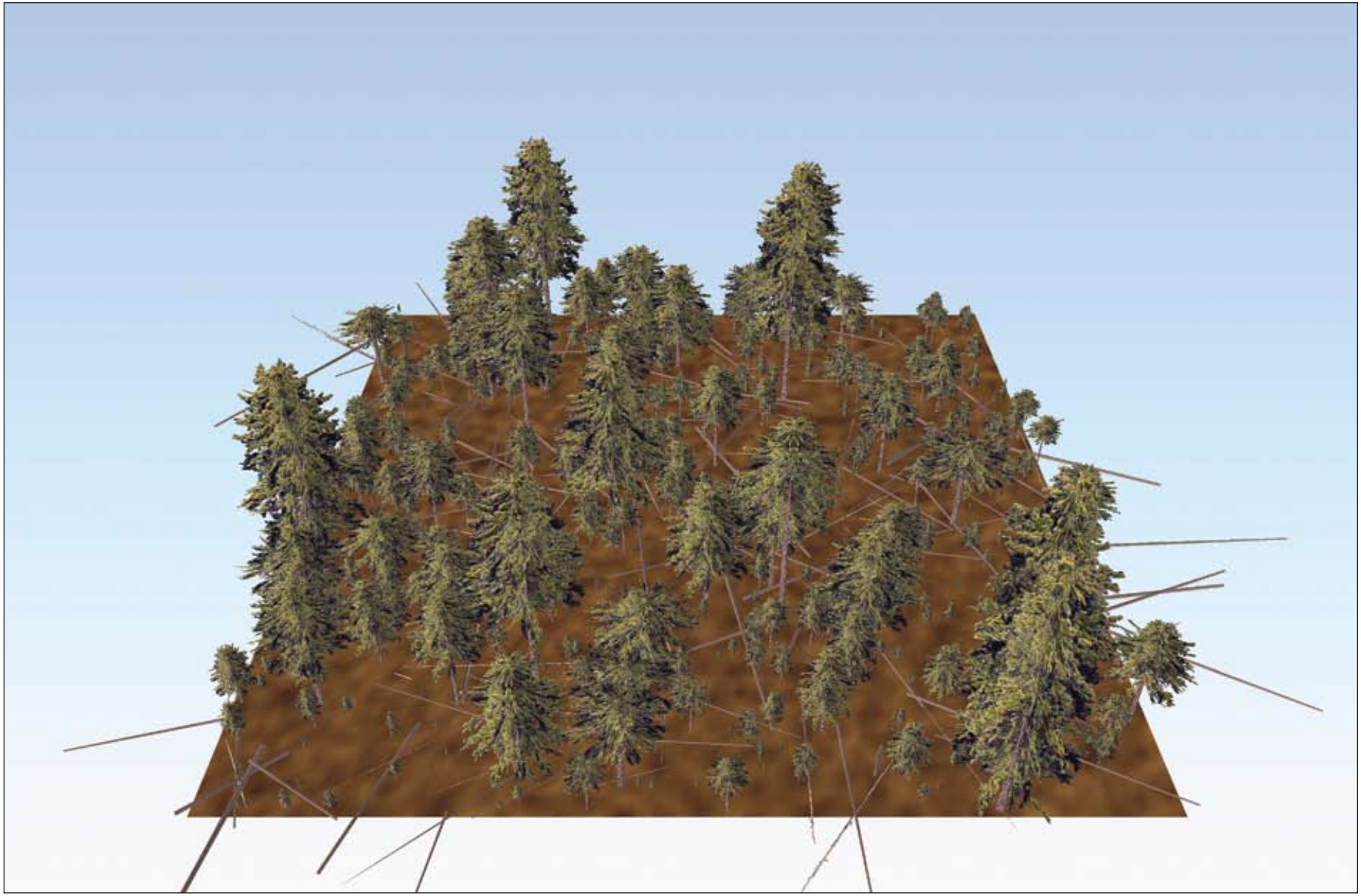
Table 9e—FVS fuel model selection

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
	Miles/hour	*°F*	*Percent*					
Severe—98th percentile	18	84	3	5	13	16	50	100
Moderate—75th 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).

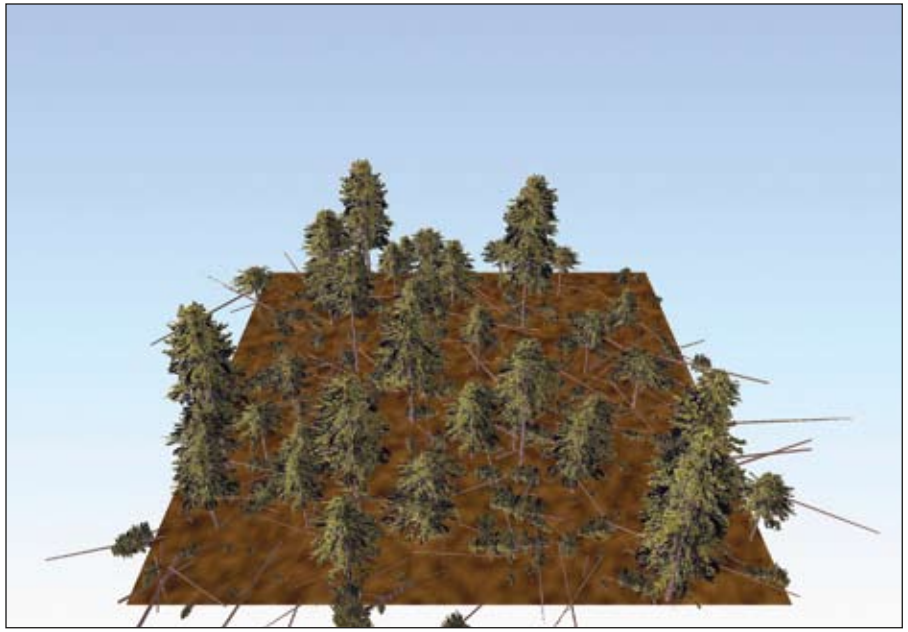


Initial stand conditions

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

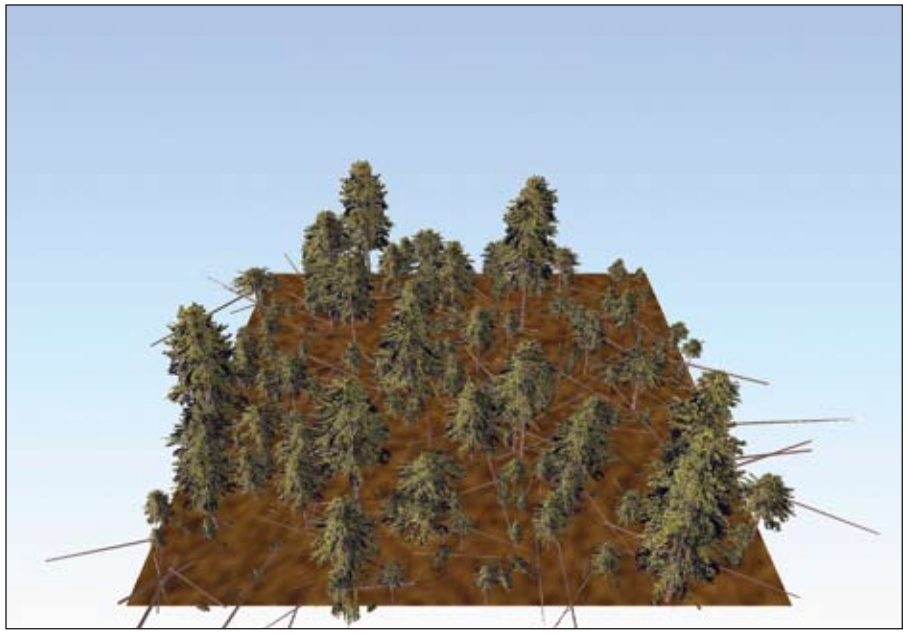
Species (based on trees per acre): Ponderosa pine (*Pinus ponderosa*) = 100 percent.

Stand attributes: Stem density = 496 tpa, basal area = 106 ft^2/ac, top height = 41 ft, stand density index = 234, quadratic mean diameter = 6.3 in, crown competition factor = 84, canopy cover = 57 percent.

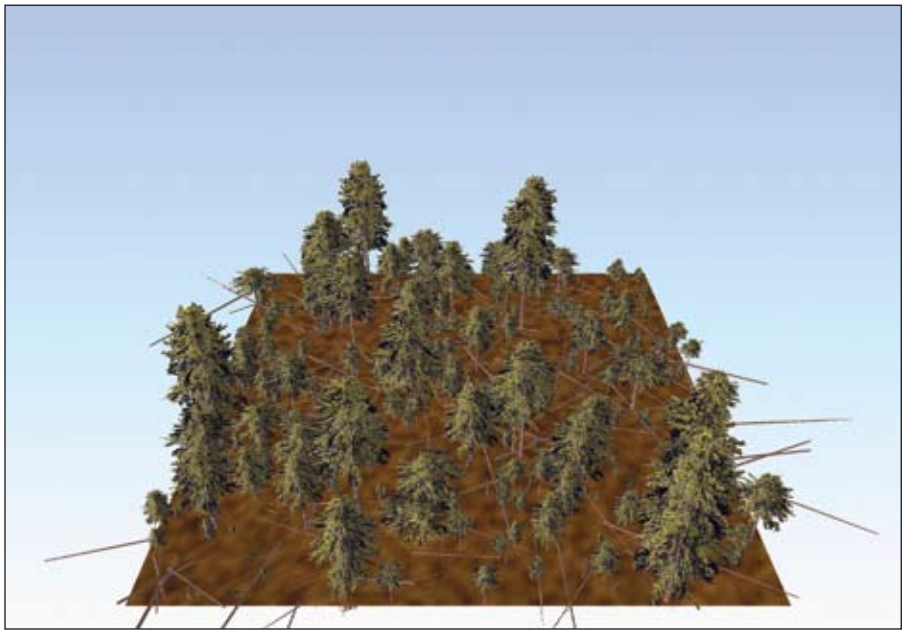


Thin from below to 50 tpa, 18-in d.b.h. limit

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	3	1	4	4	3	3
		3–6 in	2	0	2	2	2	2
		6–12 in	2	1	2	2	2	2
		>12 in	0	0	0	0	0	0
		Litter	2	1	2	2	2	2
		Duff	5	3	4	4	5	5
	Flame length (ft)	Moderate	1	1	2	2	1	1
		Severe	6	6	6	6	6	6
	Torching index	Severe	11	12	26	13	14	11
	Crowning index	Severe	29	39	41	35	29	29
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Active	Passive	Passive	Passive	Active	Active
	Potential basal area mortality (%)	Moderate	20	16	10	14	19	20
		Severe	100	98	96	98	100	100
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in			1	1	1	1
		3–6 in			1	1	1	1
		6–12 in			1	1	1	1
		>12 in			0	0	0	0
		Litter			2	2	2	2
		Duff			3	4	4	4
	Flame length (ft)	Moderate			1	1	1	1
		Severe			7	6	6	6
	Torching index	Severe			25	12	14	11
	Crowning index	Severe			41	35	29	29
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Passive	Passive	Active	Active
	Potential basal area mortality (%)	Moderate			10	14	19	20
		Severe			96	98	100	100
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in			0	0	0	0
		3–6 in			0	0	0	0
		6–12 in			1	1	1	1
		>12 in			0	0	0	0
		Litter			1	1	1	1
		Duff			3	3	3	3
	Flame length (ft)	Moderate			1	1	1	1
		Severe			7	6	6	6
	Torching index	Severe			24	11	12	12
	Crowning index	Severe			45	41	39	39
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Passive	Passive	Passive	Passive
	Potential basal area mortality (%)	Moderate			9	12	15	16
		Severe			96	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

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	4	5	6	6	7	1	4	4	4	5	5
		3–6 in	2	3	3	3	4	4	0	1	1	2	2	3
		6–12 in	2	2	2	2	2	2	1	2	2	2	2	2
		>12 in	0	0	0	0	0	0	0	0	1	1	1	1
		Litter	2	4	5	5	5	5	1	3	3	4	4	4
		Duff	5	5	5	5	6	6	3	3	4	4	4	4
	Flame length (ft)	Moderate	1	2	2	2	2	2	1	1	2	2	2	2
		Severe	6	4	4	4	4	4	6	6	6	4	4	4
	Torching index	Severe	11	25	29	41	49	56	12	27	25	46	60	71
	Crowning index	Severe	29	26	27	29	30	31	39	42	38	38	39	40
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Active	Active	Active	Cond.	Cond.	Surface	Passive	Passive	Passive	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	6	9	13	25	26	22	103	8	6	4	4	4
		18–29.9 in	0	0	0	0	0	0	1	1	1	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)	0–3 in	4	4	4	4	4	5	4	4	4	5	5	5
		3–6 in	2	2	2	3	3	3	2	2	3	3	3	4
		6–12 in	2	2	2	2	2	2	2	2	2	2	2	2
		>12 in	0	0	0	0	0	1	0	0	0	0	0	0
		Litter	2	2	2	2	2	3	2	3	3	3	3	4
		Duff	4	4	4	4	4	4	4	4	4	5	5	5
	Flame length (ft)	Moderate	2	2	2	2	2	2	2	2	2	2	2	2
		Severe	6	6	6	6	6	6	6	6	5	4	4	4
	Torching index	Severe	26	43	51	63	66	72	13	38	40	54	64	88
	Crowning index	Severe	41	57	55	55	54	55	35	41	42	42	42	43
	Type of fire	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
	Hard snags (stems/ac)	0–17.9 in	2	2	3	3	3	3	2	3	4	4	4	4
		18–29.9 in	0	0	1	1	1	1	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 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	2	3	3	4	4	1	2	3	4	5	5
		3–6 in	1	1	1	1	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	1	0	0	0	0	0	0
		Litter	2	2	2	2	3	3	2	3	3	3	4	4
		Duff	3	3	3	3	4	4	4	4	4	4	4	4
	Flame length (ft)	Moderate	1	1	1	1	2	2	1	1	1	2	2	2
		Severe	7	6	6	6	6	6	6	6	6	3	4	4
	Torching index	Severe	25	42	50	60	63	69	12	37	40	57	68	91
	Crowning index	Severe	41	53	51	52	49	51	35	41	42	40	41	42
	Type of fire	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
	Hard snags (stems/ac)	0–17.9 in	2	2	3	3	3	3	2	3	4	4	4	4
		18–29.9 in	0	0	1	1	1	1	0	0	0	0	0	0
		30–36 in	0	0	0	0	0	0	0	0	0	0	0	0
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	2	3	3	3	4	0	3	3	4	4	5
		3–6 in	0	1	1	1	2	2	1	1	1	1	2	2
		6–12 in	1	1	1	1	1	1	1	1	1	1	1	1
		>12 in	0	0	1	1	1	1	0	0	1	1	1	1
		Litter	1	2	2	3	3	3	2	2	3	3	3	3
		Duff	3	3	3	3	3	3	4	3	3	3	3	4
	Flame length (ft)	Moderate	1	1	1	1	2	2	1	1	1	2	2	2
		Severe	7	7	6	6	6	6	6	6	6	6	5	5
	Torching index	Severe	24	40	45	48	50	51	11	37	43	35	48	60
	Crowning index	Severe	45	47	46	46	43	43	41	45	45	43	43	44
	Type of fire	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
	Hard snags (stems/ac)	0–17.9 in	9	8	5	3	3	3	15	8	5	3	3	3
		18–29.9 in	1	1	1	1	1	1	1	1	1	1	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
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
		>12 in	0	0	0	0	0	0	0	0	0	0	0	0
		Litter	2	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	Severe	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	Cond.	Cond.	Surface
	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	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	Severe	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	Cond.	Cond.	Cond.	Cond.	Surface
	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 in	0	3	3	4	5	5	0	3	4	4	5	5
		3–6 in	0	1	1	2	2	3	0	1	1	2	2	3
		6–12 in	1	2	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	1	3	3	4	4	4	1	3	3	4	4	4
		Duff	3	3	3	4	4	4	3	3	4	4	4	4
	Flame length (ft)	Moderate	1	1	2	2	2	2	1	1	2	2	2	2
		Severe	6	6	6	5	4	4	6	6	6	4	4	4
	Torching index	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
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Passive	Passive	Passive	Surface	Surface	Surface	Passive	Passive	Passive	Surface	Surface	Surface
	Hard snags (stems/ac)	0–17.9 in	30	8	6	4	4	4	52	8	6	4	4	4
		18–29.9 in	1	1	1	1	0	0	1	1	1	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	Years	No action								Prescribed fire only							
		Fuel models								Fuel models							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*				
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				

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	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*				
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	Years	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							
		Model	Weight	Model	Weight	Model	Weight	Model		Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*				
None	1	5	93	10	7					5	95	10	5				
	10	9	70	10	30					9	69	10	31				
	30	10	55	9	45					10	62	9	38				
	40	10	65	9	35					10	72	9	28				
	50	10	74	9	26					10	83	9	17				
Pile and burn	1	5	100							5	100						
	10	9	98	10	2					9	96	10	4				
	20	9	77	10	23					9	72	10	28				
	30	9	62	10	38					9	56	10	44				
	40	10	50	9	50					10	57	9	43				
	50	10	60	9	40					10	70	9	30				
Prescribed fire	1	5	100							5	100						
	10	5	94	10	6					5	91	10	9				
	20	5	80	10	20					5	77	10	23				
	30	5	69	10	31					9	66	10	34				
	40	9	59	10	41					9	56	10	44				
	50	9	50	10	50					10	52	9	48				

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

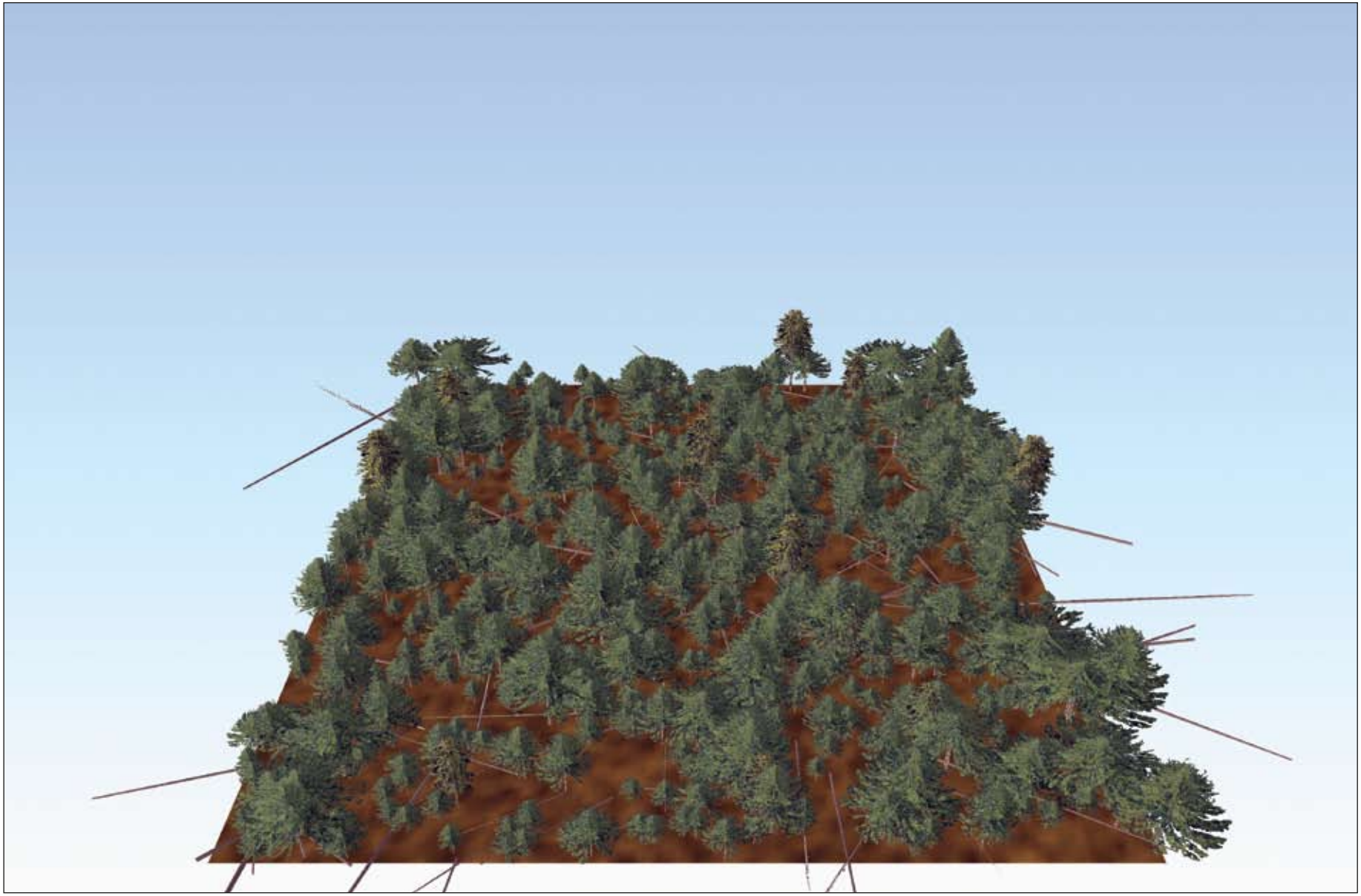
Table 10e—FVS fuel model selection

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
	Miles/hour	*°F*	*Percent*					
Severe—98th percentile	30	74	4	6	12	15	50	100
Moderate—75th 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).

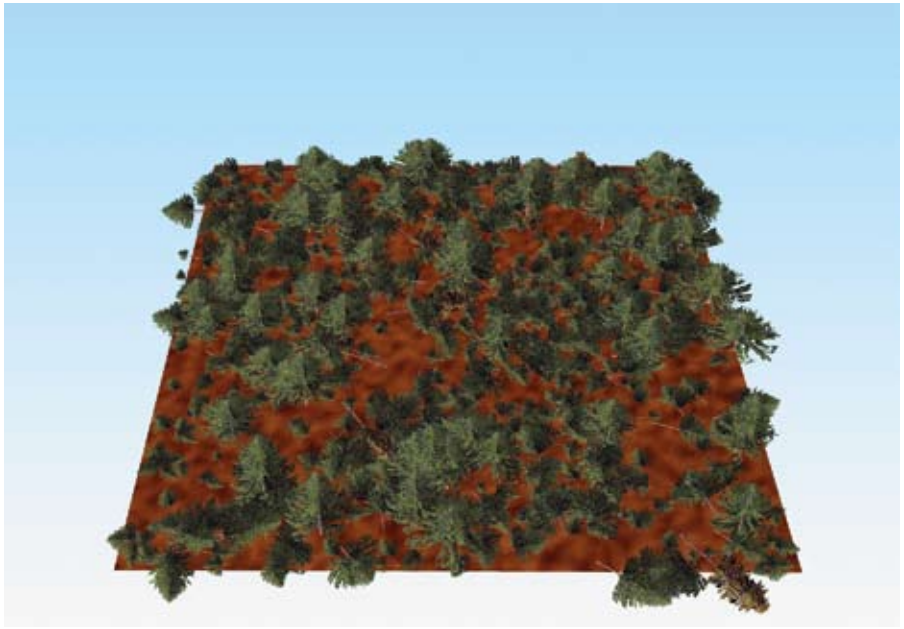


Initial stand conditions

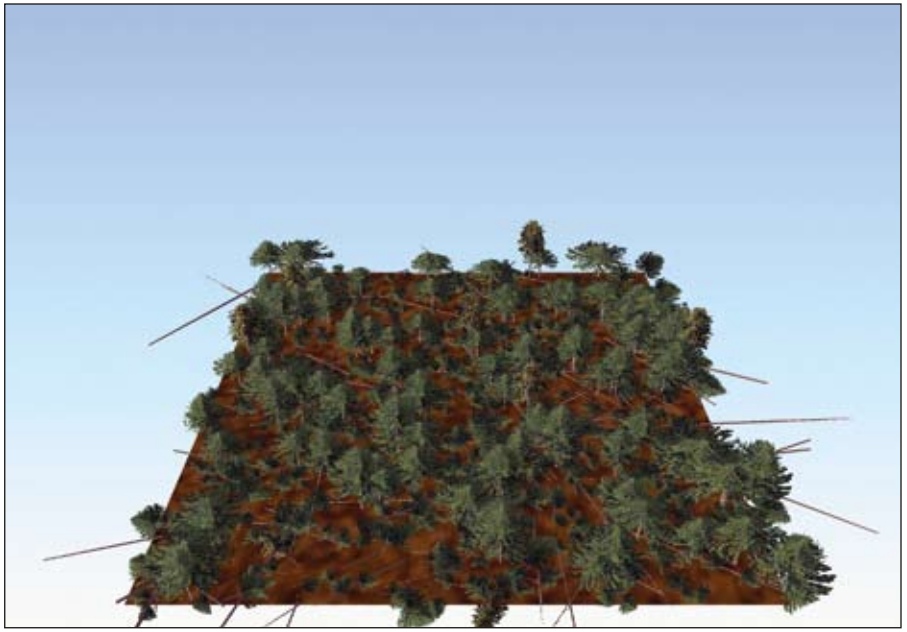
Site: Elevation = 7,100 ft, slope = 35 percent, aspect = 10°.

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

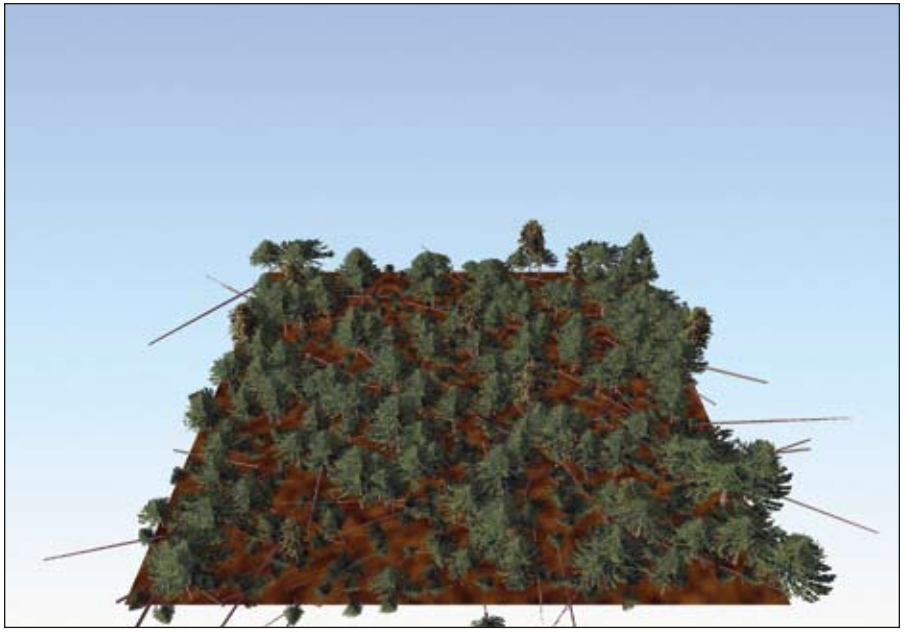
Stand attributes: Stem density = 733 tpa, basal area = 162 ft^2/ac, top height = 23 ft, stand density index = 356, quadratic mean diameter = 6.4 in, crown competition factor = 190, canopy cover = 85 percent.



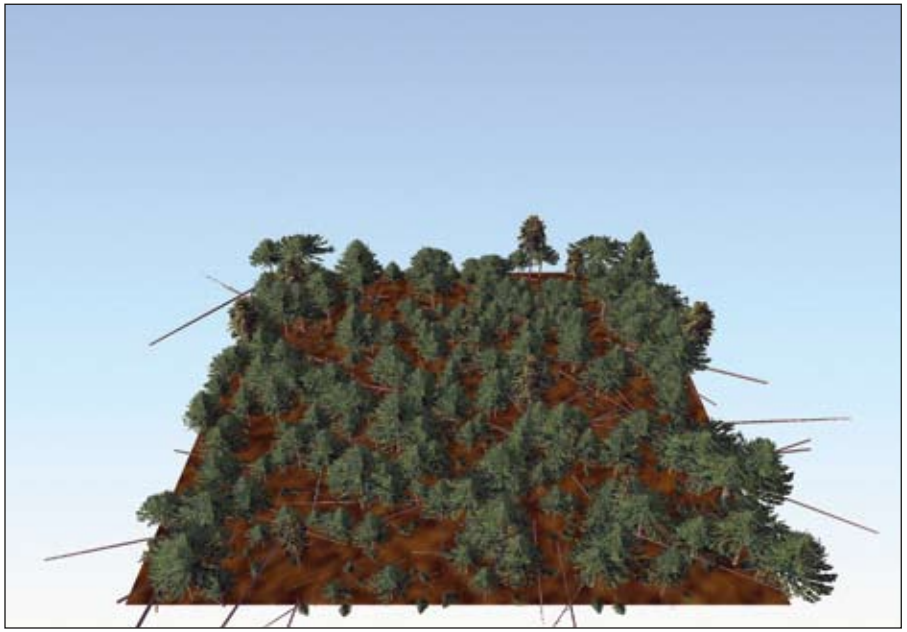
Thin from below to 50 tpa, 18-in d.b.h. limit



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	3	1	8	5	4	4
		3–6 in	1	0	12	5	5	2
		6–12 in	3	1	13	6	6	3
		>12 in	0	0	0	0	0	0
		Litter	8	0	1	3	2	8
		Duff	0	0	22	17	17	0
	Flame length (ft)	Moderate	3	4	3	3	2	3
		Severe	5	7	6	4	3	4
	Torching index	Severe	0	31	26	61	66	23
	Crowning index	Severe	34	169	146	89	57	50
	Type of fire	Moderate	Surface	Surface	Surface	Surface	Surface	Surface
		Severe	Passive	Surface	Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Moderate	93	88	66	44	47	72
		Severe	99	98	98	97	95	99
Pile and burn	Surface fuel loadings (tons/ac)	0–3 in			2	1	1	1
		3–6 in			1	1	1	1
		6–12 in			1	2	2	1
		>12 in			0	0	0	0
		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	Severe			146	89	57	50
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Moderate			32	37	43	49
		Severe			98	37	43	81
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in			0	0	0	0
		3–6 in			0	0	0	0
		6–12 in			2	3	3	1
		>12 in			0	0	0	0
		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	Severe			146	89	57	50
	Type of fire	Moderate			Surface	Surface	Surface	Surface
		Severe			Surface	Surface	Surface	Surface
	Potential basal area mortality (%)	Moderate			66	44	47	72
		Severe			98	97	95	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)	0–3 in	3	3	5	6	7	7	1	5	3	3	2	2
		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
	Flame length (ft)	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	Severe	0	0	0	6	4	0	31	24	27	27	28	29
	Crowning index	Severe	34	35	37	37	40	42	169	152	143	139	139	137
	Type of fire	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)	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

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)	0–3 in	8	3	1	1	1	1	5	4	4	4	4	5
		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
	Flame length (ft)	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	Severe	26	28	30	34	35	39	61	80	77	79	72	65
	Crowning index	Severe	146	146	143	143	141	139	89	86	85	86	87	87
	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)	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

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)	0–3 in	2	1	2	2	2	3	1	1	2	3	4	4
		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
	Flame length (ft)	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	Severe	22	25	26	30	32	38	323	384	226	174	135	111
	Crowning index	Severe	146	146	143	143	140	136	89	86	85	86	87	87
	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)	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
Prescribed fire	Surface fuel loadings (tons/ac)	0–3 in	0	1	1	1	1	2	0	2	2	2	3	3
		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
	Flame length (ft)	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	Severe	16	14	12	16	21	21	28	28	45	76	115	139
	Crowning index	Severe	346	325	341	308	194	170	134	131	130	129	128	128
	Type of fire	Moderate	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)	0–17.9 in	22	11	5	2	2	2	22	8	5	3	3	3
		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
		>12 in	0	0	0	0	0	1	0	0	0	0	0	1
		Litter	2	4	5	5	6	6	8	5	5	6	6	7
		Duff	17	17	17	17	17	17	0	0	1	1	1	2
	Flame length (ft)	Moderate	2	2	3	3	3	4	3	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	30	23	76	22	22	29	24
	Crowning index	Severe	57	57	62	64	65	65	50	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)	0–17.9 in	3	4	10	13	12	11	6	15	18	16	13	16
		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	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	1	0	0	0	0	0	1
		Litter	2	4	5	5	6	6	8	5	5	6	6	7
		Duff	15	15	15	15	16	16	0	0	1	1	1	2
	Flame length (ft)	Moderate	1	1	2	2	3	3	2	1	3	3	3	3
		Severe	1	2	3	3	4	4	3	2	4	4	4	4
	Torching index	Severe	296	253	141	85	41	41	82	194	22	22	29	29
	Crowning index	Severe	57	57	62	64	65	66	50	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)	0–17.9 in	3	4	11	13	12	11	6	15	18	16	13	16
		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 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)	0–3 in	0	2	3	3	3	3	0	3	3	3	3	3
		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
		>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
	Flame length (ft)	Moderate	1	2	2	2	3	3	4	4	4	3	3	3
		Severe	1	6	3	3	5	5	7	6	6	5	6	5
	Torching index	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
	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)	0–17.9 in	37	9	5	3	3	4	69	9	4	2	2	3
		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

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)	1,648	2,223	2,648	3,054	3,435	3,804	432	497	623	747	873	994
	Merchantable volume (ft^3)	1,565	2,072	2,468	2,912	3,327	3,762	421	486	610	733	857	977
	Basal area (ft^2)	162	182	189	195	200	205	30	32	35	38	40	42
	Stand density index	356	382	381	382	381	380	47	49	53	56	58	61
	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 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	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*				
None	1	10	75	6	25					10	100						
	10	6	56	10	44					10	67	2	33				
	20	10	66	6	34					10	58	2	42				
	30	10	91	6	9					2	54	10	46				
	40	10	92	12	8					2	63	10	37				
	50	10	81	12	19					2	68	10	32				

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	Model	Weight	Model	Weight
			Percent		*Percent*		*Percent*				*Percent*		*Percent*		*Percent*		
None	1	10	72	5	27	6	1			10	58	8	42				
	10	10	49	5	36	6	16			10	53	8	47				
	20	10	42	6	31	5	27			10	59	8	41				
	30	6	43	10	39	5	18			10	66	8	34				
	40	6	52	10	38	5	10			10	75	8	25				
	50	6	59	10	38	5	3			10	84	8	16				
Pile and burn	1	5	97	6	3					8	100						
	10	5	69	6	31					8	100						
	20	6	54	5	46					8	86	10	14				
	30	6	69	5	28	10	3			8	72	10	28				
	40	6	78	5	13	10	8			8	59	10	41				
	50	6	86	10	13	5	2			10	53	8	47				
Prescribed fire	1	2	100							2	100						
	10	2	93	5	7					2	91	10	9				
	20	2	84	5	16					2	65	10	19	8	16		
	30	2	100							2	42	8	33	10	25		
	40	2	100							8	46	10	30	2	24		
	50	2	100							2	65	10	35				

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

Surface fuel treatment	Years	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							
		Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight	Model	Weight
			Percent		*Percent*						*Percent*		*Percent*		*Percent*		
None	1	8	53	10	47					10	84	8	16				
	10	10	59	8	41					8	57	10	43				
	20	10	74	8	26					10	100						
	30	10	91	8	9					10	100						
	40	10	95	12	5					10	100						
	50	10	85	12	15					10	92	12	8				
Pile and burn	1	8	100							8	67	10	33				
	10	8	92	10	8					8	89	10	11				
	20	8	70	10	30					10	100						
	30	10	52	8	48					10	100						
	40	10	100							10	100						
	50	10	100							10	100						
Prescribed fire	1	8	100							2	100						
	10	5	72	10	28					2	57	10	43				
	20	8	62	10	38					2	56	10	44				
	30	8	56	10	44					10	100						
	40	10	100							2	46	10	42	8	12		
	50	10	100							10	43	2	36	8	21		

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
	Miles/hour	*°F*	*Percent*					
Severe—98th percentile	19	85	3	5	13	16	50	100
Moderate—75th 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).

Continue to Part C