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Donald W. Scott Craig L. Schmitt Lia H. Spiegel



Fire-damaged Ponderosa Pines on The Emigrant Creek Ranger District, Malheur National Forest.

Factors Affecting Survival of Fire Injured Trees: A Rating System For Determining Relative Probability of Survival of Conifers in the Blue and Wallowa Mountains

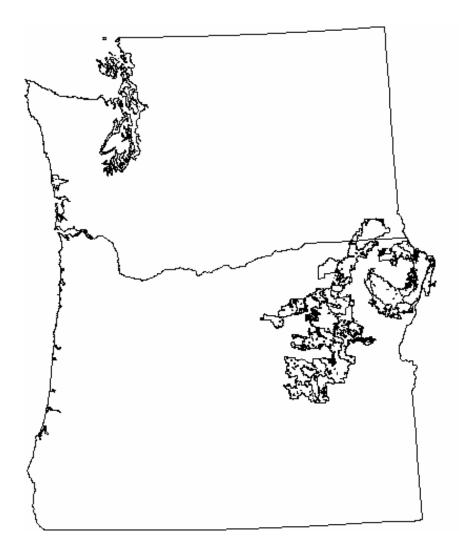


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Factors Affecting Survival of Fire Injured Trees: A Rating System For Determining Relative Probability of Survival of Conifers in the Blue and Wallowa Mountains

Donald W. Scott, Craig L. Schmitt, Lia Spiegel Blue Mountains Pest Management Service Center La Grande, Oregon 97850 November 25, 2002

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Introduction

The marking of trees for salvage following wildfire is often difficult and controversial owing to the varied and complex factors governing the survival of fire injured trees. Numerous factors often interact to determine the fate of trees following wildfire, including, but not limited to age, size, crown ratio, bark thickness, and other fire-resistance characteristics of the affected tree species; stand density, fuel loads, season of fire, and growing site quality characteristics that influence the intensity and duration of the fire, and degree of damage to trees; and insect populations and disease status within affected stands.

In addition, the Forest Service must balance various management directions as to the appropriate management for fire-damaged stands and trees. The agency has an obligation to recoup public funds spent on establishing, growing, and managing commercial timber stands damaged by wildfire. The agency also has an obligation to protect sensitive habitats and restore damaged ecosystems following wildfire. Resource managers must balance the need to remove damaged trees while still merchantable with the need to protect legacy habitats. They must protect residual stands from future wildfires that may re-burn the area if the fire created an increase in fuels. Managers also must weigh the potential harm to post-fire residual forests from secondary insects.

Given that insect attack of fire-injured trees are often a concern following wildfire, the wildfire season of 2002 prompted requests from National Forest offices for help from the Blue Mountains Pest Management Service Center in determining the survival potential of these trees. An earlier effort (Scott and others 1996) developed preliminary burn severity guidelines to assess relative risk of tree mortality from insects and/or fire. In many instances over the past half-decade, Ranger Districts used that information to develop specific salvage-marking guidelines. Since that time, more information on fire effects has become available in the published literature, mortality trends associated with measured conditions of fire-injury have been observed from formal fire monitoring plots on numerous wildfires in the Blue Mountains, and tree mortality probability models have been refined and become more widely available.

Accordingly, to provide the National Forests with information to aid in their decision-making process regarding survival of fire-injured timber resources, we herein provide a standardized rating system for determining three relative survival decision classes describing **High**, **Moderate**, and **Low** probability of

tree survival following wildfire. By defining the ranges for these class distinctions, we assume that roughly 50% of the trees falling within the "Moderate" survival class will survive and 50% will not.

Our intent is for these procedures to provide a basis upon which Districts may further develop their own specific marking guidelines. By providing these procedures we are not prescribing marking guidelines. It is possible for Forests to adopt this system, combined with other criteria for marking trees for salvage. The rating system incorporates the current state of the science and should be adequate for separating fire-injured trees into the three broad survival classes indicated above.

Methodology and Development

We have standardized these procedures for tree species, and size or age of tree as appropriate, and for various other factors so that the procedures may be applied on any wildfire on any National Forest in the Blue Mountains, now and in the future. Moreover, it should be possible to adapt these procedures to determine relative survival of similar conifer species injured by fire occurring on other National Forests outside of the Blue and Wallowa Mountains. While we sought to keep the procedure as simple to use as possible, we found that consideration of a variety of important factors to survival of trees added unavoidable complexity to the system. We do not believe a less complex system would be adequate to address all the concerns that were presented to us by the Forests. While every effort was made to ensure a reliable rating system, this rating system has not been calibrated nor field validated. This work will begin early in 2003.

We designed the system to characterize what we feel to be the most important, and easiest obtained, factors affecting the survival of fire-injured conifers by species (and age or size in some cases) here in the Blue and Wallowa Mountains of northeast Oregon and southeast Washington. These factors have come from a thorough review of the published literature (most of it weighted heavily to <u>prescribed</u> fire effects), tree mortality model outputs, and observations and data from our most recent fire reviews and monitoring plots.

The following Rating system can be used directly for field reconnaissance purposes. The system requires rating **individual trees** over areas of interest or concern on the fire. To use the system the reader works through each Part consecutively (Parts A, B, and C), selecting the appropriate rating value given in parentheses adjacent to each factor, and recording the rating value in the right-hand "Rating" column. The "Rating Score" for each part is subtotaled at the end of each part. The "Composite Rating Score" is obtained by adding together the subtotals for Part A and B, or Part A and C. Suggested Decision Classes denoting the range of scores for the **Low**, **Moderate**, and **High** Survival Potential classes follow the Composite Rating Score. The Composite Rating Score is compared with the Suggested Decision Classes to determine the appropriate relative survival potential or class. In Appendix 2, we have provided a summary of the criteria with their respective rating ranges for each of the Decision Classes for each conifer species included in this rating procedure system.

The rating system enables the determination of relative tree survival up to one year after the fire for all conifer species included in the procedure. These ratings incorporate factors that take into account insects that may attack the trees within that period of time; hence, contributing to tree mortality along with first order fire effects. A set of rating factors has also been included to rate relative potential survival of large-diameter, mature or overmature ponderosa pine for more than one year, since much evidence is accruing

for delayed mortality of that stand component, especially between the second through fourth year following the fire (Scott 2002). In addition, the rating systems for ponderosa pine, Douglas-fir, and western white pine distinguish between tree sizes, since there is a size-related preference by some of the insect species that sometimes become influential mortality factors in fire-injured trees of these species, following fire.

Part A. Factors common to all species and size classes (except as noted): (Instructions: Assign the appropriate rating value in parentheses to each factor below, then subtotal score)

<u>F</u> A	ACTOR .	RATING
1.	 Season of Fire (Wagener 1961) a. Early-season Spring prescribed fire. b. Late-season fire: Fire occurred on or after August 1st. c. Early-season wildfire: Fire occurred before August 1st. 	(0) (1) (2)
2.	 Pre-Fire Vigor, Growth Rate, and Site Quality (Wagener 1961) a. Trees injured by fire growing relatively well, or on good to moderate sites. b. Trees injured by fire exhibiting poor vigor or growth, or growing on poor quality sites. 	(0) (1)
3.	 Arrangement or Distribution of Down Woody Material (Scott 2002) a. No large, down, woody debris within a distance of one-half the crown diameter beyond drip-line of fire-injured tree. b. Large, down, woody debris in contact with fire-injured bole or within a distance of one-half the crown diameter beyond drip-line of tree. 	(0)(1)
4.	 Dwarf Mistletoe Occurrence (Hawksworth and Wiens 1996) a. No dwarf mistletoe present in fire-injured trees. b. Dwarf mistletoe present with DMR ≤ 3 in fire-injured tree. c. Dwarf mistletoe present with DMR > 3 in fire-injured tree. 	(0) (1) (2)
5.	 Root Disease Occurrence for True Firs and Douglas-fir Only (Shaw and Kile 19 a. Site or area containing fire-injured tree with no known root disease present. b. Root disease known to be present on site or area containing fire-injured tree. 	991) (0) (1)
6.	Bark Beetle Pressure—Infestations Last Year or Known Current Year (Scott What is the relative distance from this stand to the nearest known infestation of a bark beetle species that could infest the host tree species being evaluated in this stand?	1996)
	 a. > 2.0 miles b. 0.25-2.0 miles c. < 0.25 miles 	(1) (2) (3)

Subtotal Rating Score for Part A:

Continue to Part B or Part C as appropriate . . .

Part B. Factors for Determining Tree Survival up to 1 Year After Fire: (Instructions: Assign the appropriate rating value in parentheses to each factor below, then subtotal score)

Ponderosa Pine (Young and Immature Trees < 180 years old – Barrett 1979)

<u>FACTOR</u>		RATING	
7.	 Crown Volume Scorch (Powell 1997; Schmitt and Spiegel 2002) a. No visible scorching of crown present. b. Crown volume scorched is < 40% of pre-fire live crown. c. Crown volume scorched is 40-69% of pre-fire live crown. d. Crown volume scorched is > 70% of pre-fire live crown. 	(0) (2) (4) (6)	
8.	 Bole Scorch (Schmitt and Spiegel 2002; Ryan 1988; Wagener 1960) a. No visible scorching of bole present. b. < 30% circumference of bole scorched or blackened up to 1 ft. Little or no (< one-quarter of circumference) cambial kill on bole or root crown area. c. 30-50% circumference of bole scorched or blackened from 2 to 8 ft. > 75% cambium is alive at the root collar. d. > 50% circumference of bole charred to 8 ft. or more. < 75% cambium is alive at the root collar. 	(0) (1) (2) (3)	
9.	Total Scorch Height (Based on Appendix 1, Tables 1-8) (Use nearest diameter below to diameter of tree being evaluated) a. For trees 5 in. dbh: Total scorch height between 0-7 ft. (mean mortality probability 55.0%) Total scorch height between 8-13 ft. (mean mortality probability 60.9%) Total scorch height between 14-30 ft. (mean mortality probability 90.2%)	(1) (2) (3)	
	 b. For trees 7 in. dbh: Total scorch height between 0-17 ft. (mean mortality probability 41.0%) Total scorch height between 18-27 ft. (mean mortality probability 56.3%) Total scorch height between 28-50 ft. (mean mortality probability 92.9%) c. For trees 9 in. dbh: Total scorch height between 0-29 ft. (mean mortality probability 30.4%) Total scorch height between 30-37 ft. (mean mortality probability 56.0%) Total scorch height between 38-60 ft. (mean mortality probability 93.9%) 	(1) (2) (3) (1) (2) (3)	
	d. For trees 12 in. dbh: Total scorch height between 0-37 ft. (mean mortality probability 19.7%) Total scorch height between 38-49 ft. (mean mortality probability 54.4%) Total scorch height between 50-76 ft. (mean mortality probability 89.9%) Caring for the Land and Serving People	(1) (2) (3)	

Hi Me	nd Immature Ponderosa Pine (Small Trees < 16 in. dbh) gh Probability of Tree Surviving = Composite Rating Score Ranging from oderate Probability of Tree Surviving = Composite Rating Score Ranging from we Probability of Tree Surviving = Composite Rating Score Ranging from	3-8 om 10-15 17-21
00	ted Decision Classes: Appendix 2 For Rating Range Determinations)	
	Composite Rating Score Part A+B:	
	Subtotal Rating Score for Part B:	
u.	For Large Trees Only (> 16 in. dbh): Litter and duff completely consumed, and top layer of mineral soil is visibly altered, often reddish.	(¬)
	charred or consumed, but underlying mineral soil is not visibly altered.	
c.	upper duff charred, but not altered over entire depth; duff consumption usually < 4 in. For Large Trees Only (> 16 in. dbh): Leaf litter consumed; duff deeply	(2)
b.	consumed, in part or entire; mineral soil may be exposed. For Large Trees Only (> 16 in. dbh): Leaf litter charred or consumed; upper duff charred but not altered ever entire death; duff consumption	(0)
10. Duff (a.	Consumption (Ryan and Noste 1985) For Small Trees Only (< 16 in. dbh): Leaf litter and/or duff charred or	(0)
	Total scorch height between 92-116 ft. (mean mortality probability 85.2%)	(3)
	Total scorch height between 0-73 ft. (mean mortality probability 4.1%) Total scorch height between 74-91 ft. (mean mortality probability 55.1%)	(1) (2)
h.	For trees 26 in. dbh:	
	Total scorch height between 80-106 ft. (mean mortality probability 88.1%)	(3)
g.	For trees 21 in. dbh : Total scorch height between 0-63 ft. (mean mortality probability 7.1%) Total scorch height between 64-79 ft. (mean mortality probability 54.1%)	(1) (2)
	Total scorch height between 56-69 ft. (mean mortality probability 37.0%) Total scorch height between 70-100 ft. (mean mortality probability 88.1%)	(2) (3)
f.	For trees 18 in. dbh: Total scorch height between 0-55 ft. (mean mortality probability 9.5%) Total scorch height between 56 60 ft (mean mortality probability 27.0%)	(1)
	Total scorch height between 46-57 ft. (mean mortality probability 49.4%) Total scorch height between 58-86 ft. (mean mortality probability 78.6%)	(2) (3)
e.	For trees 15 in. dbh: Total scorch height between 0-45 ft. (mean mortality probability 13.0%)	(1)

Young and Immature Ponderosa Pine (Large Trees > 16 in. dbh)

<u>High</u> Probability of Tree Surviving = Composite Rating Score Ranging from	3-9
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from	13-18
Low Probability of Tree Surviving = Composite Rating Score Ranging from	21-25

Ponderosa Pine (Mature and Overmature Trees > 180 years old – Barrett 1979)

<u>FACTOR</u>		RATING	
7.	Crowi	Nolume Scorch (Powell 1997; Ryan 1990)	
		No visible scorching of crown present.	(0)
	b.	Crown volume scorched is < 50% of pre-fire live crown.	(2)
	c.	Crown volume scorched is 50-80% of pre-fire live crown.	(4)
	d.	Crown volume scorched is > 80% of pre-fire live crown.	(6)
8.	Bole S	corch (Ryan 1988; Wagener 1960; Schmitt and Spiegel 2002)	
	a.	No visible scorching of bole or damage to cambium present.	(0)
	b.	Bole scorch may or may not be present; some scorching at root collar.	(1)
		Dead cambium on bole or root crown area < one-quarter of circumference	
		and not extending above stump height, except for narrow strip kill above.	
	c.	30-50% circumference of bole scorched or blackened from 2 to 8 ft.	(2)
		and $> 75\%$ cambium is alive at the root collar.	
	d.	> 50% circumference of bole charred to 8 ft. or more; integrity of bark	(3)
		clearly altered or deeply burned over a portion of the circumference,	
		and < 75% cambium is alive at the root collar.	
9.	Total	Scorch Height (Based on Appendix 1, Tables 9-10)	
	(Use n	earest diameter below to diameter of tree being evaluated)	
	a.	For trees 32 in. dbh:	
		Total scorch height between 0-83 ft. (mean mortality probability 3.0%)	(1)
		Total scorch height between 84-109 ft. (mean mortality probability 53.4%)	(2)
		Total scorch height between 110-134 ft. (mean mortality probability 81.6%)	(3)
	b.	For trees 40 in. dbh:	
		Total scorch height between 0-103 ft. (mean mortality probability 5.1%)	(1)
		Total scorch height between 104-127 ft. (mean mortality probability 61.3%)	
		Total scorch height between 128-144 ft. (mean mortality probability 79.5%)	(3)
10	Duff (Consumption (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)	
10.		Leaf litter charred or consumed; upper duff charred, but not altered	(0)
	u.	over entire depth; duff consumption < 4 in.	(0)
	b	Leaf litter consumed; duff deeply charred or consumed, but underlying	(3)
	٥.	mineral soil is not visibly altered; duff consumption 4-7 in.	
	c.	Litter and duff completely consumed, and top layer of mineral soil	(6)
		visibly altered, often reddish; duff consumption exceeded 7 in.	(-)
		Subtotal Rating Score for Part B:	
		Composite Rating Score Part A+B:	

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

Mature and Overmature Ponderosa Pine

<u>High</u> Probability of Tree Surviving = Composite Rating Score Ranging from	3-8
<u>Moderate</u> Probability of Tree Surviving = Composite Rating Score Ranging from	10-18
<u>Low</u> Probability of Tree Surviving = Composite Rating Score Ranging from	21-27

RATING

Douglas-fir (Young and Immature Trees <20 in. dbh)

FACTOR

7.	Crown Volume Scorch (Reinhardt and Ryan 1989; Wagener 1961; Wyant and oth	ners 1986)
	a. No visible scorching	(0)
	b. Crown volume scorched is <25% (20% mortality for 14" trees)	(2)
	c. Crown volume scorched is 25-55% (20-50% mortality for 14" trees)	(4)
	d. Crown volume scorched is 55-75% (50-80% mortality)	(6)
	e. Crown volume scorched is >75% (>80% mortality)	(8)
_		
8.	Bole Char (Schmitt and Spiegel 2002, Scott and others 1996)	(0)
	a. No visible char	(0)
	b. <30% of bole circumference blackened (20% mortality)	(1)
	c. 30-50% of bole circumference blackened and >75% (40% mortality) live cambium around the base	(2)
	d. 50-75% of bole circumference blackened and >75% (50% mortality)	(3)
	live cambium around the base	(4)
	e. >75% of bole circumference blackened and <75% (>50% mortality) live cambium around the base	(4)
9.	Total Scorch Height (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)	
	(Use nearest diameter below to diameter of tree being evaluated)	
	a. For trees 9 in. dbh:	
	Total scorch height between 0-30 ft. (mean mortality probability 30.0%)	(1)
	Total scorch height between 31-42 ft. (mean mortality probability 59.2%)	(2)
	Total scorch height between 43-60 ft. (mean mortality probability 97.0%)	(3)
	b. For trees 12 in. dbh:	
	Total scorch height between 0-36 ft. (mean mortality probability 19.0%)	(1)
	Total scorch height between 37-54 ft. (mean mortality probability 52.1%)	(1)
	Total scorch height between 57-34 ft. (mean mortality probability 96.0%)	(2)
	Total scored height between 53-70 ft. (mean mortality probability 96.0%)	(3)
	c. For trees 15 in. dbh:	
	Total scorch height between 0-44 ft. (mean mortality probability 12.0%)	(1)
	Total scorch height between 45-64 ft. (mean mortality probability 41.1%)	(2)
	Total scorch height between 65-84 ft. (mean mortality probability 92.8%)	(3)
	d. For trees 18 in. dbh:	
	Total scorch height between 0-44 ft. (mean mortality probability 8.0%)	(1)
	Total scorch height between 45-68 ft. (mean mortality probability 32.4%)	(2)
	Total scorch height between 69-88 ft. (mean mortality probability 90.2%)	(3)
10	. Duff Consumption (Ryan and Noste 1985)	
- 0	a. Leaf litter charred or consumed; upper duff charred, but not altered	(0)
	Caring for the Land and Serving People	

	over entire depth.	(2)
b.	Leaf litter consumed; duff deeply charred or consumed, but underlying	(2)
	mineral soil is not visibly altered.	(4)
c.	Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish.	(4)
	Subtotal Rating Score for Part B:	
	Composite Rating Score Part A+B:	
Sugges	ted Decision Classes:	
(Refer to	Appendix 2 For Rating Range Determinations)	
Young a	nd Immature Douglas-fir	
	<u>gh</u> Probability of Tree Surviving = Composite Rating Score Ranging from	
	<u>oderate</u> Probability of Tree Surviving = Composite Rating Score Ranging	from 8-16
Lo	w Probability of Tree Surviving = Composite Rating Score Ranging from	17-25

Douglas-fir (Mature and Overmature Trees >20 in. dbh)

<u>FACTOR</u>		
7.	Crown Volume Scorch (Reinhardt and Ryan 1989; Wagener 1961) a. No visible scorching b. Crown volume scorched is <30% (10% mortality for 20" trees) c. Crown volume scorched is 30-50% (20% mortality for 20" trees) d. Crown volume scorched is 50-80% (20-80% mortality for 20" trees) e. Crown volume scorched is >80% (>80% mortality for 20" trees) (8)	
8.	Bole Char (Peterson and Arbaugh 1989; Scott and others 1996; Furniss 1965) a. No visible charring of outer bark. (0) b. <30% of bole circumference charred up to 1.5 ft. (1) c. 30-50% of bole circumference charred up to 2-5 ft. (2) Char not affecting cambium; potential for some root damage (57-86% of trees may be attacked by DFB—Furniss 1965). d. >50% of bole circumference charred up to 5-8 ft. (3) Visible damage to phloem <25% of tree's circumference at base of tree near ground (90-92% of trees may be attacked by DFB—Furniss 1965). e. >50% of bole circumference charred up to >8 ft. (4) Visible damage to phloem >25% of tree's circumference at base of tree near ground (43-82% of trees may be attacked by DFB—Furniss 1965).	
9.	(Use nearest diameter below to diameter of tree being evaluated) a. For trees 21 in. dbh: Total scorch height between 0-57 ft. (survival probability range 70-100%) (1) Total scorch height between 58-84 ft. (survival probability range 30-69%) (2) Total scorch height >84 ft. (survival probability range <30%) (3) b. For trees 26 in. dbh:	
	Total scorch height between 0-75 ft. (survival probability range 70-100%) (1) Total scorch height between 76-98 ft. (survival probability range 30-69%) (2) Total scorch height >98 ft. (survival probability range <30%) (3) c. For trees 30 in. dbh: Total scorch height between 0-83 ft. (survival probability range 70-100%) (1) Total scorch height between 84-108 ft. (survival probability range 30-69%) (2) Total scorch height >108 ft. (survival probability range <30%) (3)	
	d. For trees 32 in. dbh: Total scorch height between 0-87 ft. (survival probability range 70-100%) (1) Caring for the Land and Serving People	

	Total scorch height between 88-112 ft. (survival probability range 30-69%) Total scorch height >112 ft. (survival probability range <30%)	(2) (3)
	Consumption (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985) Leaf litter charred or consumed; upper duff charred, but not altered over entire depth.	(0)
b.	Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered.	(3)
c.	Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish.	(4)
	Subtotal Rating Score for Part B:	
00	Composite Rating Score Part A+B: ted Decision Classes: Appendix 2 For Rating Range Determinations)	-
<u>Hi</u> Mo	and Overmature Douglas-fir gh Probability of Tree Surviving = Composite Rating Score Ranging from oderate Probability of Tree Surviving = Composite Rating Score Ranging from w Probability of Tree Surviving = Composite Rating Score Ranging from	3-10 om 11-17

Engelmann Spruce (All Size Classes except as noted)

<u>FACTOR</u>	<u>RATING</u>
 7. Crown Volume Scorch (Ryan and Reinhardt 1988; Smith & Fischer 19 a. No visible scorching b. Crown volume scorched is ≤25% (80.0% mortality for 9" trees c. Crown volume scorched is 26-55% (84.4% mortality for 9" trees d. Crown volume scorched is 55-75% (92.5% mortality for 9" trees e. Crown volume scorched is >75% (>93% mortality for 9" trees 	(0) (3) (3) (6) (6) (9)
 8. Bole/Root Char at Ground Level (Weatherby and others 2001) a. No visible char b. <40% of bole circumference blackened c. 40-70% of bole circumference blackened (mortality >50% at 50% d. >70% of bole circumference blackened 	(0) (3) (6) (6) (9)
 9. Total Scorch Height (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988). (Use nearest diameter below to diameter of tree being evaluated) a. No bole scorch evident. b. For trees 9 in. dbh: Total scorch height between 0-25 ft. (mean mortality probability Total scorch height between 26-40 ft. (mean mortality probability Total scorch height between 41-60 ft. (mean mortality probability) 	(0) 80.0%) (1) y 88.0%) (2)
c. For trees 15 in. dbh: Total scorch height between 0-45 ft. (mean mortality probability Total scorch height between 46-65 ft. (mean mortality probability Total scorch height between 65-90 ft. (mean mortality probability	y 87.5%) (2)
d. For trees 21 in. dbh: Total scorch height between 0-65 ft. (mean mortality probability Total scorch height between 66-85 ft. (mean mortality probability Total scorch height between 86-110 ft. (mean mortality probabili	y 87.7%) (2)
 10. Duff Consumption (Ryan 1990; Ryan and Frandsen 1991; Ryan and No. a. Leaf litter charred or consumed; upper duff charred, but not alter over entire depth. b. Leaf litter consumed; duff deeply charred or consumed, but under the consumed of the consumer o	ed (0)
b. Leaf litter consumed; duff deeply charred or consumed, but unde mineral soil is not visibly altered.c. Litter and duff completely consumed, and top layer of mineral so visibly altered, often reddish.	

Subtotal Rating Score for Part B:

Composite Rating Score Part A+B:

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

All Size Classes of Engelmann Spruce

<u>High</u> Probability of Tree Surviving = Composite Rating Score Ranging from	2-6
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from	9-14
Low Probability of Tree Surviving = Composite Rating Score Ranging from	19-33

Lodgepole Pine (All Size Classes except as noted)

<u>FACTOR</u>	RATING
 7. Crown Volume Scorch (Ryan and Reinhardt 1989; Weatherby and others 2001) a. No visible scorching b. Crown volume scorched is ≤20% (63% mortality all trees ≤9") c. Crown volume scorched is 20-50% (80.0% mortality for 9" trees) d. Crown volume scorched is >50% (>80% mortality for 9" trees) 	(0) (1) (2) (3)
8. Bole/Root Char (Weatherby and others 2001) a. No visible char b. <30% of bole circumference blackened c. 30-60% of bole circumference blackened d. >60% of bole circumference blackened (≥50% mortality)	(0) (3) (6) (9)
9. Total Scorch Height (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988) (Use nearest diameter below to diameter of tree being evaluated) a. For trees 9 in. dbh: Total scorch height between 0-28 ft. (mean mortality probability 63.0%) Total scorch height between 29-38 ft. (mean mortality probability 72.2%) Total scorch height between 39-58 ft. (mean mortality probability 98.4%)	(1) (2) (3)
b. For trees 15 in. dbh: Total scorch height between 0-40 ft. (mean mortality probability 44.0%) Total scorch height between 41-56 ft. (mean mortality probability 65.9%) Total scorch height between 57-80 ft. (mean mortality probability 97.5%)	(1) (2) (3)
c. For trees 21 in. dbh: Total scorch height between 0-46 ft. (mean mortality probability 30.0%) Total scorch height between 47-64 ft. (mean mortality probability 54.7%) Total scorch height between 65-90 ft. (mean mortality probability 96.0%)	(1) (2) (3)
10. Duff Consumption (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)a. Leaf litter charred or consumed; upper duff charred, but not altered over entire depth.	(1)
 b. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. 	(2)
c. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish.	(4)
Subtotal Rating Score for Part B:	
Composite Rating Score Part A+B:	

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

All Size Classes of Lodgepole Pine

<u>High</u> Probability of Tree Surviving = Composite Rating Score Ranging from	4-8
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from	9-18
<u>Low</u> Probability of Tree Surviving = Composite Rating Score Ranging from	21-28

Western Larch (All Size Classes except as noted)

<u>FACTOR</u>			RATING
7.	. Crown Volume Scorch (Peterson 1983; Scott and others 1996)		
	a. No visible scorching		(0)
	b. Crown volume scorched is ≤10% (<25% mortality for (<10% mortal	· ·	(1)
	c. Crown volume scorched is 10-25% (25-35% mortality (10-16% mortality	for 6" trees)	(2)
	d. Crown volume scorched is 26-50% (36-53% mortality (17-30% mortality	for 6" trees)	(3)
	e. Crown volume scorched is 51-75% (54-70% mortality (31-50% mortality	for 6" trees)	(4)
8.	. Bole Char (Undetermined)		
9.	(Use nearest diameter below to diameter of tree being evaluated	,	
	a. <u>For trees 5 in. dbh :</u> Total scorch height between 0-21 ft. (mean mortality pro	hability 55 0%)	(1)
	Total scorch height between 22-27 ft. (mean mortality pro	2	(2)
	Total scorch height between 28-40 ft. (mean mortality programmer)		(3)
	b. For trees 9 in. dbh : Total scorch height between 0-32 ft. (mean mortality pro Total scorch height between 33-46 ft. (mean mortality pro Total scorch height between 47-62 ft. (mean mortality pro	robability 61.0%)	(1) (2) (3)
	c. For trees 15 in. dbh:		
	Total scorch height between 0-48 ft. (mean mortality pro	bability 12.0%)	(1)
	Total scorch height between 49-74 ft. (mean mortality pr	robability 47.0%)	(2)
	Total scorch height between 75-92 ft. (mean mortality pr	robability 94.4%)	(3)
	d. For trees 21 in. dbh:		
	Total scorch height between 0-62 ft. (mean mortality pro	bability 6.0%)	(1)
	Total scorch height between 63-96 ft. (mean mortality pr	,	(2)
	Total scorch height between 97-118 ft. (mean mortality page 13)	probability 89.4%)	(3)
10	0. Duff Consumption (Ryan 1990; Ryan and Frandsen 1991; Rya	n and Noste 1985)	
	a. Leaf litter charred or consumed; upper duff charred, but over entire depth.	*	(0)
	b. Leaf litter consumed; duff deeply charred or consumed, mineral soil is not visibly altered.	but underlying	(2)
	 c. Litter and duff completely consumed, and top layer of m visibly altered, often reddish. 	ineral soil	(4)

Subtotal Rating Score for Part B:	
Composite Rating Score Part A+B:	
Suggested Decision Classes:	
(Refer to Appendix 2 For Rating Range Determinations)	
All Size Classes of Western Larch	
<u>High</u> Probability of Tree Surviving = Composite Rating Score Ranging from	3-6
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from	7-13
<u>Low</u> Probability of Tree Surviving = Composite Rating Score Ranging from	14-17

Grand Fir and White Fir (All Size Classes except as noted)

<u>FACTOR</u>				RATING	
7.	a.b.c.d.	Crown volume scorched is $\overline{10\text{-}25\%}$ Crown volume scorched is 26-50%	(<46% mortality for 9" trees) (47-52% mortality for 9" trees) (53-78% mortality for 9" trees) (79-99% mortality for 9" trees)	(0) (1) (2) (3) (4)	
8.	a.	Char at Ground Level (Scott and other No charring present on bole. <10% of basal circumference of bole 10-30% of basal circumference of bole 30-40% of basal circumference of bole >40% of bole circumference charred	e charred ble charred ble charred	(0) (1) (3) (6) (9)	
9.			tree being evaluated)	(1) (2) (3)	
	b.		(mean mortality probability 45.0%) t. (mean mortality probability 65.5%) t. (mean mortality probability 97.2%)	(1) (2) (3)	
	c.	S	(mean mortality probability 23.0%) t. (mean mortality probability 53.3%) t. (mean mortality probability 96.3%)	(1) (2) (3)	
	d.	2	(mean mortality probability 12%) t. (mean mortality probability 45.9%) ft. (mean mortality probability 95.0%)	(1) (2) (3)	
10	. Duff C		Frandsen 1991; Ryan and Noste 1985)		
	a.	No leaf litter or duff scorched or con		(0)	
	b.	Leaf litter charred or consumed; upp over entire depth.	er duff charred, but not altered	(1)	
	c.	Leaf litter consumed; duff deeply ch mineral soil is not visibly altered.	arred or consumed, but underlying	(2)	

d. Litter and duff completely covisibly altered, often reddish	onsumed, and top layer of mineral soil (6)	
	Subtotal Rating Score for Part B:	
	Composite Rating Score Part A+B:	
Suggested Decision Classes: (Refer to Appendix 2 For Rating R	Cange Determinations)	
All Size Classes of Grand Fir and	l White Fir	
<u>High</u> Probability of Tree Surviv	ing = Composite Rating Score Ranging from	3-4
Moderate Probability of Tree St	urviving = Composite Rating Score Ranging from	5-10
<u>Low</u> Probability of Tree Survivi	ng = Composite Rating Score Ranging from	11-30

Subalpine Fir (All Size Classes except as noted)

<u>FACTOR</u>		RAT	IN	
7.	Crown Volume Scorch (Peterson 1983)			
	a. No visible scorching		(0)	
	b. Crown volume scorched is ≤10%	(<38% mortality for 6" trees) (<30% mortality for 16" trees)	(1)	
	c. Crown volume scorched is 10-25%	(39-48% mortality for 6" trees) (31-44% mortality for 16" trees)	(2)	
	d. Crown volume scorched is 26-50%	(49-69% mortality for 6" trees) (45-63% mortality for 16" trees)	(3)	
	e. Crown volume scorched is 51-75%	(69-85% mortality for 6" trees) (64-78% mortality for 16" trees)	(4)	
8.	Bole Char at Ground Level (Scott and other	hers 1996, with modification)		
	a. No charring present on bole.		(0)	
	b. <10% of basal circumference of bo	le charred	(1)	
	c. 10-30% of basal circumference of b	oole charred	(3)	
	d. 30-40% of basal circumference of b	oole charred	(6)	
	e. >40% of bole circumference charre	d	(9)	
9.	Total Scorch Height (Reinhardt and Ryan (Use nearest diameter below to diameter of the contract Tine dhb.)			
	a. For trees 7 in. dbh:	(mean mortality probability 59.0%)	(1)	
		ft. (mean mortality probability 72.7%)	(1) (2)	
		ft. (mean mortality probability 97.7%)	(3)	
	<u> </u>	(mean mortality probability 55.0%)	(1)	
	<u> </u>	ft. (mean mortality probability 71.8%)	(2)	
		ft. (mean mortality probability 97.9%)	(3)	
	c. For trees 15 in. dbh:			
	<u> </u>	(mean mortality probability 28.0%)	(1)	
		ft. (mean mortality probability 57.8%)	(2)	
	Total scorch height between 59-78	ft. (mean mortality probability 96.9%)	(3)	
	d. For trees 21 in. dbh:			
	Total scorch height between 0-44 ft	\ J1	(1)	
	Č	ft. (mean mortality probability 45.1%)	(2)	
	Total scorch height between 71-90	ft. (mean mortality probability 94.9%)	(3)	
10	. Duff Consumption (Ryan 1990; Ryan and	· · · · · · · · · · · · · · · · · · ·	(0)	
	a. No leaf litter or duff scorched or co		(0)	
	b. Leaf litter charred or consumed; up	per duff charred, but not altered	(1)	
	Caring for the La	and and Serving People		

mineral soil is not visibly altered.	(2)(6)
Subtotal Rating Score for Part B:	
Composite Rating Score Part A+B:	
ted Decision Classes:	
Appendix 2 For Rating Range Determinations)	
gh Probability of Tree Surviving = Composite Rating Score Ranging from oderate Probability of Tree Surviving = Composite Rating Score Ranging	g from 5-10
	Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish. Subtotal Rating Score for Part B:

Western White Pine (Young and Immature Trees <20 in. dbh)

FA	ACTOR .	RATING
7.	Crown Volume Scorch (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)	
		(0)
	b. Crown volume scorched is $\leq 10\%$ ($\leq 57\%$ mortality for 9" trees) ($\leq 35\%$ mortality for 15" trees) ($\leq 27\%$ mortality for 18" trees)	(2)
	<u> </u>	(4)
		(6)
	` '	(8)
8.	Bole Char (Undetermined)	
9.	Total Scorch Height (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)	
	(Use nearest diameter below to diameter of tree being evaluated)	
	a. For trees 9 in. dbh:	
		(1)
	· · · · · · · · · · · · · · · · · · ·	(2)
	` ; ; , , , , , , , , , , , , , , , , ,	(3)
	b. For trees 12 in. dbh:	
	Total scorch height between 0-38 ft. (mean mortality probability 44.0%)	(1)
		(2)
	· · · · · · · · · · · · · · · · · · ·	(3)
	c. For trees 15 in. dbh:	
		(1)
	•	(2)
	·	(3)
	d. For trees 18 in. dbh:	
	Total scorch height between 0-56 ft. (mean mortality probability 27%)	(1)
	Total scorch height between 57-82 ft. (mean mortality probability 55.8%)	(2)
		(3)
10	. Duff Consumption (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)	
	a. Leaf litter charred or consumed; upper duff charred, but not altered over entire depth ((0)

υ.	mineral soil is not visibly altered.	but underlying	(1)
c.	Litter and duff completely consumed, and top layer of n	nineral soil	(2)
	visibly altered, often reddish.		
	Subtotal Rating Scor	re for Part B:	
	Composite Rating So	core Part A+R.	

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

Young and Immature Western White Pine

<u>High</u> Probability of Tree Surviving = Composite Rating Score Ranging from	2-4
<u>Moderate</u> Probability of Tree Surviving = Composite Rating Score Ranging from	6-10
<u>Low</u> Probability of Tree Surviving = Composite Rating Score Ranging from	12-20

Western White Pine (Mature and Overmature Trees >20 in. dbh)

FA	RATING	
7.	Crown Volume Scorch (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)	
	a. No visible scorching	(0)
	b. Crown volume scorched is $\leq 10\%$ ($\leq 21\%$ mortality for 21" trees) ($\leq 14\%$ mortality for 26" trees) ($\leq 9\%$ mortality for 32" trees)	(2)
	c. Crown volume scorched is 10-25% (22-26% mortality for 21" trees) (15-18% mortality for 26" trees) (10-11% mortality for 32" trees)	(4)
	d. Crown volume scorched is 26-50% (27-52% mortality for 21" trees) (19-38% mortality for 26" trees) (12-28% mortality for 32" trees)	(6)
	` '	(8)
8.	Bole Char (Undetermined)	
9.	(Use nearest diameter below to diameter of tree being evaluated) a. For trees 21 in. dbh: Total scorch height between 0-60 ft. (mean mortality probability 21%) Total scorch height between 61-90 ft. (mean mortality probability 54.2%)	(1) (2) (3)
	· · · · · · · · · · · · · · · · · · ·	(1) (2) (3)
		(1) (2) (3)
	· · · · · · · · · · · · · · · · · · ·	(1) (2) (3)
10	Duff Consumption (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985) a. Leaf litter charred or consumed; upper duff charred, but not altered	(0)

	over entire depth. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish.	(1) (2)
	Subtotal Rating Score for Part B:	
	Composite Rating Score Part A+B:	
Suggest	ted Decision Classes:	
(Refer to	Appendix 2 For Rating Range Determinations)	
	and Overmature Western White Pine	
Me	 gh Probability of Tree Surviving = Composite Rating Score Ranging from oderate Probability of Tree Surviving = Composite Rating Score Ranging from Probability of Tree Surviving = Composite Rating Score Ranging from 	3-8 om 9-14 16-20

Part C. Factors for Determining Tree Survival Beyond 1 Year After Fire:

(Instructions: Assign the appropriate rating value in parentheses to each factor below, then subtotal score)

Ponderosa Pine (Mature and Overmature Trees > 180 years old – Barrett 1979)

<u>FA</u>	<u>actor</u>		RATING
7.	 Crown Volume Scorch (Miller and Keen 1960; Scott et al. 1996; Salman 1934) a. No visible scorching of crown present. b. Crown volume scorched is < 25% of pre-fire live crown. c. Crown volume scorched is 25-50% of pre-fire live crown. d. Crown volume scorched is > 50% of pre-fire live crown. 	(0) (1) (2) (3)	
	 Bole Scorch (Ryan 1988; Wagener 1960; Scott et al. 1996) a. No visible scorching of bole or damage to cambium present. b. Bole scorch, when present, is ≤ 20 %; some scorching at root collar. Dead cambium on bole or root crown area < one-quarter of circumference, and not extending above stump height except for narrow strip kill above. c. 30-50% circumference of bole scorched or blackened up to 40% of total tree height; > 75% cambium is alive at the root collar. d. > 50% circumference of bole charred to > 40% of tree height; integrity of portion of the bark clearly altered or deeply burned over a portion of the tree's circumference; < 75% cambium is alive at the root collar. 	(0) (1) (2) (3)	
9.	 Total Scorch Height (Based on Appendix 1, Tables 9-10) (Use nearest diameter below to diameter of tree being evaluated) a. For trees 32 in. dbh:	(1)	
10.	 Total scorch height between 128-144 ft. (mean mortality probability 79.5%) Duff Consumption (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985) a. Leaf litter charred or consumed; upper duff charred, but not altered over entire depth; duff consumption < 4 in. b. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered; duff consumption 4-7 in. c. Litter and duff completely consumed, and top layer of mineral soil 	(3)(0)(3)(6)	
	Caring for the Land and Serving People	(-)	

visibly altered, often reddish; duff consumption exceeded 7 in.

Subtotal Rating Score for Part C:	
Composite Rating Score Part A+C:	

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

Mature and Overmature Ponderosa Pine Delayed Mortality

<u>High</u> Probability of Tree Surviving = Composite Rating Score Ranging from	3-6
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from	7-12
<u>Low</u> Probability of Tree Surviving = Composite Rating Score Ranging from	15-24

Description of Rating System

Ryan (1990), Scott and others (1996), and Wagener (1961) previously reviewed many of the factors most affecting survival of fire-injured conifer tree species. The detailed discussion of those factors will not be repeated again here; however, we will highlight certain points for clarification of the rating factors. A detailed discussion of dwarf mistletoe and root disease occurrence has been included because these factors have not been previously used to help characterize survival of fire-injured trees. By including them, we elevate their importance as factors in the post-fire survival of conifers in the Blue and Wallowa Mountains.

Each of the factors comprising our rating system is keyed to specific references identifying or describing the relative importance of the factor to tree survival, or providing the criteria or probability equations for that factor which we incorporated into our rating system. The rating values assigned to each factor have been deliberately kept simple to facilitate ease in field scoring and computation of subtotal and composite scores. The Decision Class Rating Score ranges were developed based on a synthesis of several data sources including observations from past and current wildfire and prescribed fire monitoring (e.g., Scott and others 1996; Scott 2002), tree mortality probability model outputs (e.g., Andrews and Bevins 1999; Powell 1997; Reinhardt and Ryan 1989; Ryan and Reinhardt 1988), and graphical representations of results from actual prescribed fire or wildfire studies correlating degrees of fire injury with tree mortality or survival (e.g., Bevins 1980; Peterson 1983).

Organization

The rating system has been organized into three parts. **Part A** lists factors common to all species and sizes of trees. **Part B** and **C** contain fire injury factors specific to the given tree. Summing **Part A** with either **Part B** or **C** will give a composite score. This score can then be compared to the suggested ranges for a resulting **High**, **Moderate**, or **Low** probability of survival for a given tree.

The first part, **Part A**, contains the factors that may affect the overall vigor of trees involved in the fire by virtue of tree growth rates and the quality of site on which they are growing, or due to predisposition by weakening agents such as dwarf mistletoe or root diseases. The time of year in which the fire occurred is also considered in this part. Tree tissues are more vulnerable to injury by fire during active growth than they are when growth has slowed in the fall (Wagener 1961). Proximity of the fire to active insect infestations is also considered in this part. Insect populations close to a fire can sometimes cause many losses to trees that survived the fire, for several years after the fire. This is easily demonstrated by the dramatic population increases witnessed on the Summit Fire (Malheur NF) of 1997, and the Tower Fire (Umatilla NF) of 1997, a few years following those fires.

Parts B and C contain the specific fire injury factors that are most important in causing injury or death to living tissues of the tree, including injury to needles and buds, bole cambium, and roots and root cambium. Not all injuries of living tissues on trees are easily observed. For example, root injuries are typically hidden from view, and assessing damage is difficult without chopping into roots or excavating them for examination. We have attempted to include factors in the rating system that can easily be observed or obtained through direct measurement. These include measurements or estimates of crown volume scorch, bole scorch, total scorch height, and duff consumption (see Ryan and Noste 1983 for a discussion of vegetation response related to fire severity as determined by flame length class and ground char class). Because the degree of burning of duff and larger surface fuels determines the depth of lethal heat penetration into the soil (Ryan and Noste 1983), duff consumption, as used in this rating system, serves as a surrogate indicator for root injury. The quantity consumed, and characteristics of duff and exposed mineral soil observed can be related in a general way to degrees of root injury of various conifer species in the Blue and Wallowa Mountains.

Dwarf Mistletoes

Dwarf mistletoes (*Arceuthobium* spp.) occur throughout northeastern Oregon. Four species are present: *A. campylopodum* on ponderosa pine, *A. americanum* on lodgepole pine, *A laricis* on western larch and occasionally on lodgepole pine, and *A. douglasii* on Douglas-fir. Dwarf mistletoes are found throughout the host distribution of Douglas-fir and western larch in the Blue Mountains, varying substantially in occurrence and severity of infestation at stand levels. Conversely, occurrence of dwarf mistletoes of ponderosa pine and lodgepole pine varies substantially throughout the area host type. For example, *A. campylopodum* does not occur in the ponderosa pine types in the northern part of the Umatilla and Wallowa-Whitman National Forests, but is common in the southern Blue Mountains, especially on the Baker and Unity Districts of the Wallowa-Whitman and many portions of the Malheur National Forest. Substantial portions of the lodgepole pine type throughout the Blue Mountains are also uninfected.

Wildfires are the single most significant ecological factor in governing the distribution and abundance of dwarf mistletoes (Alexander and Hawksworth 1975, Wicker and Leaphart 1974). In most cases occurrence of dwarf mistletoes is reduced following stand replacement fires as hosts are killed and reinfection is much slower than re-establishment of host trees. Lighter burns can partially sanitize infected stands since infected trees, especially those that are severely infected, will be more likely to be killed as a result of ground fires being carried into the crown by low-hanging flammable brooms. This is especially true in Douglas-fir, but occurs also in ponderosa pine and lodgepole pine. In some cases fires can result in increased mistletoe infection. This is probably most common where infected seral species survive and fire-susceptible shade-tolerant regeneration under those residuals was killed. The most

common example of this is where larch and lodgepole pine regenerate under mistletoe-infected larch survivors replacing the true firs and Douglas-fir that had formed the understory.

Most stand types that have host conifers with mistletoe infections have not been visited by ground fire since the late 1800's when active fire suppression began. These stands often will have relatively high fuel loading and are therefore more susceptible to conflagrations than similar uninfected stands. Characteristic low-hanging brooms develop and persist, as they do not effectively self-prune. Often dead brooms are scattered around the bases of infected individuals where they have broken from the bole. Snags, the result of mistletoe-caused mortality and severely infected and stunted understory can also contribute to increased fire susceptibility. Carefully controlled fire can be used to clean up some of these fuels as well as to reduce average stand mistletoe levels by preferentially removing most severely infected trees (Koonce and Roth 1980). Studies in Colorado lodgepole pine communities have shown that more frequent fire intervals correspond to lower levels of dwarf mistletoe (Zimmerman and others 1990).

Following wildfires, dwarf mistletoe infected trees that survive can act as infection sources where susceptible species are planted or regenerate within trajectory spread distance. This distance will vary due to a number of factors, but can extend up to 100 feet horizontal distance from infected overstory although seed dispersal from these trees exponentially decreases over that distance.

Dwarf mistletoe-infected trees that initially survive wildfires are less likely to remain alive than similar uninfected trees. Tree vigor is impacted proportional to degree of dwarf mistletoe infection. Cumulative impacts on tree vigor by fire injury and that resulting from mistletoe infection should be considered when evaluating post-burn survivor potential. Harrington and Hawksworth (1990), investigating ponderosa pine in Arizona, found that with crown scorch between 40 and 90 percent, healthy trees were more than twice as likely to survive as severely infected trees during the first year after a fire. It is likely that delayed mortality in subsequent years will also be higher in mistletoe-infected trees than in healthy trees. Ponderosa pine seems most likely to be affected by delayed mortality (trees succumbing later than 1 year following the fire), and insects, primarily bark beetles and woodborers, are associated with tree death. Several studies indicate dwarf mistletoe infection renders ponderosa pine increasingly susceptible to bark beetles (Miller and Keen 1960, Owen 1985, Johnson and others 1976, McCambridge and others 1982) and wood borers (Swain and others 1974, Wood and others 1979). Fire damaged mistletoe-infected trees, especially ponderosa pine and Douglas-fir, are *probably* more likely to be subject to delayed insect attack from cumulative stresses of fire and mistletoe infection.

It is probable that dwarf mistletoe-infected larch, firs, and pines, have an increased likelihood of being killed from fire due to increased fuels and fire susceptibility. Dwarf mistletoe infection on fire-damaged trees should be easily identified in the field by branch brooming, spindle-shaped swellings, and aerial shoots of mistletoe observable on trees and on the ground under subject trees. These trees should be considered at higher risk to mortality than similar mistletoe-free trees in project documentation and salvage marking guides.

Root Diseases

A number of conifer root diseases are common in the Blue Mountains. Included are laminated root rot, caused by *Phellinus weirii*, Armillaria root disease, caused by *Armillaria ostoyae*, blackstain root disease, caused by *Leptographium wageneri*, and annosus root disease, caused by *Heterobasidion annosum*. These

root diseases often occur in centers that vary in size but are often many acres, although *H. annosum* centers seldom are more than half an acre in size. Root disease centers are usually characterized as having exceptionally high fuels due to on-going mortality. Even residual root disease-resistant and – tolerant cohorts are at risk during fires due to the adjacent heavy fuels.

Most applicable information available concerning fire and root disease describes the effects on conifer species composition and stand structure under current and historical fire regimes and the changes that have occurred over the last 120 or so years as a result of fire suppression (Byler and others 1990, Hagle and Goheen 1988). Historic frequent periodic fires in dry mixed conifer types were generally underburns and tended to remove the younger shade-tolerant species that had become established in the interim since the last fire. Historical fires in wet grand fir-dominated communities were infrequent stand replacement fires that likely regenerated to a substantial component of larch and lodgepole pine; that succeeded to shade tolerant species over time. Root disease is believed to have become established in affected sites but varied in prominence and activity proportional to the advancement of plant succession.

Many mixed conifer stands in the Blue Mountains have had several partial removal harvests, primarily for selection of the most valuable seral pines and larch as well as Douglas-fir. Fire has not occurred for a century or more. These stands now are typified by a substantial true fir component much greater than existed in recent historical times. Wildfire occurring now will usually kill a substantial proportion of stand composition, especially fire-susceptible true firs. If root disease, especially Armillaria, is present, stumps of fire-killed susceptible species, such as grand fir, represent a substantial inoculum base that *could* quickly become colonized, and *could* result in higher root disease activity subsequently on the site (Kile 1980). However, this scenario has not been documented in eastern Oregon.

Stands with active root disease activity usually support high endemic levels of bark beetles, especially Douglas-fir beetles, fir engraver beetles, and mountain and western pine beetles. A high endemic population of beetles can quickly develop into epidemic populations following wildfires. Thus, live fire-damaged trees in areas having root disease are probably more likely to be attacked by beetles than fire-damaged trees in areas without root disease.

Root diseases are usually slow killers of trees. Larger trees will often take decades to die since it takes years for root disease pathogens to grow throughout their root systems. Often, trees will have 25 percent or less of their root system remaining alive before crown symptoms are apparent. Trees in and adjacent to visible root disease centers likely have some portion of their root system infected and killed. Wildfire, coupled with higher than average fuel loads and resulting high burn intensity, will probably result in increased short and long term mortality in these areas relative to areas without root disease due to compounded stress associated with both fire damage and root disease infection. As in other cases resulting in vigor impacts, bark beetles and woodborers will usually be involved in causing mortality.

Areas of root disease infection are likely to be difficult to identify in recently burned areas. Some areas in the Blue Mountains have had root disease infection centers mapped in recent years. These include surveys done by Regional Forest Health Protection staff and Blue Mountains Pest Management Service Center staff. More common are insect and disease evaluations including information on root disease occurrence and severity that are descriptive at stand, planning area, or watershed level but usually do not include maps of root disease centers. Other information includes stand exam plots, special surveys, and Research studies that include root disease occurrence information.

Most of the northeastern portion of the 2002 Malheur Complex Fire, for example, burned in an area well known for having extensive Armillaria root disease. An Armillaria genetics study with principle cooperators at Oregon State University (Brennan Ferguson) and the USFS Pacific Northwest Forestry and Range Sciences Laboratory (Catherine Parks), has been underway in this area and documented the world's largest *Armillaria ostoyae* single genet in the Reynolds Creek/Grouse Knob/Mossy Gulch area. Nearly all of this large center is included within the perimeter of the fire. Two of five additional smaller genets also burned. While six genets were mapped, there is substantial additional root disease in this area as well, both within and adjacent to the burned area. Due to the high endemic levels of bark beetles, and increased fuels and fire damage to trees with pathogen-caused root damage, short-term and delayed-mortality levels are expected to be higher than usual in the perimeter of this burn. For other wildfires that occur in areas of root disease, the outcome would be similar, all other conditions being equal.

While root diseases may occur in other areas burned by 2002 wildfires in the Blue Mountains, incidence is believed to be minimal in most cases due to vegetation community type, or not noted during BMPMSC personnel field reviews in these areas in the past. District records, especially stand examinations, may provide some information. The influence of root diseases on short-term and delayed tree mortality should be taken into account during salvage marking of future wildfires.

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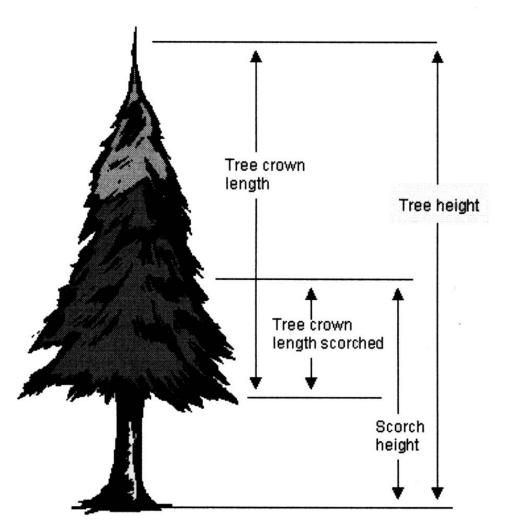
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Appendix 1 – Tree Mortality Probability Tables

Probability of tree mortality can be calculated using fire mortality equations developed by Ryan and Reinhardt (1988) that use percentage of crown scorch and bark thickness as independent variables to predict the mortality probabilities for a given conifer species of given diameter. These equations, based on their implementation in First Order Fire Effects Model: FOFEM 4.0 (Reinhardt and others 1997) have been incorporated into the BehavePlus Fire Modeling System (Andrews and Bevins 1999) that we used to develop the following tables for ponderosa pine of given tree diameters: 5-in., 7-in., 9-in., 12-in., 15-in. 18-in., 21-in., 26-in., 32-in., and 40-in. The diameters selected represent the standardized tree classes, and their mid-point values, recognized in the Blue Mountains and included in the EVG Layer of the corporate National Forest system GIS databases. The diagram below (from the BehavePlus program) illustrates several of the terms referred to in the accompanying tables. Several of these terms are defined in the BehavePlus program as follows:



<u>Scorch Height</u> – The height above the ground that the temperature in the convection column reaches the lethal temperature to kill live crown foliage. This temperature is assumed to be 140 degrees Fahrenheit (60° Celsius).

<u>Tree Crown Length Scorched</u> – The length of the tree crown that is scorched. It is calculated as **Scorch Height** – (**Tree Height** – **Live Crown Length**). If **Scorch Height** is greater than the **Tree Height**, then the length of tree crown scorched equals the live crown length. **Tree Crown Length Scorched** is used to calculate percent of crown volume scorched, which is used to calculate tree mortality.

<u>Tree Crown Volume Scorched</u> – The percentage of the tree crown volume that is scorched is calculated from the length of tree crown scorched and the total crown length. It is used to calculate tree mortality.

<u>Probability of Mortality</u> – The probability of mortality is the likelihood that a tree will be killed by fire. Probability of mortality is based on bark thickness and percent of crown volume scorched which are derived from **Scorch Height**, **Tree Height**, crown ratio, species, and tree diameter. BehavePlus uses the mortality equations from "First Order Fire Effects Model: FOFEM 4.0 User's Guide (Reinhardt, and others 1997) to calculate these probabilities.

The tables were calculated assuming a standardized crown ratio of 0.5. This may over or underestimate the actual probability of tree mortality depending of the site quality and actual crown ratio of the tree being evaluated. However, it was assumed by using this crown ratio that it would approximate the "average" crown ratio of trees in most stands of the Blue Mountains. Limitations of time and space prevented us from producing tables of other crown ratios, or for other tree species. We did, however, use the BehavePlus tree mortality module to derive some of the crown scorch mortality probabilities and the total scorch height mortality probabilities for those factors in the rating system for all the species included.

The tables are displayed by total tree height in feet on the left side of the table, and with total scorch height in feet at the top of the table. It was assumed that measuring total scorch height in the field would be easier and more accurate than estimating crown volume scorched by field crews; therefore, total scorch height (assuming the 0.5 crown ratio) was the fire-injury variable included in these tables. The range of tree heights included in the tables for each of the diameters were approximated using height-diameter equations developed by Moore and others (1996) plus or minus several feet to extend the range to compensate for site quality differences not covered by the datasets used to develop the equations, including some that originated from northeastern Oregon and eastern Washington.

To use the table, three variables are needed: total tree height, total scorch height, and diameter at breast height. Select the table closest to the actual diameter of the tree. Enter the table with the total tree height on the left side of the table and the total scorch height at the top of the table. Where the two variables intersect in the body of the table, the probability of that tree dying will be given as a percentage.

Since most of the fires of 2002 in the Blue Mountains which prompted development of these tables occurred in stands dominated by ponderosa pines, mortality probability tables were only developed for that species. There was not sufficient time to develop similar tables for other species, although that may be done in the future. Also, time limited the development of tables for every possible diameter-class; therefore, we selected the diameter classes that are currently most meaningful in the management of

stands in the Blue Mountains. Moreover, after examining these results, we felt that mortality probabilities for the range of actual tree diameters falling between the tabled mortality classes could be approximated without appreciable error by using the table for the nearest diameter class to the tree's actual diameter.

Table 1. Probability of fire-induced mortality of a 5-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height. 1

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Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 15-30 feet. Probabilities

Table 2. Probability of fire-induced mortality of a 7-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.¹

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47	41	41	41	41	41	41	41	41	41	41	41	41	41	46	57	70	82	90	95	97	98	99	99	99	99				_	1	1
48	41	41	41	41	41	41	41	41	41	41	41	41	41	44	53	66	78	88	93	96	98	99	99	99	99		2000	2000			4
49	41	41	41	41	41	41	41	41	41	41	41	41	41	43	50	62	74	85	92	95	97	98	99	99	99	99	-		1	1	1
50	41	41	41	41	41	41	41	41	41	41	41	41	41	42	48	58	71	82	90	94	97	98	99	99	99	99	10000		100		4
51			-	- 5-	-							-			-	-		-			-			-				-	-	-	1
52	1000	100	10000			1000	1000	1000				200	1000	00000	10000						10000	100000			1000	10000			150000		4
53	-						-						-		-	-	-		-	-	-	-	-		-	-	1	-	-		4
54	1000	1000		1000		1000		1000	1000	1000				1000		1000	20000		2000	1000		10000		100000		100000	-			2000	4
55						-			-	-	-	-	-		-		-	100000000000000000000000000000000000000			10000000	-	-	-			-	-	- Control of the Cont	-	ł
56	1000	1000	1000					1000	-	10000	10000	100000	0.000	000000	10000	100000	-	100000	,	10000	100000	100000	2000				100000			20.000	4
57										-		-	-				-	-													ł
58						1000	1			2000	10000	100000	10000	10000	1000	100000	20000		10000		10000	100000	100000	100000		100000		100000	190055	2000	4
59	_	_	_	-	_	-	-	_			-	-				-	000000000000000000000000000000000000000	0000000000					100000000					2000000000		00000000	ł
60	1000	1237	1000	1000	130,40	1.575	1000	s Fire	1993	13960	100	130000	10033	100	10000	189630	1000	1000	100000	100	100000			10000	100	10000	-	200	1000	15000	4

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 30-50 feet.

Table 3. Probability of fire-induced mortality of a 9-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.¹

																DRCH						1000			1 10						6
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	+
35	-	-	_		100000	-	-	10000	-	Charles.	10000	acres 1	No.	100000	11500	2000	0.010.00	No.	100000	0830	Name of	0500	45-56	22.45	6-295	121918	5000	Sec. 25.	21.5%	52.63	te
36	97.75	1000	2112	2500	16.03	200	0.75	Trib	EFC90	10000	1000	259	HOSE	KORSTO,	SEASON	100000	SERVICE	Barress.	100000	5.00	rivers of	LUBER	0000	98220	2000	-			-	-	Ħ
37	-	-	12000	10000	2000	275.00	5.72	AURINO	10100	Same.	NAME OF TAXABLE PARTY.	VCDR-1	100000	1000	MORR	TICLE!	1300	10000	200	94-1322	25-520	3953	4659	800	105-120	69650	9350	91735	dired	5132	ti
38	2.6%	SEPT	37-78	SHEE	3795	1090	200	2015.00	CON C	23/00	100000	2000	90707	1000	2000	10000	SCHOOL SECTION	Sano	100000	100000	-	10000	9000	- American	-						Ť
40	-	-	200000	and the		and the		2500	TUNES.	50000	67/2/2019	ALC: U	25.05	0520	555560	(REALIS)	25000	96070	ef GPB	01530P	E.1025	esin.	13085	COLOR	5088	2550	1995	1025	R-90	203	t
41	317 30-00	1500	SS = 37	10000	96555	1000	500	4.732	10202	10000	200	2000	27400	Cherry	10000	2000	900	7	10000	-			-	100000	2100						Ť
42	100000	4500	0000	100000	Decision.	1000	10000	100000	1420	5239	1000	(20.25%)	ROUGH.	(25)50	10000	ASS IN	Date St	Cubit	358	Hosti	SC-915	- CHICA	SUE	2072	549	1500	CHE	2000	12.76	6000	Ħ
43	9150	200.0	2.40	STOREGE	2762	1395	1220	COVE	The State of the S	17950	-	1000	7550	-	10000	-	The latest	-						TV.							T
44	5000	195650	2515676	5550	50000	1000	0/11/00	20238	290/25	54000	0250	6650	1000	3000	dage	0.2016	2007	SECTION .	02288	16258	02/62	Helia.	经增	01:02	25/86	1000	1296	(52)	THE	毛霉素	t
45	9335	2552	3.1550	STORES.	50,000	-	-	-	-	-	-	2000	10000	-	-	-	200														T
46	30	30	30	30	30	30	30	30	30	30	30	30	31	37	49	64	78	88	93	96	98	98	99	99	35.50	5000	1995	100	1018	100	I
47	30	30	30	30	30	30	30	30	30	30	30	30	30	35	45	59	74	85	92	95	97	98	99	99	99	7.72					T
48	30	30	30	30	30	30	30	30	30	30	30	30	30	33	41	54	69	81	90	94	97	98	99	99	99	188	1284	1500	828	F-578	1
49	30	30	30	30	30	30	30	30	30	30	30	30	30	31	38	50	64	77	87	93	96	97	98	99	99	99					Ι
50	30	30	30	30	30	30	30	30	30	30	30	30	30	31	36	46	59	73	84	91	95	97	98	99	99	99	11,000	15%	部院	933	1
51	30	30	30	30	30	30	30	30	30	30	30	30	30	30	34	42	55	69	81	89	94	96	98	98	99	99	99				1
52	30	30	30	30	30	30	30	30	30	30	30	30	30	30	32	40	51	64	77	86	92	95	97	98	99	99	99	NOT	EW.	1,700	4
53	30	30	30	30	30	30	30	30	30	30	30	30	30	30	31	37	47	60	73	83	90	94	97	98	98	99	99	99			1
54	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	35	44	56	69	80	88	93	96	97	98	99	99	99	85X38	503	4
55	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	33	41	52	65	77	86	91	95	97	98	98	99	99	99	_	1
56	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	32	38	48	61	73	83	90	94	96	97	98	99	99	99	5000	4
57	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	31	36	45	56	69	80	87	92	95	97	98	98	99	99	99	4
58	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	34	42	53	65	76	85	91	94	96	98	98	99	99	99	4
59	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	33	39	49	61	73	82	89	93	96	97	98	99	99	99	1
60	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	32	37	46	57	69	79	87	92	95	97	98	98	99	99	4
61														_	_				_	-	_	-	-	-	-	-	10000	100000	-	-	+
62		1200	FIG.	1770	Andreas	CEV	2882	Mary	100	ROYS	N. San	PRO	635	292	100	8578	1000	1256	1000	1000	2450	No.	1000	SEE SE	10200	Colta	Albert S.	5290	100	ESSOR.	Ŧ
63											_	_		-	-		-			-			100000	1000	1000000	-		2000000	10000	EVALUATION	÷
64	1000	CHRE	1720	538	1347	1200	1727	723	13/4	1155	1755	1900	150	2219	1000	955	0.756	0.76	100	293/6	45.43	10%2	0000	19963	CAUSE	100	27.2	STATE OF	ACRES .	1000	4
65						100							-	-	-		-				-	-	-	11000	1000	10.000	10.00	0.000	11 680	11584	÷
66	0.75	1290	1000	1000	100	1977	Post 75	10.93	1000	P. T.	1000	5000	19859	100	1.25	1000	0.55	-	15600	-50	1000	1623	9623	PECEDO	9025	0.25	1000	10.32	100	200	4
67					_				_		-	-	_	-	-		-	-	-	-	10.00		-	-	Senior	Distri	100000	GEO PER	100.00	6.40	+
68	3288K		1000	1975	3775	188	1999	100	9560	030		27-10-	G 7.5	9796	44.5	132.77	Sec.	CRE	100	10000	3922	1000	100	PESD	1000	CUS.	1	C 100	1000	2 45	4
69			_		_	-			_	-	-	-	-	-	-		-	75013.50	-	000710		0.00	400000	CAL 8.0	9453476	1590	15303	45/637	11/2/200	KY1000	+
70	Scher	963V	3503	Date Se	19833	50007	VID216	1986	100185	PERM	(Faller	Andre	P-115-	13019	1300	14 Cm	37763	19.36	ALC: N	15,50	100	2.90	12050	400 10	200		1001	1	15.75	100	4

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 46-60 feet.

Table 4. Probability of fire-induced mortality of a 12-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.

				_												DRCH				20	1 40	142	44	146	48	50	52	54	56	58	Т
1.45	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	34	34	50	20	t
45	10000000	00000000	0000000	0000000	1000000	0000000	10000000		200000	100000	5000000				100.00	000000	2000	20000	100000	102.53		2000	10000	200	10000	10000	10000	2430	100001	1000	đ
47	822533	8000000	000000	1000000	20000000	2000000	20000			-	-	-	SEC. 27.00	27/2/2	-	-	1000000	-	-	-	-										1
48	100000	800000	1800000	-32500	22000	10000	-	100000	100000	100000	00000	60000	5000	20000	100000	2000	10000	9300	200					10000	100			1000			đ
49	20000000		20000	-	200000000	100000000	-		-	-				-																	1
50	1000000	800/0	100000	70000	20000	92555	6000	1600	0000	2000	10000			0530	10000	3233	1930	10000	14500			2000	10000	1000	29030	2700	1000		1000	-	i
51	-	-	-	-	100000000	-	-						-	70.7				10		- N		12		0.7	39		98	00	0.5		Ī
52	10000	50000	9523	53000	123333				100.00	1000	10000	-	(E) (E)	19000	350	10000	-0.33	19,000	E355	2500	93555	12.950	3333	1000	1000		10000		1000	1000	Ī
53	-			-	-				-			30					-	111	35		SU				0.1	27				22	
54	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	22	29	40	54	68	80	88	92	95	97	97	98	98	2000	1000	j
55	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	27	37	50	64	76	85	91	94	96	97	98	98	98		
56	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	25	33	45	59	72	82	89	93	95	97	97	98	98	1000	1
57	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	23	30	41	54	68	79	87	92	95	96	97	98	98	98	
58	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	22	28	37	50	63	75	84	90	94	96	97	98	98	98	ı
59	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	26	34	46	59	71	81	88	92	95	96	97	98	98	
60	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	24	31	42	54	67	78	86	91	94	96	97	98	98	ĺ
61	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	23	29	38	50	63	74	83	89	93	95	97	97	98	
62	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	27	35	46	59	70	80	87	92	94	96	97	98	4
63	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	25	32	42	54	66	77	85	90	93	95	97	97	
64	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	23	30	39	50	62	74	82	88	92	95	96	97	ij
65	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	22	28	36	46	58	70	79	86	91	94	96	97	
66	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	26	33	43	54	66	76	84	89	93	95	96	Ä
67	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	24	31	39	50	62	73	81	87	92	94	96	d
68	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	23	28	36	47	58	69	78	85	90	93	95	į
69	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	22	27	34	43	54	65	75	83	88	92	94	è
70	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	25	31	40	51	62	72	80	87	91	94	į
71	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	24	29	37	47	58	69	78	85	89	93	d
72	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	22	27	34	44	54	65	75	82	88	91	Ą
73	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	26	32	41	51	61	71	80	86	90	
74	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	24	28	38	47	58	68	77	84	89	á
75	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	23			_	51	61	71	79	85	d
76	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	22	26	33	41	31	01	/1	19	63	4
77					-			-	-	-	-	1000000				-			-	-		-		-	-	-	0000000	-	10000000	1000000	d
78	1000	1		1000							-	10000	10000	100000	1	1000	1000		100000	10000	100000		100000	100000	100000	1000000	-	100000	200000	100000	ă
79					_	-								-			-					1000				0 0000000	10000000			2500000	d
80	1		1000	1000			vePlu		100	1000	2555	1000	19396	18:0	1000	1298	186	TOP OF S		10000		10000		1000		1000		1000			į

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 54-76 feet.

Table 4 (continued). Probability of fire-induced mortality of a 12-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.

12-INCH (DBH) PONDEROSA PINE MORTALITY Probability of Mortality (%)

																L SC					-									+20	12
1	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	1
45	-	-					-		-	-		-	-		0.00	-	2000	-	PS\$1-95	Lorenza .	1000000	2930	SEW MA	SOUTH.	5000,00	20.755.50	Doles V	25074590	5019546	45P356)	de
46	100	3590	-TSD	310	Livi	2303	125.7	2000	20/27	1001	EC/10	908	TOP	W150	ROW	0.00	20120	2000	100000	69565	47/67	3 Sec. 10.	No.	0.000	10-64	-	2000	7,5100,35	CPINAL	COCUS.	
48	-	Ch. State	Tarres.	Table 1	C.A.	1000		MODEL OF THE PARTY.	20000	200.00	10000	200	25000	Leta Seu	00/40	1000	6222	14000	PRO-BIG	SPEAN	45500	175040	SERVICE.	WEARS.	963	MARLS.	N 23/56	367/29	305005	4850	
48	15/269	PHISSLE	1200	CORNE	MEN	7753	E/256	6200	2000	1000	10000	77.00	1000	700	COLOR	2000	YYZ	10000	10000	100000	No. of Co.	1000000	201112	PARTY AND	-	-	2420	-	-		Г
50	onuni	0000	(0267	2000	15300	SCENE	2000	1000	10HB2	550	5000	reasa	1500	5000	1200	11,800	5.5700	192304	Cition	COSTS N	2008	NCS/AN	SUNCE	42FP32	MED (C)	1000 K	13393	190000		ONES!	28
51	2000	2377.4	1952	1000	China	DOCU	16.7515	0000	SE MILE	-	-	Same I	-	-	-	-		-	-	-	-	-									Г
52	OWE:	100000	NAME OF	2,950	94553	70000	2420	9200	225	COL	1200	220	1250	3185	233	Mark	5,605	3000	SERVE .	Sens	160(R)2	19556	OF SHOW	5,563,65	ALC:	90 Unio	SELEC	37.50	S. Holes	1927	120
53	0.30	100.00	-	-	1000	27400	-	-	-	-	-	-																			Г
54	9:90	196.9	(EME)	929%	15093	551	25391	1000	968	95049	(500)	(SSEA)	(Salak	425	200	200	19790	1825	17500	MENTE	(B49)	SELECTION OF SELEC	allog	RESERVE.	4.10	0/4/2	CONT.	376	27761	(410.75)	美
55	1000	-	100	100000	-	-	100 6.0	20.00		-	-		-																		
56	29/09/	100	18762	12862	126	500	FREE	SHE	503	35-6	6030	(BE35)	(4)	235	100	5.3	199	製造	2,340	DAG	SHOS	1514	THE.	DESTR.	(Kita)	SEX	HIM	(FEE	0000	(5 E)	8
57		_				_	-																		100						
58	200	学生	3554	7935	HEST.	PER	(4)03	3	\$3 P	250	SOF	363	13:25	150	099	1700	TO SA	497	(100)	1845	W. 1965	FERSE	2355	100	255	2039	198,32	Marie Control	经的	313	3
59																												1.0			L
60	1775	SIL	STORY OF THE	300	5220	1355	2019	何の	100	爱老	100	100	686	162	Sec.	SHE	250	PR	447	無理	100000	0040363	2000	CONT.		100	16,250	HER	250	300	2
61	98															-					1							_			L
62	98	F.13	200	Testi .	2525	的辩	200	100.5	86	SHE	500	654	1966	1000	1900	門腔	1466	视机	1423	23/69	\$500H	1000	150	THE PROPERTY.	ET ACE	125.6	DEED	SPARE	6893	22/20	2
63	98	98																						_			-	-		_	L
64	98	98	3233	1800	420	125	APRILIT	7523	想形	1992	TO U	85%	99.5%	Sec.	500	6550	660	5640	1000	126	1540	1.500	影房	0.000	SEED	200	SPR-459	1300	231	180	E.
65	98	98	98											_	_										_	-		-	-	-	-
66	98	98	98	The	233,0	5700	1920	的极	75%	规型	1995	202	6.50	1999	61.5	1505	599	25,635	465	225	100	2544	SPECE.	100	2250	549	000000	2422	18934	Chica:	U
67	67	98	98	98		1						_	_	_	_	_	_	_	_		_	_	_	_	-	-	-	-	-	THE REAL PROPERTY.	-
68	97	98	98	98	12:0	2200	1,59	YES	世界	1992	ST.	700	PER	150	934	1177E	26/15	899	SEP.	9590	0.40	0017	3050	HERSER	MFSD	1066	7111111	3,576	6000	Period	18
69	97	97	98	98	98				_	_	-	_	-	-			-	-		-	-	-	-			-		5000	F265 F34 S	100000	-
70	97	97	98	98	98	100	3370	535	100	1000	1000	1155	1000	大学 大学	2/12	2525	1096	183	396E	1000	PS-62	THE	200256	(100 Pa	73345	NOT NO	192000	00000	2000	20029	-
71	96	97	97	98	98	98	_	_	_	_	_	_	-	-	_	-	-	-	-	-	-	-	-	-	100.00	10000	Tork and the	100000	100000	1500	-
72	96	97	97	98	98	98	8391	2000	CAL	CED:	272	F122	77.5	CSFF	37.50	5388	3/1/20	100	PER.	PESSON	011504	10000	ST1606	100-964	10.77	0.000	nocks	COLUMN TWO	822har2	125.65	-
73	95	96	97	98	98	98	98	_		-	-			-	-	2000	-	Della Control	12.000.00	100000	-	C-00000	700000	Toward and	+0.400	0.00413	100000	133673	209CM	0.87589	-
74	94	96	97	97	98	98	98	1910	1000	EEE	E500	183	233	956	1200	2070	CHE	1000	195000	1010105	WITH STREET	19576	PERSONAL PROPERTY.	00.29	5,0900	Control 2	10000	39-265	000000	00WE	F
75	93	95	96	97	98	98	98	98		-	-		-	-	-	10000	-	20,000	1000	2000	0.000	55500	930.7	25030	Sec. 1	0.575	03569	3,2350	/5/0/49	Gentle	100
76	93	95	96	97	97	98	98	98	1000	35.30	225	1966	18,19	19000	attle	THE	100	1200	10:33	STEEL SE	intrins.	2017/1	PELLEY	Pricks.	tie-dick	055	1000	35	to Library	00001	+
77		2000	-	-		-	-	22.00	100000	2000		-	-	0000	all the same	1915	SANO	Service .	- NII	MICHEO	ENGLES.	COUNTY	10000	53,600	No.	nsout	104,040	10000	DE1436	442,735	di
78	23.02	2.700	122	27.7	5555	200	1000	CAC	534F7	50,10	200	EV.	1000	0008	20.00	17.83	0.3	13.3	100	69-75	ench	0.5000	Sec. Se	6.365	00000	1000	VILLAND.	100000	0.0000	-	۲
79 80	201200		90e0	1000	25.50	-5/1922	10000	ELDUY	0000	10000	14000	2000	10000	0100	1000	538755	55550	10000	RECAL	8.800 S	0.000	100000	(7bt)A	179897	55.00	10200	1.000	GERGE	SHEDN)	RWEST	10
80	B13357	1000	2750	1056	1000	1655	13837	C	KTI25	Sale.	0	2013	1	19349	1000	177-9	144.60	TYPE	113.00	120	(C) (F)	1000	Cthe Di	100000	48.55				-	1000	

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins, 1999, Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 54-76 feet.

Table 5. Probability of fire-induced mortality of a 15-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.

															LSCC									1 44	1			T	1		1 6
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	+
55	-	Towns Co.	-	San San	-	No. of Contract	Part State of State o				100000	-	The same	Contract of	10000	COST		CONSTR	CLUMA	1000	20.00	2000	Section	9000	SULCE.	10000	3500	1000	0000	1000	t
56	NEW CO.			WE S	NAME OF	200	9500	1050	-	1000			Spicine.	939500		NO.	Mary Co	-								-					T
58	-	-	20000	Chicago	10000	-	2000	HE SHOW	10000	MISHOL	D-Deb	Total S	SHARE	1000	2500	10000	1000	Sec.	0000	455020	ADJES!	223.15	12300	130,00	15000	- 10	(c)(C)(S)	13.19	500	100	t
59	Gistori	2222	STATE OF	20.0	100, 150		1000	Dig Spirit	17.00	100	-			-		-			-	-	-										T
60	Name of Street	LOSE ASI	Service	3-5-91	Sec.	(Alleks)	(300)	estile.	iona-su	(H) EDS	1000	995	HELISTS	100000	1000	000	3379	HOSE.	(1972)	750	Sec.	Breits	4000	200	0.000	Sec.	5500	32	1000	OF E	t
61	20000	Sell Hill	1000000	1000		-		-			-																				Т
62	CHICAGO	9301	COLUM	912999	62193	23300	-	GOVERN	STREET	1005	1	ALC: N	STEEL ST	200	100	400	632%	SELE	L. Pilery	586	100	Home	UK2	1000	1000	3300	100	1	130	577	π
63	-	100000															-														Ι
64	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	20	28	38	50	62	73	82	88	91	94	95	
65	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	15	19	25	34	46	58	70	79	86	90	93	95	Ι
66	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	17	23	31	42	54	66	76	83	88	92	94	1
67	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	16	21	28	38	49	62	72	81	87	91	93	1
68	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	19	26	34	45	57	69	78	85	89	92	81
69	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	18	23	31	42	53	65	75	82	88	91	ł
70	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	17	21	29	38	49	61	71	79	86	90	4
71	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	14	20	26	35	45	57	68	77	83	88	1
72	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	18	24	32	42	53	64	73	81	87	1
73	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	17	22	29	38	49	60	70	78	85	
74	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	16	20	27	35	45	56	67	75	82	Ŧ
75	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	19	24	32	42	52	63	72	80	
76	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	14	18	23	29	38	49	59	69	77	+
77	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	17	21	27	35	45	55	66		+
78	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	16	19	25	32	38	52 48	59	68	Ŧ
79	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	14	18		28	35	45	55	65	
80	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	14	17	21	25	33	42	51	61	Ť
81	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	19	24	30	38	48	58	t
82	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	18	22	28	36	45	54	Ť
83	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12		12	12	12	12	12	14	17	20	26	33	42	51	t
84	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	16	19	24	31	39	48	Ť
85	12	12	12	12	12	12	12	12	12	12	12	12	12	12		12	12	12	12	12	12	12	12	13	15	18	22	28	36	45	
86	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	12	14	13	13	10	Section	20	30	40	Ŧ
87	-				-	-	-		-	-	-	-	-		1000			100000	-	100000	100	1000	Deline.		100	No.	1000	Sec.	955119	10000	t
88	1400	1	-	1.30			1000		10000		-				-	-	-						-							1	Ť
90		_	-	-	_	_	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	1	-	-	+

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 64-86 feet.

Table 5 (continued). Probability of fire-induced mortality of a 15-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.

15-INCH (DBH) PONDEROSA PINE MORTALITY Probability of Mortality (%)

																LSC					1 100	1 101	1 100	100	110	112	114	116	118	120	1:
55	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	110	118	120	۲,
56	Total i	2000	School St	100000	105400	1010	100000	0090	d Long	STATE OF	District of	0.000	0.000	Contract of	50000	NO STORY	180191	5255	100000	122990	ADMIN'S	00000	500000	SCOTE.	DATE OF	ALZHVIS	12958	16,1010	5-200EX	ecu.	to:
57	10104	1000	CORPO	Other	10.45	official	-	Section.	2000	275353	10073	SARANGE.	CONT.	-	10000	19257	10000	00000	1000	100	STERRING ST	-	-	and the same of	100000	-	-	-	-	-	T
58	10000	62521	NES-R	CHECK!	10000	12000	5000	Vicini)	10000	Securi	07555	2009	97350	125954	9000	rine	-1.000	1000	ACTIVATE N	10991	1000	CSANIO	P-94/2-47	-600gr	048225	94525	F168780	25000e	54720	1906LJ	to
59	20.00	20100	7-57	2000	CP-SA	100000	1000	Children	6.000	ASSET OF	10000	1000	CORP.	-	100000	100000	2000	1000	190000		00000		-	-	-	II AS INVE				-	f
60	1000	10000	U5280	2000	102814	25/01	255	565/26	2000	0000	359aB	255	ARES	Sulci	SLEED	allega	163561	1200	1000	100.400	SMECK	85.6	COLUE S	92/50	PER SE	FF-0.54	910.75	153 mg	1000	1000	ħ
61	10000	17/200	-	774.30	-	-	20041	11/2/17	200	MOTE	20000	-	150,000	CT-S-	2000		-	-	-	-		-	-		-						т
62	17900	17615	20000	15374	22/12	150.05	10255	0.750	9200	200.01	200	150	DEC.	5353	23350	(Ebs)	3650	1200	1000	(353)	12000	522.00	60/63	150/240	5503	7653		dillis	2000	SHEE	to the
63	-	-	1000			-	-	-	-	-	-						-				1.7										Т
64	96	97	2515	(540)	(Salpi)	2000	19409	20750	228	SCOVE.	5455	(Sh)	10'54	LATE A	1550	1000	190255	2803	1000	1013/6	HARMA	REGI	358E	1023	86903	532	18617	595508	52886	1533	18
65	96	97	97																	111	100										Г
66	96	97	97	616	5000	2-30	9526	948	100	19-30	15 kg	事功	4556	(ALTHE	AFR.	15.50	1126	NES	1000	1.645	8/5/5	Total S	1222	3.23	93,00	10.00	COOLER Button	SEC. LO	G5823	1342	18
67	96	96	97	97																	-										
68	95	96	97	97	emes.	3359	-50°H	220	350	1	11-75	19194	34	STATE OF	2450	253	450	5/4/6	27,020	57.75	23/52	U-SAS	250	1932	1470	30375		4025	Res	APPEN	3
69	95	96	96	97	97				-												1		1								L
70	94	95	96	97	97	(C.3)#	Point	跨型	ME	STATE OF	學例	1938	9006	(HEA)	1007	3766	07.75	ALC:	127	34934	0059	REAL	3800		200	11.65	12450	SET ES	5 772	250	1
71	94	95	96	96	97	97						7				- 1			1	-											L
72	93	94	96	96	97	97	999	2549	5900	259	698	Agree	4500	5066	SHIP		400	100	12/19	2049	\$4.63	P(S)	55-5	(5,376)	2622	RUSS	WEST.	Bank	dispe	17943	10
73	92	94	95	96	.96	97	97													+	4										1
74	91	93	95	96	96	97	97	942	9.99	25%	100	1015			my fo		中台		MUR.	400	4,005 2	18503	0000	を改善	S.E.	Date	35300	35.9	3750	9(33)	18
75	90	92	94	95	96	96	97	97																			1 11		-	-	L
76	88	91	93	95	96	96	97	97	200	256	1940	學的	138	Sept.	200	5150	示事	433	经单	4903	3150	SEC	362	MODE	STEEL ST	2000	139	255	EEE	0.2543	10
77	86	90	93	94	95	96	96	97	97			100												_	_	_			-	_	1
78	85	89	92	94	95	96	96	97	97	999	200	1000	135	152	2529	E-1	10	483	243.7	Ser.	936	065.44	HOUSE.	· Chick	5020	150	2500	10000	3003	333	F
79	83	87	91	93	94	95	96	96	97	97										-						_	-		-		1
80	80	86	89	92	94	95	96	96		97	27.53	15/57	100	250	1000	25.2	10.10	16.2	5.3	0.000	250	123/34	(DAN)	05-18	355	P. Sales	250	LECTED AND ADDRESS OF THE PERSON NAMED IN	DOM:	nevan	F
81	78	84	88	91	93	94	95	96	96	97	97		_		_	_	_	-				-	-	-	-	-	-	-	-	100.000	+
82	75	82	86	90	92	94	95	96		97	97	230	THE P	SATE.	200	WH 5H	500	3700	100.99	1965	200	200	(Service	No.	192-22	50000	Service.	196-5-196	12000	45.00	Ŧ
83	72	79	85	89	91	93	95	96	96	96	97	97	_		-		-	-		-			-		1000	- Andrews	10000	1000	0.000	N. S. S. S. S.	b
84	70	77	83	87	90	93	94	95	96	96	97	97	200	7227	555	1276	500	599	Materia	SPRING.	1752	HOUSE.	N.C.	4005(3	SSERIE .	OT PER	442000	10000	1000	Call No.	4
85	66	74	81	86	89	92	93	95	96	96	96	97	97		-	-	-		-	-	-	-	-	-	1000	92.52	1000	1000	10000	100000	÷
86	63	72	78	84	88	91	93	94	95	96	96	97	97	9	200	100	200	1100	P. Cont.	100	Christin	15-CEP1	1000	5000	10-96C	Frank's	66,000	SECTION.	10.155	1000	F
87	_	-	_	_	_				-	-	_	-	-	-		-	-	-	-	177.870	-		-	10.000	2000	NI OSan	CUI SERVI	-	THUSE.	5730	t
88	3.75	1000	375.59	257	100	0896	CORE C	24×	deta	57.18	5.00	8070	100	9.50	22.5	200	1200	3535	2000	2/2/2	20,770	REPORT.	07540	2.00	age S	DOM:	40.50	5000	N. D. Carlot	577ZW	Ŧ
89		-		200.00	-	-	-	-	-	-	Trans.	27,700,00	-	ACCOUNTS NO.	-	-	1000	- No. 10	-	C3-181	-	1000 and 1000	100000	Cred St.	Print of the	CONTRACT	170000	solle.	ALC: N	NOSS.	t
90	17502	50354	355	6688	(1970)	043	houaP	10/20	Sails.	1462	DOFF	1995	13650	中国 图	53.65	28 3	13.793	18405	1100	K45-95	DIST	1650700	15797	TSS P	C2194.8	220,000	11703	1756	12000	DEC-16	40

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins, 1999, Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 64-86 feet.

Table 6. Probability of fire-induced mortality of a 18-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height. 1

18-INCH (DBH) PONDEROSA PINE MORTALITY Probability of Mortality (%)

																DRCH				1 20	T 40	1 40		100	10	F0.	52	54	56	58	T
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	50	58	t
70	-	-	-				-	10000	10000	Name of	-	100000	and the	1000	2000	1	20254	12000	all the last	1000	10000	NAME OF	4000	1000	1040	100	OTE	CHECK	12000	1000	ŧ
72	1000	275	2000	200	1000	-	-		100000	-	-	150500	-	-			-	-	-												Ť
73	2020			-	A STATE OF	-	1000	1000	1000	100	Contract of	5550	10000	CHICAGO.	500	SHOL	(000)	Contract of	10000	CUST.	COST.	565.5	93500	Short	10013	1945	1216	N/A	2000	1650	t
74	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	14	19	26	35	46	57	67	75	1
75	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	13	18	24	32	42	53	63	72	1
76	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	16	21	29	38	49	59	69	1
77	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	10	12	15	20	26	35	45	56	66	4
78	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	14	18	24	32	41	52	62	I
79	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	13	16	22	29	38	48	58	4
80	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	15	20	26	35	44	55	1
81	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	14	18	24	32	41	51	4
82	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	13	17	22	29	38	47	1
83	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	16	20	27	35	44	4
84	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	14	19	24	32	41	4
85	8	8	8	8	8	8	8	8	8	8	8	8	-8	8	8	8	8	8	8	8	8	8	8	9	11	13	17	22	29	37	4
86	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	13	16	21	27	35	4
87	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	15	19	25	32	4
88	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	11	14	18	23	29	4
89	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	13	16	21	27	4
90	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	15	19	25	d
91	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	14	18	23	4
92	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	9	11	13	17	21	d
93	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	13	16	20	4
94	8	8	8	8	8	8	8	8	8	8	8	8	8	8	-8	8	8	8	8	8	8	8	8	8	8	9	10	12	15	18	d
95	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	11	14	17	4
96	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	13	16	d
97	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	15	4
98	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	14	d
99	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	-01	9	11	13	4
100	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	12	d
101	100		1			66	103	150	1000	1	100		100	100	1	-	100		-	100	1	100			100		1 3	200		100	4
102					-	-	-	-	-	-	-	-	-		-			-		-	-	-	-		-	-	-	-	-	-	d
103		1	1	1	700		1	1	1	1	100	1,123	1945	150	1	100		100		1	-	1700	1	3 /112	-		-	Street, or other	Programme and the		4
104					_	_		-		_	_	-	-	-	-	_	-	-	-	-	-	-		-	-			-	-		d
105	100	100	194	100		1000	1550	160	100	10-11	100	A STORY	1000	350	145	9 - 5 - 6	CAL	1000			1	The said	75.10	25,00	1000	12.3	10.00	1000	1100	1500	4

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 74-100 feet.

Table 6 (continued). Probability of fire-induced mortality of a 18-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.

18-INCH (DBH) PONDEROSA PINE MORTALITY Probability of Mortality (%)

																L SC															
70	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	12
70	10000	-	and the same	Toron a	2000	100000	-	-	-	-	10000	200	10000	TOO TOO	Contract of	-	45000	ACCUPATION N	150-11	-	ARREST NO.	100000	ASSESSED AND	- Contract of	10000	400-23	53,52553	18604	AVECUAL DES	CONTRACTOR OF THE PARTY OF THE	66
72	1555	200/0	20115	1,000	Section	10000	0524	FEED	April 1	2022	11000	19-10	5553	24000	J. Charles	-0.0394	SECTION.	100,000	Chrysl	Carrier is	130013	2000	STATE	the state of	No.	-	-		-	-	
73	100000	HEERON-	23/53/5	960079	15000	CHANG.	1000	2 550	200.00	15250	59540	Heaves.	200	0000	200	Calco	POLIS	9.500	1200	FEE200	97900	Kirish	2016/201	e/Careto	13600	0910	5000	IPS WE	Shirtle S	52358	123
74	87	90	92	93	94	95	95	10000	5.3875	223149	Charles of	DBC/D	-	SC APP	10000	ALC: UNKNOWN	271285	10000	1000	100000	1000	-	200000	-							
75	85	89	91	93	94	95	95	95	2455	ADM N	BOSH C	GOVES!	12000	220%	353/5	1000	14.500	0553A	UF652	STEE	10000	TO COLOR	550295	80,0060	5-650	TO SERVICE	2200	Plantis.	STEEPLE	3832	100
76	83	87	90	92	94	94	95	95	-	COLUM	105907	1950	1000	2000	-	-	20000	127970	-	0.000	-	-	-		-						Т
77	81	86	89	91	93	94	95	95	95	100000	12200	SECT.	W.F. 12.	and a	1000	5502	34365	105345	750%	12000	100000	535850	940/0	STATE	Calon	3505	\$5000	1355	911/952	felian.	12
78	78	84	88	91	92	94	94	95	95	N. WOLE	2000	2000	1000	10000	-	-		-	1000	The same of	1000		-								
79	76	82	86	89	92	93	94	95		95	(255)	10000	2012	NG EN	Senso	0005	le sua	OBLE	356	NO.	92538	31625	Pitte	994EZ	SEN	(34/2)	(Referred	85,53	1200	1/455	95
80	73	80	85	88	91	93	94	94	95	95	-	-	2000																		Г
81	70	77	83	87	90	92	93	94	95	95	95	(85/8))	068	7,015	SSEE.	2550	15851	30500	2350	29.36	2509	(味)	5000	152.12	1954395	12433	HEET?	COLEMNS.	sath.	100	83
82	67	74	81	85	89	91	93	94	94	95	95											1.5		-							
83	63	72	78	84	87	90	92	93	94	95	95	95	2008	G259	NEWS P	STATE OF	in Rich	128.83	.835	200	1000	12.50	2500	Park	1000	0.3000	S1/665	SUSTER	5000	266	90
84	60	69	76	82	86	89	91	93	94	94	95	95																			
85	56	66	73	80	84	88	90	92	93	94	95	95	95	DE CO	1700	(577)	1500	350	1300	9300	PERM	THE SEC	CUE	1987	ALT (2)			100	Partie	Heat	100
86	53	62	70	77	83	87	89	91	93	94	94	95	95						1												
87	50	59	68	75	81	85	88	91	92	93	94	95	95	95	16/3	345	1585	E400	1636	N. 8538A	19000	10945	1747	THE STATE OF	F&03	1600	TO SHE	的是	中原	5.50	83
88	46	56	64	72	78	83	87	90	92	93	94	95	95	95												2.44					
89	43	52	61	69	76	82	86	89	91	92	94	94	95	95	95	200	538	Sign (17.00	(MES)	51313	Made	1750	SERVICE OF THE PERSON NAMED IN	26534	4.50	2250	學也	The state	SING	88
90	40	49	58	66	74	80	84	88	90	92	93	94	95	95	95																
91	37	46	55	63	71	77	82	86	89	91	93	94	94	95	95	95	THE S	1000	250		Hills	1833	7.60	WELL ST	STEE	2007	355E		EED I	世代大学	83
92	34	43	52	60	68	75	81	85	88	90	92	93	94	95	95	95														_	_
93	32	40	48	57	65	73	79	83	87	89	91	93	94	94	95	95	95	1.98	350	9080	Oile	The sec	FERST	SEC. 2	25150	1000	1883	FREEK	8,0393	1000mg	30
94	29	37	45	54	62	70	76	81	85	88	91	92	93	94	95	95	95			100											_
95	27	34	42	51	59	67	74	80	84	87	90	92	93	94	94	95	95	95	300	234	1912	1000	0.00	Mr.	120 190	PER COLUMN	COL	THE SE	1000	T. Carlo	133
96	25	32	39	48	56	64	72	78	82	86	89	91	92	93	94	95	95	95							_					_	-
97	23	29	37	45	53	62	69	75	81	85	88	90	92	93	94	94	95	95	95	12000	100	1000	2000	250	12.55%	227	CRET	CITE	- ALTO	2333	
98	22	27	34	42	50	59	66	73	79	83	86	89	91	92	93	94	95	95	95											-	_
99	20	25	32	39	47	56	64	71	77	81	85	88	90	92	93	94	94	95	95	95	100	E 30	186	Sec	1997	(8x-)	385.7E	Marie	26373	9355	100
100	19	24	30	37	44	53	61	68	74	80	84	87	89	91	93	93	94	95	95	95								_		-	-
101	TO THE	186.2	特征	100	220	1000	14.28	2/4	201	267	925	25.5	COURT	10:25	400		明朝	100	100		257	27.0	45	1770	60	馬德	SHELL	Profession of the last of the	902	75003	100
102																								_	_	_			_	-	-
103	1000	233	1220	585	1967	534	12.45	035	53	Perfs	200	200	433	3.00	393	THE S	155	0.5	2000	28548	PER S	O.P.	5288	2/200	CPENS	77.70	33.0	E E	12.5	900	-
104																									_				-		-
105	1170	1000	1,250	COURTER	SEE	535	表	16736	3260	WHY.	253	F239	(E34)	2019	1376	1000	100	50250	House	16537	Things.	POTEK	0.933	LAVE	85.40	35	12990	SSA	1.933	12574	100

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins, 1999, Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 74-100 feet.

Table 7. Probability of fire-induced mortality of a 21-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.

				_												COR										1					Т
00	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	+
80	-		Delica Service	-	1000	Artists.	and the same	100000	000000	CONTRACTOR OF	ALC: UNK	-900	19/15/20	10000	STATE OF	No.	Design Co.	100000	090000	10000	16075	198530	AARO	CONTRACT OF	all all res	Serio-	190000	OFFICE OF	10/00/06	WENCH!	đ
82	Contract of	9843	2000	91925	10000	1079610	-	-	1000000	Contract of	-	-	-		-	-	-	1000000				-	-								Ť
83	milita	6400	0.00	2000	COLUMN TO A STATE OF	diam'r.	000	1000	MARCH	10000	100000	25000	35%	Chicago	15000	NAME OF	100	1000	100000	1000	1200	1200000	E-000	9509	15050	2000	CONTRACT OF	125100	1000	00000	đ
84	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	11	14	19	25	33	Ť
85	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	13	17	23	30	đ
86	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	9	12	15	21	27	Ť
87	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	9	11	14	19	25	а
88	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	13	17	23	T
89	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	12	16	21	Л
90	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	9	11	14	19	T
91	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	13	17	1
92	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	12	16	Ι
93	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	9	11	15	4
94	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	9	11	14	1
95	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	13	4
96	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	9	12	1
97	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7	9	11	4
98	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	4
99	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	4
100	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	9	4
101	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	9	4
102	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	4
103	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	4
104	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	ł
105	6		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	4
106	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	/	ł
107	0.75	-	500	1000		12010	1000	1000	1000		No. of Lot,	1000	-	1000	1000	200	1000	2000	10000		CHE SH	BESS	1000	-						-	4
108	_			_	_	_	-	-		-		-				-	-	200000		10000		COLUMN TO SERVICE	-	Contraction of the Contraction o					2000		ł
109	7.7		DERV	980	1	1	1	1000	1000	100	1000	1,157	3.00	1000	100000	1000	10000	Marie .	1000	0.000		91754	1000	-	-	100000	1000	100	arried)	-	4
110	-	-	-	-	-	-	-		-	-	-		1717000	-	-	-	-	-		- Contract	-	No. 10	CONTRACT.	-	and the same	December	100.00	10000	N=00	Page 15	d
111	1997	17.00	1000	-		1000	100	1		-			400	-000		1000	2000	-					1000					-	- 111		4
112			-	-	-	-	100000		175000	175.00	10000	90000	10000	15000	111111111111111111111111111111111111111	-	01560		4000	100		1000	-	(New York	- SECTION	NEED A	HIMES!	10000	(90)00	1000	d
113	1000	100	-		100	10000	1	-	1000	-	No. of Street,		-	-	-	-	1		-			-	-		-	-	-	-			f
114	_	_	_	_	-		-	-	-	-		-	-	-	-						-			-	-				10000	1000	÷

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins, 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 84-106 feet.

Table 7(continued). Probability of fire-induced mortality of a 21-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.

21-INCH (DBH) PONDEROSA PINE MORTALITY Probability of Mortality (%)

																			IGHT												
	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	12
80	-	10000			10000	-	-	-	-	PRAIS.	-	-			-	10050	-	-	-	1000000	Total Control	114800	-	Total State of State	THE COL	50150000	100000	(3000)	Sec.	BUDISH	200
81	200	00018	20.00	200	SUS	True Contract	2/2	TARRE	2007	200	9280	SEC.	4000	10.0002	State of	19/9	10000	No.	10000	TO SHIP	100000	HERMON	10000	State of the last	The same	Service	FEGURA.	10/52/11/2	1000000	Marin Co.	
82	Total Control	115.20	10-5170	35190	2000	-	10000	-	10000	-	10000	1000	100	100.00	2000	1000	10000	10000	200.00	distant.	2000	dichies.	SATISTICS.	20000	OR COL	(00/00	Chesta	1145412	din Line	CANADA S	100
84	51	61	69	76	81	85	88	90	91	92	93	93	GPYS.	RECE	170577	2018	1979	45.53	7.20	2753300	10/00	Married Co.	CHCSS	SUPE	Contract of the Contract of th	-000	CYCLE !	approprie	100000		
85	48	57	66	73	79	84	87	89	91	92	93	93	93	92055	CONTRACT OF	1000	1200	45.50	00001	55950	GP-(C-)	657000	-543vc	SHEED	2000	4500.0	10000	0:505	15845	23/635	323
86	44	54	63	71	77	82	86	88	90	92	92	93	93	THE	195350	THE REAL PROPERTY.	10000	SUBSTITUTE OF	10000	200000	04194	Service.	Control	SALVE	See See	-	-	2000	of China	-	
87	41	50	60	68	75	80	84	87	89	91	92	93	93	93	LEGIS.	3000	30050	diam'r.	03230	District.	55563	EARS.	DECEM	ACRES.	400	AUFED)	1278.257	G.(6)	20303	10%	313
88	38	47	56	65	72	78	83	86	89	90	92	92	93	93	1000	2000	31.50	100.700	5.000	PERM	-	The same	-		77.50	-	-	-	-		
89	35	44	53	62	69	76	81	85	88	90	91	92	93	93	93	100/542	15/5	100.00	6896	WHEET.	EFE.O	104506	No.	E015-32	0199	8350	SACCA!	56250	2840	NAME OF	150
90	32	40	49	58	66	73	79	83	86	89	91	92	92	93	93	-	-	-	-	-	100	2.50	1	-	-	-				-	
91	29	37	46	55	63	71	77	82	85	88	90	91	92	93	93	93	MAGE.	STATE OF	942	DEU.	CHUB	DECEM	Jale12	355E	5,050	ISE.	NAME	(525%)	2000	256.0	100
92	27	34	43	52	60	68	75	80	84	87	89	91	92	92	93	93									-						Г
93	25	32	40	49	57	65	72	78	82	86	88	90	91	92	93	93	93	3/5/2	20/56	12000	1350	Comp.	SHA	2232	200 G	azha	1552	2430	16.275	2174	100
94	23	29	37	45	54	62	70	76	81	84	87	89	91	92	92	93	93														Г
95	21	27	34	42	51	59	67	73	79	83	86	88	90	91	92	93	93	93	03:550	200	1900	1127	1525	1080	OR OTHER	NO.	12,77,92	50234	3700	1000	303
96	19	25	32	39	48	56	64	71	77	81	85	87	89	91	92	93	93	93													
97	18	23	29	37	45	53	61	68	74	79	83	86	89	90	91	92	93	93	93	NEW Y	50.195	120203	04000	(0.855)	100000	1000	SEE THE	1957	354748	1150	353
98	16	21	27	34	42	50	58	66	72	78	82	85	88	90	91	92	93	93	93							4			1		
99	15	19	25	31	39	47	55	63	70	76	80	84	87	89	90	91	92	93	93	93	150.00	17250	(U_2)2)	PARTY.	La Paris	1946	电影 发	275	DEST	100	包
100	14	18	23	29	36	44	52	60	67	73	78	82	86	88	90	91	92	93	93	93											
101	13	17	21	27	34	41	49	57	65	71	77	81	84	87	89	90	92	92	93	93	93	2000	Sec.	3985	AMC U	SETTE	TEN B	0000	1000	235	22
102	12	15	20	25	31	38	46	54	62	69	74	79	83	86	88	90	91	92	93	93	93										_
103	11	14	18	23	29	36	43	51	59	66	72	77	82	85	87	89	91	92	92	93	93	93	1483	Marie	FORES	250	1000	(F-38)	\$25518	222	420
104	11	13	17	21	27	33	41	48	56	63	70	75	80	84	86	88	90	91	92	93	93	93									_
105	10	12	16	20	25	31	38	46	53	61	68	73	78	82	85	88	89	91	92	92	93	93	93	100 p	1000	Bell to	666	STATE A	468	200	100
106	10	12	15	18	23	29	35	43	50	58	65	71	76	81	84	87	89	90	91	92	93	93	93	_	_	_	_			_	_
107	SES.	257	Zh4	635		25.73	127年	100	1000	1000	878b	255	700	189	257	100 m	2962	100	1000	250	5776	19.4	ESS.	18091	Bish	1349	>350	9,000	200	ARRAN	200
108	_				_			_	_	_	_				_	_			_		-		_	-	_	_	-		-		_
109	Pres		1000	100	1000	200	575	1000	SEL	5.000	735	0%	27	253	5.7	TRUE !	2000	253	855	200	1253	des	18075	Bre Ste	200	thicke.	Supply	Sharin.	7-6-74	7000	100
110	_		_		_			_	_		_	_	_	_	_	-	_	-	-	-	-	-	-	-		-	-	-	TOTAL PARTY	-	-
111	100	Fall	1550	Total	250	200	0.50	130	560.8	100	200	200	7593	68/39	E000	25	22.72	21/32	1000	(Cold	1	25-10	1500	1000	100	1000	ther bo	Cour	ESPECIAL PROPERTY.	26,63	193
112			_		_	_	_	-	_	_	-	_		-	-		-		-	-	-	-		-			-	-	10000	and the same of	-
113	1100	SATU	250	000	252	100	23 P	2727	E-COLE	2392	1000	75.3	See	1000	1501	200	10/0	188	0220	Chee	Table S	BOX.	2000	200	15.00	Ch. 55	12.50	7,000	159600	1923	135
114	-	_	_		-	_	_	_	-	_		-		_	_	_	-	-		-	-			-		100000	20000		15000000	N. Procedure	-
115	100	1999	Vo By	100	2968	1280	DI.	1300	1300	1100	Percent.	TO	19(3/5)	UPTO E	1808	100	end.	15750	1300	1000	20603	no-qu	LIHERS	1275	RESPONSE.	1/00/9	15/36	0.79813	1,5289715	15078.5	136

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 84-106 feet.

Table 8. Probability of fire-induced mortality of a 26-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.

26-INCH (DBH) PONDEROSA PINE MORTALITY Probability of Mortality (%)

																	ORC														T
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	╀
90								_		-		_	-	-	_	-	-	Acres de		A CONTRACTOR OF THE PARTY OF TH	- Charles	100000	SHEE	2000000	The state of	100000		NAME OF TAXABLE PARTY.	0.1531.7	00000	t
91	1200	THE S	25505	SECON.	9000	199	1980	10000	STATE OF	75.50	DOM	1500	1000	1000000	2000	1	SPEC	COLUM	000000	COURT	10000	PERSONAL PROPERTY.	5000000	2000,770	170000	-	Balling Street	50000	-	100000	Ŧ
92	_	_					-	_	_	-	-	-	-	-	-		-	-	-	Total Control	-	-	-	Section 2	The Country of	All lines	C. Service	Committee of the	STORY S	El tori	÷
93	1790	9531	3000	Only	500	No.	1000	5000	-	1000	-	A STATE OF	-	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	7	9	Ť
94	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	7	8	đ
95	4	4	4	4	4	4	4	4	4	-	-	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	8	Ť
96	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	7	ł
97	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	7	Ť
98	4	4	4	4	4	4	4	4	-	_	_	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	6	đ
99	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	Ť
100	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	đ
101	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	Ť
102	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	đ
103	4	4	4	4	4	4	100	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	Ť
104	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	đ
105	4	4	4	4	-	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	Ť
106	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	đ
107	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	Ť
108	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	đ
109	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	Ť
110	4	-	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	đ
111	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	Ť
112	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
113	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	1
115	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	1
116		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	1
117	4	1	1	-	-	1	1000	1	1	1	100	No.	1000	1	i i	100		1000		62658	1005	100	100	1000	100	1000	100		12:27	2393	4
118	-					-																									1
119	to the con-	1000	0.00	10000	Hillian	-	fig.	1000	1455	100	1000	100		0.250	1763	199	100	135	2.03	100	1018	100	5-3	6-30	15.0	100	153	22	-	M	4
120	-					1																									1
121		1000	-	100	CON	150	100	Charles	100	GIG	1000	Sign	150	They	1700	2500	100	1000	200	1/2/201	1000	1	Story	1000	444	1125	155.5	1253	Mine		ı
122																															Ī
123		100	100	1000	100	1000	1000	555	100	1000	100		100	100	1500	100	1000	72.5	199	1 210	100	100		200	13.5	1750	132	(Sec.)	MET ST	1959	I
124		-	-	1						1																					T
125		1 21550	20000			1200	4000		1000	1	1		1000			1000	1000	33.1	1000		1000	1000	E CONTRACT	1000	25.00	111111111111111111111111111111111111111	18.00	5/2	4233	-7/16	41

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 94-116 feet.

Table 8 (continued). Probability of fire-induced mortality of a 26-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.

26-INCH (DBH) PONDEROSA PINE MORTALITY Probability of Mortality (%)

	172							1777		1			-	TOTA	L SCO	RCH I	IEIGH	IT (ft)	San J		y-yr-									_
90	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	1
91	1000000	2000	0000000	1000000	0.002.00	Name of the last	2000000		100000000	2000000	F05.000		0.000	1000000	1000000	10000	CORPORAL PROPERTY.	-	-		2000	-	1000000	10000000	B-000	0.00000	1000000	000000	A4675.50	23
92	8620	2952	57.20	CRES	95790	100000	The second	No.	N.F.S.	100000	1000000	Cross, 4	1000000	100.000	The same of	575.7923	ASSESS.	100,700,000	2000000	200000	1000000	2000,000	1000000	100000000000000000000000000000000000000	100.000	100000000	1200010 000	500000000000000000000000000000000000000	BBUCKES.	1
93	201000	16 4 80	D-SP CA	NAMES OF	303090	1000000	100000	6635734	C15 300	NAME OF TAXABLE PARTY.	J 1850-54	10000	20000	2000	0.8405	E93532	100000	100.000	1000000	SC2.09	100000	1000	175000	R000000	120000	Service Sci	90000	Supplied.	135700	40
94	16	21	27	35	43	51	59	67	73	77	81	84	86	88	89	89	89	Sales Control	100000	22.20	-	-	2000000		-	20020020	0.00000	Control of	2200	T
95	14	19	25	32	40	48	56	64	70	76	80	83	85	87	88	89	89	89	1000000	100000	1000000	10000	100000	1000.90	150,000	10000	22920	10000	35000	48
96	13	17	23	29	37	45	53	61	68	73	78	82	84	86	88	89	89	89			-	-		-					-	۲
97	12	16	21	27	34	42	50	58	65	71	76	80	83	86	87	88	89	89	89	200	B1600078	0.5200	2248	200000	2000	W. S. S. S.	90X80	200000	1000	1
98	11	15	19	25	31	39	47	55	62	69	74	79	82	85	87	88	89	89	89			-	-		-				-	T
99	10	13	17	23	29	36	44	52	60	66	72	77	81	84	86	87	88	89	89	89	75.583	76295	1500	22,000	55080	1000	52455	0.5587	9460	ħ
100	9	12	16	21	27	33	41	49	57	64	70	75	79	82	85	87	88	89	89	89				-						T
101	9	11	15	19	24	31	38	46	54	61	68	73	78	81	84	86	87	88	89	89	89	100,00	2000	PESS.	50,833		100000	(CEE)	7857	E
102	8	10	13	17	22	28	35	43	51	58	65	71	76	80	83	85	87	88	89	89	89				James I.					Τ
103	8	10	12	16	21	26	33	40	48	55	62	69	74	78	81	84	86	87	88	89	89	89	25596	10000	10000	200	1000	6600	63.34	I
104	7	9	11	15	19	24	30	37	45	53	60	66	72	76	80	83	85	87	88	89	89	89			-					Τ
105	7	8	11	14	17	22	28	35	42	50	57	64	70	75	79	82	84	86	88	89	89	89	89	Service Servic			98.73	0.365		I
106	6	8	10	12	16	20	26	32	39	47	54	61	67	73	77	81	83	85	87	88	89	89	89		-					Ι
107	6	7	9	12	15	19	24	30	37	44	51	59	65	71	75	79	82	85	86	88	89	89	89	89		2000	1905	NOE:	275.2	1
108	6	7	9	11	14	17	22	28	34	41	49	56	63	68	73	78	81	84	86	87	88	89	89	89	-					L
109	5	6	8	10	13	16	20	26	32	39	46	53	60	66	71	76	80	82	85	86	88	89	89	89	89	2000	S CHARLE		1000	1
110	5	6	7	9	12	15	19	24	30	36	43	50	57	64	69	74	78	81	84	86	87	88	89	89	89					┸
111	5	6	7	9	11	14	17	22	27	34	41	48	55	61	67	72	77	80	83	85	87	88	89	89	89	89	25.35	NO.		1
112	5	6	7	8	10	13	16	20	25	31	38	45	52	59	65	70	75	79	82	84	86	87	88	89	89	89		-		1
113	5	5	6	8	9	12	15	19	24	29	36	42	49	56	63	68	73	77	80	83	85	87	88	89	89	89	89	6393	(A.P.)	1
114	4	5	6	7	9	11	14	17	22	27	33	40	47	54	60	66	71	76	79	82	84	86	87	88	89	89	89			1
115	4	5	6	7	8	10	13	16	20	25	31	37	44	51	58	64	69	74	78	81	83	85	87	88	89	89	89	89	5000	1
116	4	5	5	6	8	10	12	15	19	23	29	35	42	48	55	61	67	72	76	80	82	84	86	87	88	89	89	89		1
117	755	200			1	200	12372	1000	375000	2000	2623	Press	12.00	25000	0.538	1200	200	25280	F100	10000	5500	2500	MAK	6886		- 50	100000	1000	20042	13
118						-	_						7 7					-	-			-				-	-	-100		Ŧ.
119	1330	200	100	100	0000	10000	1555	1000	100	1992	10000	1000	2000	0000	12197	0.1997	Control	100	100	1200	0000		572578	Perrille	13000	0.152	100,000	NAME OF	5250.0	F
120				-		-			16.				-				-	-			-	-	-				-	100000000000000000000000000000000000000	D. P. S.	ŧ.
121	1000	PERS.		30.00	95.00	100	200	10000	0.50			0.750	1000	1075.0		200	ECS.	1 1 1 1 1	100	12700	1000	0.2555	100000	20000			100000	DATE:	100000	+
122	-	-		-		-	-			_		_			-	-	-	-			-	-	190.00000		-		B. 2000		000000	ł
123	1000		200			1000	0230	1583	2000	8,200	200	1985	(C. 18)	2000	10,00	10000		120725	10000	132578		10000	2253	20.00	10000	200000	10000	2000	2000	4
124							-	-	300.000	10.00	-	-		100000		-	NAME OF TAXABLE PARTY.	State of the last	100000		-			2000000	N. (C.) (C.)	100000000	700.955.0	NO SECOND	15.00 15.00	t
125	20070	195%	F2748-81	0.890	27500	PERSONAL PROPERTY.	10,000	1000	Carrier !	CONTRACTOR OF THE PARTY OF THE	1200555	17945	deresid	7,799-8	150,017	(8/0/5)	CERTSON	2003	120-00	1002003	124.02	K17900	353600	177.35	CT 2000	825.0	2000	X 300 C. C.	3296.45	Æ

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 94-116 feet.

Table 9. Probability of fire-induced mortality of a 32-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.

								_	-	-						LSCC					40	- 42		44	10	T 50	52	54	7.6	58	6
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	- 0
100			-		-	-	-		2000000	-	100000	0000000	100000	1000000	10000	-		100000	10000000	120000	0.000	2000000	100000	200000	100000	100000		-		-	100
101	2000	1000	200	2000		00000	22200	100000	100000	2000	40000	20.00	-	10000000	20000000	100000	100000	10000000	0,000,000	-	000000	-	-	2000000000	10000000	-	-	-	-		
102			-	0000000	20000	1000000	-	2200	10000	1000000	- ESCOLUT	100000	140000	20000	100000	100000	10000	5000	100000	100000	100000		10000	10000	20000		100000			100	100
103	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4
	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4
105	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4
107	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4
108	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
109	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
110	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
111	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
112	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
113	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
114	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
115	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
116	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
117	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
118	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	. 3
119	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
120	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
121	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
122	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
123	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
124	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
125	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
126	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
127	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
128	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
129	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	-
130	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
131	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
132	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
133	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
134	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	13	3

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 104-134 feet.

Table 9 (continued). Probability of fire-induced mortality of a 32-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.

32-INCH (DBH) PONDEROSA PINE MORTALITY Probability of Mortality (%)

					_	_									TO	TAL S	COR	CHE	EIGI	HT (ft)										
		62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120
- 1	100																_	_				_	-		-	-	-	-	-	1000000	2015/00
- 1	101	6.53	13.57	8750	ESS	2507	355	1000	770	770	200		100	42.0	13972	2000	9-4	0550	255	1986	686	E-Par	RINGS	200	400	505		NO.	SCHOOL S	STAGE !	Digital St
ı,	102	_			_	_	-		-		_	-	-		-	-	-	_	-	-	-	-	-	THE REAL PROPERTY.	Contract in	1000000	-	-	100000	17543	0000
- 1	103	000	108	808	5357	9500	1380	GES	(000)	100	70000	2000	7000	1871	1000	22	22	0.0	0.0	100	85	85	85	1000	991200	CLISPIN	RUDNE	HIDRO.	13/20/00	200	SU/USE
1	104	5	6	8	11	14	18	23	29	36	43	51	57	64	69	73	77	80 79	82	84	84	85	85	85	0.00	Tions.	CHECKEN.	2552.9	115010	13/2/2/2	1000
ŀ	105	5	5	8	9	13	16	19	27	33	38	48	55	59	67	72	74	77	80	82	84	85	85	85	COFFEREN	DOSHO	1058/90	Service Co.	200000	100000	-
Н	106	4	-	-	8	12	15	_	25	29	35	42	49	56	62	68	72	76	79	81	83	84	85	85	85	23045	10000	9635.21	CENTED IN	57123	200
Н	107	4	5	6	200	10	14	18	23	26	33	39	46	53	60	66	70	74	78	80	82	84	85	85	85	Children or the Children	Debug.	SOCIETY	and the same	350	-
Н	108	4	5	6	8	9	12	15	19	24	30	37	44	51	57	63	68	73	76	79	81	83	84	85	85	85	1052575	60955	412.02	15000	5300
Н	110	4	4	5	7	8	11	14	18	22	28	34	41	48	55	61	66	71	75	78	80	82	84	85	85	85	-			None II	
Н	111	4	4	5	6	8	10	13	16	21	26	32	38	45	52	58	64	69	73	77	79	82	83	84	85	85	85	R255-21	- Direct	58839	100
H	112	3	4	5	6	7	9	12	15	19	24	30	36	43	49	56	62	67	72	75	78	81	82	84	85	85	85			-	
ŀ	113	3	4	4	5	7	9	11	14	17	22	27	34	40	47	53	60	65	70	74	77	80	82	83	84	85	85	85	12553	100	1.5
ŀ	114	3	4	4	5	6	8	10	13	16	20	25	31	38	44	51	57	63	68	72	76	79	81	83	84	85	85	85	-		
ŀ	115	3	3	4	5	6	7	9	12	15	19	24	29	35	42	48	55	61	66	70	74	77	80	82	83	84	85	85	85	10000	E31
ŀ	116	3	3	4	5	5	7	9	11	14	17	22	27	33	39	46	52	58	64	69	73	76	79	81	83	84	85	85	85		
h	117	3	3	4	4	5	6	8	10	13	16	20	25	31	37	43	-50	56	62	67	71	75	78	80	82	83	84	85	85	85	1643
ľ	118	3	3	3	4	5	6	7	9	12	15	19	23	28	34	41	47	53	59	65	69	73	76	79	81	83	84	85	85	85	
h	119	3	3	3	4	5	6	7	9	11	14	17	21	26	32	38	45	51	57	63	67	72	75	78	80	82	83	84	85	85	85
ı	120	3	3	3	4	4	5	6	8	10	13	16	20	25	30	36	42	49	55	60	66	70	74	77	79	81	83	84	85	85	85
h	121	3	3	3	4	4.5	5	6	7	9	12	15	18	23	28	34	40	46	52	58	63	68	72	76	78	80	82	84	84	85	85
ı	122	3	3	3	3	4	5	6	7	9	11	14	17	21	26	32	37	44	5	56	61	66	71	74	77	80	81	83	84	85	85
ı	123	3	3	3	3	4	4	5	7	8	10	13	16	20	24	29	35	41	48	54	59	64	69	73	76	79	81	82	84	84	85
1	124	3	3	3	3	4	4	5	6	8	9	12	15	18	23	27	33	39	45	51	57	62	67	71	75	77	80	82	83	84	85
ì	125	3	3	3	3	4	4	5	6	7	9	11	14	17	21	26	31	37	43	49	55	60	65	69	73	76	79	81	82	84	84
ı	126	3	3	3	3	3	4	5	5	7	8	10	13	16	19	24	29	35	40	46	52	58	63	68	72	75	78	80	82	83	84
ı	127	-3	3	3	3	3	4	4	5	6	8	9	12	15	18	22	27	32	38	44	50	56	61	66	70	74	77	79	81	83	84
Ī	128	3	3	3	3	3	4	4	5	6	7	9	11	14	17	21	25	30	36	42	48	54	59	64	68	72	75	78	80	82	83
1	129	3	3	3	3	3	3	4	5	6	7	8	10	13	16	19	24	28	34	40	46	51	57	62	67	71	74	77	79	81	83
ſ	130	3	3	3	3	3	3	4	4	5	6	8	10	12	15	18	22	27	32	37	43	49	55	60	65	69	73	76	78	80	82
-	131	3	3	3	3	3	3	4	4	5	6	7	9	11	14	17	20	25	30	35	41	47	53	58	63	67	71	74	77	79	81
	132	3	3	3	3	3	3	4	4	5	6	7	8	10	13	16	19	23	28	33	39	45	50	56	61	66	70	73	76	78	80
	133	3	3	3	3	3	3	3	4	5	5	6	8	10	12	14	18	-22	26	31	37	42	48	54	59	64	68	72	75	77	80
	134	3	3	3	3	3	3	3	4	4	5	6	7	9	11	14	17	20	25	29	35	40	46	51	57	62	66	70	73	76	79
П	135	12715	COLUMN COLUMN	27-526	- CE	6,635	100	BEAT.	Sec. 8	1900	35.5	看得	Selection of the leading of the lead	2529	232	帰り	5.5%	及器	BRE	1828	539 5	POPY !	168	15,090	37800	100	C-10	1500	CASE.	D-3250	1040

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 104-134 feet.

Table 9 (continued). Probability of fire-induced mortality of a 32-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.

32-INCH (DBH) PONDEROSA PINE MORTALITY Probability of Mortality (%)

	Γ						-						TOTA	L SCC														
		122	124	126	128	130	132	134	136	138	140	142	144	146	148	150	152	154	156	158	160	162	164	166	168	170	172	17
	100								_			-				-	-	-	-			200000000000000000000000000000000000000		10000000000	200000000000000000000000000000000000000		0000000	-
	01		10000		30000		10000				PROPERTY.	20000	2000	100000	200000	2000000		-		1000000	B000000	20022	2000000	2300000	2000000	-	200000	1000
	102			10									-		-	-	-	-				-	100000	-	-	2000000		100
	103	1000			11000		E 200		100000	100000	200000	000000	100000			1000000		-		1000000	0000000	2000000	2000000	1000000	200000	-	2265000	100
	104	2		1.7			> 1		-	-	-	-	-	-		-	-	-	-		-	-	-	1000000	10000000		-	100
	105		198000	1000000	REAL PROPERTY.			1000000	100000		1000000	000000	10000		200000	2000000	1000000	20000000	20000000	10000000	1000000	2000000	10000000	-	-	10000000	100000000	1000
	106								-	-	-		-	-	1000000	-	200000	-	-	200000	-	-	1000000	10000000	200000	-	800000	100
	107				100000	100000	100000	100000	100000	-		000000			10000000	100000000000000000000000000000000000000	2500000	10000000	00000000	-	-	2000000	20000000	-		-	-	-
	108			-	1	-	0	-	1.0	-	-	-	-	-	-		-		-	1000000	-	-	1000000			2000	100000	-
	109	200		2000	00000	2000	100000		2000000				2200		100000	-	1000000	10000000	3000000	10000000	2000000	2000000	1000000	-	1	2	10000000	-
	110	7			100	5		-	-	-	-	-	2000000	Total Control	-	-	-	-	10000000	100000000	1000000	0.000000	10000000	100000	-	000000	1000000	100
	111				1000000	1000000	200000	100000	100000	200000	200000		-	1000	2000000	1000000	-	-	-	-	7	-	200000000	-	-		C C	-
	112			-	1.0	-	-	-	and the same				0000000	-	-	-	-	-	-	1000000	-	000000	100000	0000000		200000	100000	100
. 📃	113			350	100000	100000	2000		-	20000	20000	-				355-753	200000	1000000	-	2700000	1000000	2000000	-	200000	-	200000000000000000000000000000000000000	100000000000000000000000000000000000000	-
	114	-				-	-		-	-	-	-	-	-	-	-					-	-					20000000	100
	115		100 500	10000	10000	1000	100000	-	100000	2000000	200000	000000	1000000	1000000	1000000	100000	-		-	-	20000000	1	1000000	-	-	1000000000	Designation of the last	F
	116			-	-	-	-	distribution in	-	and the same of	-	10000000	2000000	1000000	-	2000000	100000	1000000	100000	1000000	100000	100000			00000	100000	2003000	100
	117	2000		200	400000		100000	U.S.		2000000	-	-	2333	-	1.3	40.1			-	-	1 0	-	1	-	-	-	-	t
	118			-	-	1	-	0.00	-	and the same	1000000	10000000	-	1000000	1000000	1000000	-	-	-	-	100000	100000	CONTRACT OF THE PARTY OF	100000	202233	10000000	00000	100
	119		200000	200000	1000000	000000	1000000	0000000	1000000	2000000	1000000	2000000	10000000	BOOLEGO SE	200000000000000000000000000000000000000	BOSON NAME OF THE PARTY OF THE	100000000000000000000000000000000000000	-	-	000000000000000000000000000000000000000	-	-	-		-		-	т
	120	0.5		200000000				CONTRACTOR OF THE PARTY OF THE		100000000	100000000000000000000000000000000000000	1000000	000000	20000000	1000000	1000000	1000000	000000			1000000	200000	1000000	-		100000		100
	121	85	0.000	C12000	100000	B10000000	10000000	1000000	1000000	20000000	10000000	20000000	0000000	-	-	-	-	-	-	-	-	-	-	-	-	2000	-	T
	122	85	85	B0000000		10000000		-	M00000000	-	10000000		2000000		-	E000000	1000000	0000000	1000000	4000000	E000000	1000000			100000	100000	2020	100
	123		85	10000000	100000	100000	200000	0.00000	20000000	200000000	2000000	2000000	2000000		-	MODEL SCHOOL SCH	-	-	-	-	-	-	-	-		-	-	т
	124	85 85	85	85	-	100000000	-		100000000	800000000	0000000	SECTION 1	200000	-	-	-	100000	100000	1000000	1000000		100000	100000	2000	100000	100000	2000	100
	125	85	85	85	1007-0000	1000000	10000000	SC-9000	100000	33060600	-	1000000	-	-	-	-	-	-	-	-	-					-	-	т
	126		85	85	85	40000000	10000000		1000000	1000000	2000000	000000	0.000		100000	E001500	CONTRACT	1000000	1000000	00000		100000	100000	10000	10000	100.000	103333	100
	127	85 84	85	85	85		-	-	-	-	-	-	-												1			Т
	128 129	84	85	85	85	85	100000	100000	000000	100000	10000		10000		00000	100000	100000	1000000	2000	100000	0.000	100000		100000	H-5855	95.596	140000	tion.
		83	84	85	85	85	-	-	-	-	100000000	-	-	1		-	-	-										T
	130 131	83	84	85	85	85	85	-	1000000	100000	200000	Charles.	1000	1000000	2000	1000000	60000	100000	1000	10000	10000	B1000	10000	100	9913	93.00	2000	100
	132	82	83	84	85	85	85	-	-	-	-			1007	G13 17	11.11	(00)											T
	133	81	83	84	85	85	85	85				0.000	2000	100000	00000	100000	1000	1000	100000					10000				die:
	134	81	82	83	84	85	85	85	-				-				-											T
	135	01	0.2	6.5	84	63	83	63	100000000	100000000		100000	Calles	1000000	1000000	10000	1000000	100000	NAME OF TAXABLE PARTY.	0000000		1000000	100000	1000000			18000	155

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins, 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 104-134 feet.

Table 10. Probability of fire-induced mortality of a 40-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.

	-		_	_												LSC									1 40			1	1	F0	T
117	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	t
115	and a	Test	Allega	100000	00.590	Secretary.	1000	06536	LINES CO.	0.000	2000	(9.00)	39/30/20	SIE	SUM.	16000	16.0521	20192	5/250	9000	175543	NEEDS.	lo rost	-015A	2252	3565014	3/50%	12503	130997	30150	由
117	10,90	1000	31.9	SOUT.	C-CCC	-	COLO	a College	22.230	TENOT C	332/55	11/202	77.7	0.000	T-SILES	190000	0.3980	25,15	U-CATA	700	1000	V (1900)	100000	2000.200		-	-	100.00		-	Ť
118	KING.	1820	SOFTER STREET	and the second	52342	20420	000000	107559	19302	1050040	SECO	250	10000	2421	ANTE DE	1379	100.000	1500	25126	950	SU.	10.0	E-PESON	65533	SASI	30 St.	1000	2003	1000	SCENE S	丰
119	1000	100	DAY.	22.00	Dist.	170000	12.000	-	2000	0.00	-	-	-					-	-	-	-	-									Ť
120	052	1000	BEAS	Sings.	105(5)	50963	2560	0100	1320	State	27/850	27550	278/25	05252	21523	22500	177110	2967	75583	SESS	1400	65259	238Sb	10:55	RESOT	20/163	3000	Y2255	THE LA	ETE	t
121	1000	200	3594	10000	-	-	-	-	-	200000	23300	PODE ST	-	100	-	-		-		-	-	-			1	-			17		T
122	0456	0.00	2440	SERVICE.	1000	E3350	20,80	FX500	1000	CORE	STREET	12125	5283	1010	12/200	Wall's	EDE)	(127)	26120	2505	(619)	WAR.	2550	DIME	1551	30,33	E619	Chi A	ESPECIAL DE	385	ı
123	100000	1000	-	-	-	-		-	-	-		-	-																1150		Т
124	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3
125	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	Т
126	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	E
127	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	Ι
128	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
129	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	Ι
130	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	91
131	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	Ι
132	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
133	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1
134	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	9
135	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1
136	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
137	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1
138	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4
139	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1
140	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4
141	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1
142	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
143	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	111
144	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4
145																												_		_	4
146	100	5252	335	500	15%	25.50	4.50	200	057	333	23	10.77	-43	125	ART.	500	100	1776	0.60	27.02	0(9)	17.5	882	Silv		TABLE	SEL	130	150	525	4
147																										_		-	-	-	4
148	796	100	55	288	910	11/3	(S)	0.0	1330	533	500	50	LO	250	188	雅等	930	5100	ASS.	0.55	26	2.25	1000	17/694	1000	200	307	100.50	4000	100	4
149																					_		_	_		_	_	-	-	-	4
150 morta	5236	040	33.38	20%	8316	228	0.88	1955	1300	370	1000	1964	1886	322	100/0	1000	1000	1982	Relation in	CHES	1900	HEAR	4635	PARTE	1933/5	使销	THE PARTY	596	133.17	0.896	4

Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 124-144 feet.

Table 10 (continued). Probability of fire-induced mortality of a 40-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height. I

40-INCH (DBH) PONDEROSA PINE MORTALITY Probability of Mortality (%)

			12				111									SCO														-
T	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	1
115			-		-	-	-	-		-	THE REAL PROPERTY.	100	-		1000	Property lies	The state of	1000	NAME OF TAXABLE PARTY.	In Table	STATE OF	2000	9000	District of the last	1000	A COLUMN	SERVICE	OSSESSION OF THE PERSON	100.00	0000
116		1000	10000	200	10000	10000			10000	10000	200000	-		-	10000	1000000	Contract of the last	CONTRACTOR OF THE PARTY OF	-	STATE OF THE PARTY.	-	2000		Total Control	-	-	-	-	-	
117		-		100000	10000	226500	Carlo	-	26565	THE REAL PROPERTY.	10000	- Constant			Sales Co	1000	45000		Contract of	560000	SCHOOL ST	15/0/03	(Suice	Arching.	100	13/25	00101	125538	1005	0300
119		-	1000	City C		100000	2000	-	No.	100000	100000				-		-	_	-		-									
120		1000	e Production	10000	District Control	No.	1000	Total Control	1000	25000	10000	200	10000	9.85	725	120399	69352	2300	2000	-31-00	0000	GE III	F17563	3500	500	B 183	1000	135		(40)
121		-	1000																											
122		Name of	123/50	10000	13000	4007	1000	Cons.	1566	-190	112250	Best a	1	2020	9891	HOSTE	1	1000	5000	22.77	100000	SOF!	10000	THE REAL PROPERTY.	100000	560	250	2000	1000	
123																														
124		12	2	2	3	3	4	5	6	7	9	11	14	17	22	26	32	37	43	49	55	60	64	68	71	74	76	78	79	80
125		2	2	2	3	3	4	4	5	7	8	10	13	16	20	25	30	35	41	47	52	58	62	66	70	73	75	77	79	80
126		12	2	2	2	3	3	4	5	6	8	9	12	15	19	23	28	33	39	44	50	55	60	65	68	72	74	76	78	75
127		2	2	2	2	3	3	4	5	6	7	9	11	14	17	21	26	31	36	42	48	53	58	63	67	70	73	76	77	79
128	2	2	2	2	2	3	3	4	4	5	7	8	10	13	16	20	24	29	34	40	46	51	56	61	65	69	72	75	77	78
129	2	2	2	2	2	3	3	3	4	5	6	8	9	12	15	18	22	27	32	38	43	49	54	59	64	67	71	73	76	78
130	2	2	2	2	2	2	3	3	4	5	6	7	9	11	14	17	21	25	30	36	41	47	52	57	62	66	69	72	75	77
131	2	2	2	2	2	2	3	3	4	4	5	7	8	10	13	16	19	24	28	34	39	45	50	55	60	64	68	71	74	76
132	2 2	2	2	2	2	2	3	3	3	4	5	6	8	9	12	15	18	22	27	32	37	42	48	53	58	62	66	70	73	75
133	1 2	2	2	2	2	2	3	3	3	4	5	6	7	9	11	14	17	20	25	30	35	40	46	51	56	61	65	68	71	74
134	1 2	2	2	2	2	2	2	3	3	4	4	5	7	8	10	13	16	19	23	28	33	38	44	49	54	59	63	67	70	73
135	5 2	2	2	2	2	2	2	3	3	4	4	5	6	8	9	12	14	18	22	26	31	36	41	47	52	57	61	65	69	72
136	5 2	2	2	2	2	2	2	3	3	3	4	5	6	7	9	11	13	17	20	24	29	34	39	45	50	55	59	64	67	70
137	7 2	2	2	2	2	2	2	2	3	3	4	5	6	7	8	10	13	15	19	23	27	32	37	43	48	53	58	62	66	69
138	3 2	2	2	2	2	2	2	2	3	3	4	4	5	6	8	9	12	14	18	21	25	30	35	40	46	51	56	60	64	68
139	2	2	2	2	2	2	2	2	3	3	3	4	5	6	7	9	11	13	16	20	24	28	33	38	44	49	54	58	63	66
140	2	2	2	2	2	2	2	2	3	3	3	4	5	6	7	8	10	12	15	19	22	27	31	36	42	47	52	56	61	65
141		2	2	2	2	2	2	2	2	3	3	4	4	5	6	8	9	12	14	17	21	25	30	34	40	45	50	55	59	6.
142		2	2	2	2	2	2	2	2	3	3	4	4	5	6	1	9	11	13	16	20	23	28	33	38	43	48	53	57	6
143		2	2	2	2	2	2	2	2	3	3	3	4	5	6	7	8	10	12	15	18	22	26	31	36	41	46	51	55	60
144		2	2	2	2	2	2	2	2	2	3	3	4	4	5	6	8	9	12	14	17	21	25	29	34	39	44	49	53	51
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Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 124-144 feet.

Table 10 (continued). Probability of fire-induced mortality of a 40-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.¹

40-INCH (DBH) PONDEROSA PINE MORTALITY Probability of Mortality (%)

														DRCH													
	122	124	126	128	130	132	134	136	138	140	142	144	146	148	150	152	154	156	158	160	162	164	166	168	170	172	17
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138	71	73	75	77	79	80	80	81	81	1000	2500	100000	2000	10000		2000		10000	100000	2000	100000	10000	10000	1000	102000		8
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142	65	69	71	74	76	77	79	80	80	81	81	1000			1000	1000	555				1000		10000			1000	
143	64	67	70	73	75	77	78	79	80	81	81	81															Γ
144	62	66	69	72	74	76	78	79	80	80	81	81	1000	50753	1000	1000	2000		1000	100000		3333		100000	155		
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Tree mortality values calculated with the BehavePlus Fire Modeling System (Andrews, P.L. and C.D. Bevins, 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 124-144 feet.

Appendix 2 – Criteria For Determining Rating Ranges For Decision Classes

Ponderosa Pine Young and Immature Trees

(Survival One Year After Fire)

Small Trees (< 16 in. dbh):

Composite Rating Ranges

	By Sur	vival Decisio	n Classes
	<u>High</u>	Moderate	Low
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	0-1	1-1
Dwarf Mistletoe Occurrence	0-1	1-1	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-2	4-4	6-6
Bole Scorch	0-1	2-2	3-3
Total Scorch Height	1-1	1-2	2-3
Duff Consumption	0-0	0-0	0-0
Totals	2-8	10-15	17-21

Large Trees (> 16 in. dbh):

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	Moderate	Low
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-1	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	0-1	1-2	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-2	4-4	6-6
Bole Scorch	0-1	2-2	3-3
Total Scorch Height	1-1	1-2	2-3

Duff Consumption		0-0	2-2	4-4
	Totals	2-9	13-18	21-25

Ponderosa Pine Mature and Overmature Trees

(Survival One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	Moderate	Low
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	0-0	0-1	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-2	4-4	4-6
Bole Scorch	0-2	2-2	3-3
Total Scorch Height	1-1	1-2	2-3
Duff Consumption	0-0	0-3	6-6
Totals	2-8	10-18	21-27

Ponderosa Pine Mature and Overmature Trees

(Survival Beyond One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	Moderate	<u>Low</u>
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	0-0	0-1	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3

Totals	2-6	7-12	15-24
Duff Consumption	0-0	0-0	3-6
Total Scorch Height	1-1	1-2	2-3
Bole Scorch	0-1	2-2	2-3
Crown Volume Scorch	0-1	1-1	2-3

Douglas-fir Young and Immature Trees

(Survival One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	Moderate	Low
C CE.	0.2	1.2	1.2
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	0-0	0-1	2-2
Root Disease Occurrence	0-0	0-1	1-1
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-1	1-2	3-4
Bole Scorch	0-1	1-2	3-4
Total Scorch Height	1-1	1-2	2-3
Duff Consumption	0-0	2-2	2-4
Totals	2-6	8-16	17-25

Douglas-fir Mature and Overmature Trees

(Survival One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

<u>High</u>	<u>Moderate</u>	Low
0-2	1-2	1-2

Season of Fire

Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	0-0	0-1	2-2
Root Disease Occurrence	0-0	0-1	1-1
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-2	2-2	4-8
Bole Scorch	0-1	1-2	2-4
Total Scorch Height	1-1	2-2	3-3
Duff Consumption	0-3	3-3	3-6
Totals	2-10	11-17	19-31

Engelmann Spruce All Size Classes of Trees

(Survival One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	Moderate	Low
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	N/A	N/A	N/A
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-0	3-3	6-12
Bole Scorch	0-3	3-3	6-9
Total Scorch Height	0-0	0-1	2-3
Duff Consumption	0-0	0-1	1-2
•			
Totals	1-6	9-14	19-33

Lodgepole Pine All Size Classes of Trees

(Survival One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	Moderate	Low
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	0-0	0-1	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-0	1-1	2-3
Bole Scorch	0-3	3-6	9-9
Total Scorch Height	1-1	1-2	2-3
Duff Consumption	1-1	1-2	2-4
T-4-1-	2.0	0.10	21.20
Totals	3-8	9-18	21-28

Western Larch All Size Classes of Trees

(Survival One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	Moderate	Low
Season of Fire	0-2	1-2	2-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	1-1	1-2	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	N/A	N/A	N/A
Crown Volume Scorch	0-2	3-3	4-4
Bole Scorch	N/A	N/A	N/A
Total Scorch Height	1-1	1-2	3-3
Duff Consumption	0-0	0-2	2-4

Totals 2-6 7-13 14-17

Grand Fir and White Fir All Size Classes of Trees

(Survival One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	Moderate	Low
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	0-0	0-1
Dwarf Mistletoe Occurrence	N/A	N/A	N/A
Root Disease Occurrence	0-0	0-1	0-1
Bark Beetle Pressure	1-1	1-2	1-3
Crown Volume Scorch	0-0	0-1	2-4
Bole Scorch	0-0	1-1	3-9
Total Scorch Height	1-1	1-2	2-3
Duff Consumption	0-0	1-1	2-6
	===		
Totals	2-4	5-10	11-30

Subalpine Fir All Size Classes of Trees

(Survival One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	<u> Moderate</u>	Low
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	0-0	0-1
Dwarf Mistletoe Occurrence	N/A	N/A	N/A

	Totals	2-4	5-10	11-30
Duff Consumption		0-1	1-1	2-6
Total Scorch Height		1-1	1-2	2-3
Bole Scorch		0-0	1-1	3-9
Crown Volume Scorch		0-0	0-1	2-4
Bark Beetle Pressure		1-0	1-2	1-3
Root Disease Occurrence		0-0	0-1	0-1

Western White Pine Young and Immature Trees

(Survival One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	Moderate	Low
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	N/A	N/A	N/A
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	2-2	3-3
Crown Volume Scorch	0-0	0-2	4-8
Bole Scorch	N/A	N/A	N/A
Total Scorch Height	0-1	2-2	2-3
Duff Consumption	0-0	0-0	1-2
Totals	1-4	6-10	12-20

Western White Pine Mature and Overmature Trees

(Survival One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	Moderate	Low
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	N/A	N/A	N/A
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-4	4-6	8-8
Bole Scorch	N/A	N/A	N/A
Total Scorch Height	1-1	2-2	3-3
Duff Consumption	0-0	0-0	1-2
Totals	2-8	9-14	16-20

Factors Affecting Survival of Fire Injured Trees: A Rating System For Determining Relative Probability of Survival of Conifers in the Blue and Wallowa Mountains

AMENDMENT 1

Donald W. Scott, Craig L. Schmitt, Lia Spiegel Blue Mountains Pest Management Service Center La Grande, Oregon 97850 June 26, 2003

Report No. BMPMSC-03-01 Amend. 1

This amendment documents changes to the parent document for grand fir/white fir, and lodgepole pine. The parent document is Report No. BMPMSC-03-01 dated November 25, 2002.

Preliminary field validation of the rating system on the Monument Fire on June 25, 2003 found that the rating system as described in the parent document worked relatively well for the species validated: immature and mature/overmature ponderosa pine, immature and mature/overmature Douglas-fir, white fir under 25 inches dbh, and western larch at various stages of maturity. Although we did not examine a complete range of conditions for lodgepole pine and mature/overmature white fir, we found that the lodgepole pine system tended to underestimate probability of tree mortality more times than not, and the grand fir/white fir system tended to overestimate probability of tree mortality for the mature or overmature grand firs; i.e., trees larger than roughly 25 inches dbh.

We have attempted to correct these problems in the rating systems included in this amendment. The mature/overmature grand and white fir rating system is entirely new, and is based in large part on running the Behave Plus model using a data set for grand fir from the Blue Mountains (southern Umatilla National Forest) to provide regression estimators for tree height based on diameter to use in the Behave Plus model. This rating system should be used on larger trees that are 25 inches and larger in diameter. We provide rating criteria for 30-40 inch trees. Trees 25-29 inches in diameter should use the 30-inch tree criteria; trees larger than 40 inches should use the 40-inch criteria. The original rating system for grand and white fir should continue to be used on all trees of these species under 25 inches in diameter.

The lodgepole pine rating system included in this amendment was modified from the original by adjusting the distribution of rating scores for individual criteria for the Decision Classes, and also increasing the penalty scores for the duff consumption criteria. We believe both these rating systems provide more accurate probability of tree mortality determinations than the original rating systems.

Grand Fir and White Fir (Mature and Overmature Trees ≥ 30 in. dbh)

(Use nearest diameter below to diameter of tree being evaluated)

RATING FACTOR

(2)

(3)

	n ratio) No visible scorching	(0)
u.	140 Visible scorelling	(0)
b.		
	Crown volume scorched between 0-64% (mortality probability 6-35.0%)	(1)
	Crown volume scorched between 65-83% (mortality probability 36-71%)	(2)
	Crown volume scorched between 84-100% (mortality probability 72-93%)	(3)
c.	For trees 32 in. dbh:	
	Crown volume scorched between 0-67% (mortality probability 5-38%)	(1)
	Crown volume scorched between 68-85% (mortality probability 39-71%)	(2)
	Crown volume scorched between 86-100% (mortality probability 72-92%)	(3)
d.	For trees 34 in. dbh:	
	Crown volume scorched between 0-68% (mortality probability 5-36%)	(1)
	Crown volume scorched between 69-85% (mortality probability 37-68%)	(2)
	Crown volume scorched between 86-100% (mortality probability 69-91%)	(3)
e.	For trees 36 in. dbh:	
	Crown volume scorched between 0-68% (mortality probability 4-33%)	(1)
	Crown volume scorched between 69-86% (mortality probability 34-69%)	(2)
	Crown volume scorched between 87-100% (mortality probability 70-90%)	(3)
f.	For trees 38 in. dbh:	
	Crown volume scorched between 0-71% (mortality probability 4-35%)	(1)
	Crown volume scorched between 72-87% (mortality probability 36-69%)	(2)
	Crown volume scorched between 88-100% (mortality probability 70-89%)	(3)
g.	For trees \geq 40 in. dbh:	
Ο.	Crown volume scorched between 0-71% (mortality probability 3-34%)	(1)

8. **Bole Char at Ground Level** (Scott and others 1996, with modification)

(To ensure accurate interpretation of the following criteria, the cambium at the root collar should be sampled from 4 areas of equally spaced quadrants from around the bole on a subsample of trees. The numbers enclosed in parentheses following the bole char criterion are the numbers of sampled quadrants with **dead** cambium out of the 4 quadrants sampled)

a. No charring present on bole or charring, if present, is light or only at surface (0)

Crown volume scorched between 72-89% (mortality probability 35-71%)

Crown volume scorched between 90-100% (mortality probability 72-88%)

- b. <20% of base of bole deeply charred (0 or 1 quadrant with dead cambium) (1)
- c. 20-60% of base of bole deeply charred (1 or 2 quadrants with dead cambium) (2)

		60-80% of base of bole deeply charred (2 or 3 quadrants with dead cambium) >80% of base of bole deeply charred (3 or 4 quadrants with dead cambium)	(3)
9.	(Use r	otal Scorch Height (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988) nearest diameter below to diameter of tree being evaluated) No visible scorching	(0)
	b.	For trees 30 in. dbh: Total scorch height between 0-74 ft. (mortality probability 6-35.0%) Total scorch height between 75-84 ft. (mortality probability 36-71%) Total scorch height between 85-106 ft. (mortality probability 72-93%)	(1) (2) (3)
	c.	For trees 32 in. dbh: Total scorch height between 0-80 ft. (mortality probability 5-38%) Total scorch height between 81-90 ft. (mortality probability 39-71%) Total scorch height between 91-112 ft. (mortality probability 72-92%)	(1) (2) (3)
	d.	For trees 34 in. dbh: Total scorch height between 0-84 ft. (mortality probability 5-36%) Total scorch height between 85-94 ft. (mortality probability 37-68%) Total scorch height between 95-116 ft. (mortality probability 69-91%)	(1) (2) (3)
	e.	For trees 36 in. dbh: Total scorch height between 0-88 ft. (mortality probability 4-33%) Total scorch height between 89-100 ft. (mortality probability 34-69%) Total scorch height between 101-122 ft. (mortality probability 70-90%)	(1) (2) (3)
	f.	For trees 38 in. dbh: Total scorch height between 0-94 ft. (mortality probability 4-35%) Total scorch height between 95-106 ft. (mortality probability 36-69%) Total scorch height between 107-128 ft. (mortality probability 70-89%)	(1) (2) (3)
	g.	For trees ≥ 40 in. dbh: Total scorch height between 0-98 ft. (mortality probability 3-34%) Total scorch height between 99-112 ft. (mortality probability 35-71%) Total scorch height between 113-134 ft. (mortality probability 72-88%)	(1) (2) (3)
10	. Duff (Consumption (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)	
	a.	No leaf litter or duff scorched or consumed	(0)
	b.	Leaf litter charred or consumed; upper duff charred, but not altered	(1)
	c.	over entire depth. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered.	(2)
	d.	Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish.	(3)

Subtotal Rating Score for Part B:	
Composite Rating Score Part A+B:	

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

Mature and Overmature Grand Fir and White Fir

<u>High</u> Probability of Tree Surviving = Composite Rating Score Ranging from	2-12
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from	13-16
Low Probability of Tree Surviving = Composite Rating Score Ranging from	17-21

Grand Fir and White Fir All Size Classes of Trees

(Survival One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	Moderate	Low
Season of Fire	0-2	2-2	2-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-1	1-1	1-1
Arrangement/Distribution of Down Woody Material	0-1	1-1	1-1
Dwarf Mistletoe Occurrence	N/A	N/A	N/A
Root Disease Occurrence	0-1	1-1	1-1
Bark Beetle Pressure	1-2	2-3	3-3
Crown Volume Scorch	1-2	2-2	2-3
Bole Scorch	0-1	1-2	3-4
Total Scorch Height	0-1	2-2	2-3
Duff Consumption	0-1	1-2	2-3
Totals	2-12	13-16	17-21

Lodgepole Pine (All Size Classes except as noted)

(This page replaces pages 17 and 18 in the original document)

RATING FACTOR

7.		n Volume Scorch (Ryan and Reinhardt 1989; Weatherby and others 2001)	(0)
		No visible scorching Crown volume scorched is ≤20% (63% mortality all trees ≤9")	(0) (1)
		Crown volume scorched is $\leq 20\%$ (80.0% mortality an trees ≤ 9)	
		Crown volume scorched is 20-30% (80.0% mortality for 9" trees) Crown volume scorched is >50% (>80% mortality for 9" trees)	(2)
	u.	Crown volume scorched is >50% (>60% mortainty for 9 frees)	(3)
8.		Root Char (Weatherby and others 2001)	
		No visible char	(0)
		<30% of bole circumference blackened (20% mortality)	(3)
		30-60% of bole circumference blackened (40% mortality)	(6)
	d.	>60% of bole circumference blackened (\geq 50% mortality)	(9)
9.	(Use 1	Scorch Height (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988) nearest diameter below to diameter of tree being evaluated) For trees 9 in. dbh:	
		Total scorch height between 0-28 ft. (mean mortality probability 63.0%)	(1)
		Total scorch height between 29-38 ft. (mean mortality probability 72.2%)	(2)
		Total scorch height between 39-58 ft. (mean mortality probability 98.4%)	(3)
	b.	For trees 15 in. dbh: Total scorch height between 0-40 ft. (mean mortality probability 44.0%) Total scorch height between 41-56 ft. (mean mortality probability 65.9%) Total scorch height between 57-80 ft. (mean mortality probability 97.5%)	(1) (2) (3)
	c.	For trees 21 in. dbh:	
		Total scorch height between 0-46 ft. (mean mortality probability 30.0%)	(1)
		Total scorch height between 47-64 ft. (mean mortality probability 54.7%)	(2)
		Total scorch height between 65-90 ft. (mean mortality probability 96.0%)	(3)
10.	Duff (Consumption (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)	
		No leaf litter or duff scorched or consumed	(0)
	b.	Leaf litter charred or consumed; upper duff charred, but not altered over entire depth.	(4)
	c	Leaf litter consumed; duff deeply charred or consumed, but underlying	(5)
	٥.	mineral soil is not visibly altered.	(=)
	d.	Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish.	(6)

Subtotal Rating Score for Part B:

Composite Rating Score Part A+B:

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

All Size Classes of Lodgepole Pine

<u>High</u> Probability of Tree Surviving = Composite Rating Score Ranging from	2-5
<u>Moderate</u> Probability of Tree Surviving = Composite Rating Score Ranging from	6-10
<u>Low</u> Probability of Tree Surviving = Composite Rating Score Ranging from	14-30

Lodgepole Pine All Size Classes of Trees

(Survival One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	Moderate	Low
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	1-1
Arrangement/Distribution of Down Woody Material	0-0	0-1	1-1
Dwarf Mistletoe Occurrence	0-1	2-2	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-0	1-1	2-3
Bole Scorch	0-0	0-0	0-9
Total Scorch Height	1-1	1-1	1-3
Duff Consumption	0-0	0-0	4-6
Totals	2-5	6-10	14-30

Factors Affecting Survival of Fire Injured Trees: A Rating System For Determining Relative Probability of Survival of Conifers in the Blue and Wallowa Mountains

AMENDMENT 2

Donald W. Scott and Craig L. Schmitt Blue Mountains Pest Management Service Center La Grande, Oregon 97850 August 30, 2006

Report No. BMPMSC-03-01 Amend. 2

Summary of Changes:

This amendment documents changes to the parent document for ponderosa pines 21-inches dbh and larger. The parent document is Report No. BMPMSC-03-01 dated November 25, 2002. Specifically, this amendment makes these changes:

- 1. Temporarily suspends use of Part C of the current Rating System until it can be validated with long-term survivorship data.
- 2. Modifies Part B: Ponderosa Pine (Mature and Overmature Trees >180 years old—Barrett 1979)
- 3. Specifies the site of cambium sampling for the **Bole Scorch** Factor (Factor No. 8) of Part B of the Rating System for all ponderosa pines to be the recesses formed at the interstices between major lateral roots at the root crown or root-collar region, where cambium is afforded greater protection from heat generated by smoldering duff against the bole.
- 4. Changes the **Bole Scorch** Factor (Factor No. 8) to clarify terminology used and to specify distinctions between penalty criteria related to numbers of quadrants sampled with dead cambium.
- 5. Modifies diameter classes for **Crown Volume Scorch** (Factor 7) and **Total Scorch Height** (Factor 9) to more accurately estimate large ponderosa pine survival by 2-inch dbh classes.
- 6. Modifies **Suggested Decision Classes** for mature and overmature ponderosa pine in Part B. of Rating System.
- 7. Specifies use of Part B of Rating System: Ponderosa Pine (Young and Immature Trees <180 years old—Barrett 1979) for trees up to 26 in. dbh that are in the young "Black-Bark" or "Bull Pine" form, and specifies use of <u>Amendment 2</u> Part B: Ponderosa Pine (Mature and Overmature Trees >180 years old—Barrett 1979) for ponderosa pines 21 in. dbh and larger that are in the older "Yellow-Brown Bark" form.

Discussion:

There are two types of fire effects recognized in the published fire effects literature: First-order and Second-order fire effects. Reinhardt et al. (2001) defined these as follows. "First-order fire effects are those that are the direct result of the combustion process such as plant injury and death, fuel consumption and smoke production." First-order fire effects occur at the time of the fire or shortly afterwards. "Second-order fire effects are the indirect consequences of fire and other post-fire interactions such as weather." They may take place a few hours to years after a fire. Important second-order fire effects include vegetation succession, release of serotinous cones by lodgepole pine, and trees succumbing to insect or disease infestations (Jain 2004; Caratti et al. 2005).

The Rating System takes into account First-order fire effects as well as incorporating factors that, for many species and size classes of trees, help characterize conditions in which trees undergo delayed post-fire tree mortality due to Second-order fire effects; that is, the mortality that continues well beyond the time First-order fire effects should have been complete. This amendment includes First-order fire effects and short-term Second-order fire effects; primarily mortality likely to be caused by an endemic population of western pine beetle and woodborers being attracted to and killing trees severely damaged and stressed by fire.

Delayed tree mortality is a post-fire effect of growing concern, particularly in silvicultural efforts to restore historic stand conditions containing large, old trees that previously survived frequent, lowintensity, low-severity fire regimes (Arno 2000). The proportion of trees dying from First- and Secondorder fire effects declines every year after the fire, but may extend out over a long period of time. Covington et al. (1997) observed that previous research near their study site showed prescribed burning resulted in high mortality of presettlement ponderosa pines (60 percent mortality over a 20-year period) and lethal soil temperatures under presettlement tree canopies (Covington and Sackett 1984, 1990, 1992; Harrington and Sackett 1990; Sackett et al. 1993) We have observed delayed mortality commonly occurring to large, mature and overmature ponderosa pines that were exposed to long-duration heating of roots and the root crown from smoldering combustion of deep accumulations of litter and duff at the base of these trees (Scott 2002). Published studies demonstrate that basal girdling and root injury are especially critical to initiating delayed mortality (Connaughton 1936; Herman 1954; Kaufmann and Covington 2001; McHugh and Kolb 2003; Rust 1933; Ryan and Amman 1996; Sackett and Haase 1998; Thomas and Agee 1986; Agee 2003). Hence, this amendment was prepared in an attempt to more accurately characterize large, old ponderosa pine survival after wildfire, as influenced by First-order and short-term Second-order fire effects.

While lethal First-order fire effects are immediate, or occur within a relatively short period of time after fire, those trees may not be readily recognized as being dead until two or possibly more years because the crowns may remain green. Crown symptoms of chlorotic to red foliage, though commonly recognized as being indicative of trees that are dying or dead, are often delayed in being expressed. While a tree requires live functioning roots, stem, and crown to remain alive, oftentimes, close inspection of recently fire-damaged trees will indicate that the roots or the stem of the tree have been killed while the crown (foliage) remains green. Crown fading will follow, but may be delayed depending on a variety of factors. A tree with the root system, stem, or crown lethally damaged, is a dead tree (Filip et al, *in press*; Schmitt and Filip 2005). Signs of stem mortality include deep charring completely encircling the circumference such that the phloem and cambium are girdled, or evidence of successful bark beetle colonization, also

extending completely around the circumference. Lethal root collar damage can be recognized by excessive or deep charring around the entire circumference at the base, with little or no remaining live cambium. The significance of these fire-induced injuries is affirmed by the fact that "burning locally destroys the phloem tissue and thus cuts the pathways for translocating carbohydrates and nutrients towards the root system" (Ducrey et al. 1996).

In the Rating System we have made a distinction between ponderosa pine younger than 180 years and ponderosa pine older than 180 years, and rate these trees for post-fire survivability differently. While in most cases, smaller pines will be younger trees, and trees larger than 21-inches dbh will be in the older age-class, there will be cases where mature, old pines are in the smallest (21-inch dbh class), and young pines that are growing on good sites and well-spaced, will be larger trees. Thus, the size classes can overlap, and the age distinction should be made on a stand basis, or between individual trees if they both occur in stands to be marked. These two age-classes are treated differently in our Rating System because of the likely differences in accumulated fuels between these groupings and the differences in potential damage when this material burns. Young, fast-growing pines normally have blackened deeply furrowed bark (Harlow and Harrar 1969) and have not yet developed the sloughing, plate-like bark. Sometimes, these trees are referred to as "bull," "Black-bark," or "blackjack" pines. The accumulated fuels around the bases of these trees are primarily cast needles. Older, slower-growing pines have the characteristic yellow-brown coloration and flattened surface of the bark. The dead outer bark of these older trees is comprised of a thick layer of plates that continually exfoliate and accumulate along with needles and other debris at the base of trees. Additionally, and in most cases, older trees and older stands have deeper accumulations of debris as a result of abbreviated recent fire periodicity and severity, and larger diameter trees have correspondingly more debris (Ryan and Frandsen 1991).

A number of formal and informal efforts at monitoring survival of large diameter ponderosa pines after wildfire and prescribed fire have been on-going in the Pacific Northwest and elsewhere for a number of years. During August 2006, we reviewed survival of large ponderosa pines 4 years and 10 years after fire on 2 different wildfires on the Malheur National Forest. Our observations revealed that delayed mortality of large, old ponderosa pines has not occurred at the rate projected by the current Rating System. Some large ponderosa pines that have been rated with the original procedures contained in Part B or Part C of the Rating System have survived 4 years, and some even up to 10 years, with 75% of the root quadrants containing dead cambium. We believe there are a number of reasons for longer-than-anticipated survival times for trees with sub-lethal injuries to roots, bole, and crown that are expected to undergo delayed mortality from Second-order fire effects: (1) basal sampling locations for the Bole Char factor (Factor 8) may be overestimating actual basal circumference with dead cambium; (2) epidemic insect populations have failed to develop within areas with numerous large-diameter root-injured trees; (3) drought has been moderated with good winter snow-packs containing high water content, and back-to-back "wet" springs with precipitation levels at or above normal precipitation have prevented moisture from becoming limited in trees with fire-induced root injuries; and (4) Larger trees having a greater range of variability of bark thickness, injury level, rooting habit and root-grafting potential, crown size and condition, etc., take longer to die resulting from changes in available moisture.

Accordingly, we do not believe that the current Rating System for Part C is refined enough at the present time to confidently rate trees having Low or Moderate probability to survive within any specified timeframe. There is broad variability of delayed mortality of trees rated under the present Part C of the Rating System, and that variability is influenced by moisture changes in growing seasons following the

fire, inconsistency in injuries from fire, site quality, size class, aspect, location, and insect populations and other factors that are unpredictable. For a few large ponderosa pines, delayed mortality may extend farther into the future than anticipated. For these trees, the duration of survival is imperfectly known and depends on many factors, some of which are largely unpredictable. Hence, we are temporarily withdrawing Part C from the Rating System until validation data supports its refinement and re-inclusion in the Rating System.

Given these issues, we believe it is necessary to review and refine Part B of the Rating System, specifically for mature and overmature ponderosa pines, and incorporate any needed changes. We have done that in preparing this amendment. First, we believe our training of marking crews to sample the cambium at the base of the tree by chopping through the bark to examine cambium near the root crown or on the main lateral roots may be providing overestimates of basal girdling since these sites are ones usually most exposed to heat from smoldering fire and most likely to contain fire-killed cambium. In this amendment, we are changing the location of cambial sampling for the **Bole Char Factor** (Factor No. 8) to the recesses formed at the interstices between major lateral roots, rather than on the roots themselves. Root crown or root-collar cambium tends to be protected from fire by thicker bark at these locations (Dickinson and Johnson 2001); hence, measurements of cambial survival or mortality for purposes of estimating the amount of circumference with basal girdling, will be more accurate if sampled at these locations.

In addition, we have attempted to improve accuracy in the Rating System with other changes in Part B for mature and overmature ponderosa pines, as included in this amendment. The changes in the Rating System covered in this amendment are based in large part on re-running the Behave Plus model (Andrews and Bevins 1999) using a data set for large-diameter ponderosa pines from the Blue Mountains (Malheur National Forest) to provide regression estimators for tree height based on diameter to use in the Behave Plus model. The Behave Plus model uses the Ryan and Reinhardt (1988) logistic regression equation and the bark thickness equations from Reinhardt et al.(1997) for different tree species, to compute probability of fire-induced tree mortality. Through these modeling runs, we have produced diameter classes for **Crown Volume Scorch** (Factor 7) and **Total Scorch Height** (Factor 9) to more accurately estimate large ponderosa pine survival by 2-inch dbh classes.

This amended Rating System should be used on larger ponderosa pines that are ≥ 21 inches in diameter. We provide rating criteria for 21-40 inch trees. Large trees ≥ 21 inches in diameter not included in this amended Rating System should use the nearest inch-class criteria to the tree being rated. For young and immature ponderosa pines up to roughly 26 inches in diameter, continue to use the original Rating System for these "black-bark" forms or size classes of ponderosa pines, as given in the original.

Thus, in this amendment we are specifying using Part B of the original Rating System for **Ponderosa Pine (Young and Immature Trees <180 years old—Barrett 1979)** for trees up to 26 in. dbh that are in the young "Black-Bark" or "Bull Pine" form, and specify using **Amendment 2** Part B: **Ponderosa Pine**(Mature and Overmature Trees >180 years old—Barrett 1979) for ponderosa pines 21 in. dbh and larger when these trees are in the older "Yellow-Brown Bark" form.

In this amendment, we have also modified the Rating System from the original by adjusting the distribution of rating scores for some of the criteria and the **Suggested Decision Classes**. Notably, we

have increased the penalty score for the **Bole Char Factor** (Factor No. 8) to reflect the significance of complete basal girdling to delayed mortality from Second-order fire effects.

Trees having High probability of survival are those that had non-lethal First-order fire effects and are unlikely to succumb to Second-order fire effects in the short term (2 to 3 years). These trees are identified in the Rating System as having a relatively low Composite Rating Score.

Trees having a Moderate probability of survival are those having been damaged by First-order fire effects where either the damage is sufficiently severe that tree mortality may result from injury to the roots, stem or crown (Ryan 1990; Schmitt and Filip 2004; Filip et al. *in press*), or where First-order fire effects are initially sub-lethal, but mortality from Second-order fire effects may result from insect attack, where trees are killed by a resident endemic population of western pine beetles or woodborers due to fire-induced damage and stress in the short-term (2 to 3 years). These trees have a Composite Rating Score that falls between the High probability and Low probability for survival. There is a lower certainty of survival or morality of trees in this class, scoring in the gray area between the trees likely to live and likely to die. We envision roughly half the trees falling within this category will die while roughly half will remain alive over the several years following the fire based on Ryan's statement "*in the absence of significant crown injury, most trees survive up to 25% basal girdling, but few trees survive more than 75%. Between these ranges about one-half of the trees survive"* (Ryan 1990). Trees identified as having a Moderate probability of survival have midrange Composite Rating Scores.

Trees having Low probability of survival are those that have been damaged by lethal First-order fire effects, or sufficiently injured that they are susceptible and highly likely to be affected by Second-order fire effects; killed by the resident endemic population of western pine beetles or woodborers in the short-term (2 to 3 years). It is expected that the large majority of trees that do die as a result of the fire will die within this timeframe. These trees are identified in the Rating System as having a relatively high Composite Rating Score.

Tree scoring in this Rating System has a variety of possible scenarios, and the probability of tree survival decreases with increasing Composite Rating Scores, even within the three individual Decision Classes. In addition, this Rating System may not fully account for interactions between different fire-caused injuries, some of which may combine to exacerbate mortality rates (Ryan 1990). In view of this, the Rating System will provide more liberal estimates of probable tree survival. Although the divisions between the Suggested Decision Classes are based on common outcomes of the likely conditions encountered after fire, these classes are not absolute. For example, it is possible for a tree to have lethal root collar damage (essentially 100% of the circumference girdled at the base), and by definition be dead (see Filip et al. *in press*; and Schmitt and Filip 2005), but the tree may rate out into the Moderate survival category, especially if the remaining portions of the tree experienced little or no visible damage. Another similar example would be a tree that had complete lethal crown volume scorch—again a dead tree—but, without lower bole or root-collar char. Trees that are rated using this system and fall into the Moderate survival probability class should be evaluated, particularly, for presence of the critical factors that determine tree survival such as live cambium at the root collar, or a viable live crown.

We believe the modified Rating System contained in this amendment provides refinements that reflect more accurate determinations of tree survival than the original Rating System contained in Part B for Mature and Overmature Ponderosa Pine. Moreover, we believe this modification of the Rating System offers a conservative approach to salvage marking and will result in the retention of greater numbers of large-diameter, mature and overmature ponderosa pines that may survive non-lethal First-order fire effects, and may not experience Second-order fire effects. Hence, this modification is consistent with Forest Service policy and the purpose of the Eastside Wildlife Screens: to preserve living old-growth forest for wildlife needs.

Part B. Factors for Determining Tree Survival up to 1 Year After Fire:

(Instructions: Assign the appropriate rating value in parentheses to each factor below, then subtotal score)

RATING

(3)

Ponderosa Pine (*Trees* ≥ 21 in. dbh; usually >180 years old—Barrett 1979)

(Use nearest diameter below to diameter of tree being evaluated)

<u>FACTOR</u>	<u>]</u>
7. Crown Volume Scorch (Reinhardt and Ryan 1988; assumes 50% pre-fire lands. No visible scorching	ive crown ratio) (0)
f. For trees 21 in. dbh: Crown volume scorched between 1-67% (mortality probability 6-419) Crown volume scorched between 68-85% (mortality probability 42-6) Crown volume scorched between 86-100% (mortality probability 76)	75%) (2)
g. For trees 24 in. dbh : Crown volume scorched between 1-71% (mortality probability 5-419) Crown volume scorched between 72-88% (mortality probability 42-7) Crown volume scorched between 89-100% (mortality probability 76)	75%) (2)
h. For trees 26 in. dbh : Crown volume scorched between 1-73% (mortality probability 4-42° Crown volume scorched between 74-90% (mortality probability 43- Crown volume scorched between 91-100% (mortality probability 77	76%) (2)
 i. For trees 28 in. dbh: Crown volume scorched between 1-74% (mortality probability 3-39) Crown volume scorched between 75-91% (mortality probability 40- Crown volume scorched between 91-100% (mortality probability 76) 	75%) (2)
j. <u>For trees 30 in. dbh :</u> Crown volume scorched between 1-76% (mortality probability 3-40° Crown volume scorched between 77-93% (mortality probability 41-° Crown volume scorched between 94-100% (mortality probability 76°).	75%) (2)
k. For trees 32 in. dbh: Crown volume scorched between 1-78% (mortality probability 3-419 Crown volume scorched between 79-94% (mortality probability 42- Crown volume scorched between 95-100% (mortality probability 77)	76%) (2)
1. For trees 34 in. dbh: Crown volume scorched between 1-78% (mortality probability 2-39) Crown volume scorched between 79-94% (mortality probability 40-	, , ,

Crown volume scorched between 95-100% (mortality probability 76-84%)

m. For trees 36 in. dbh:

- Crown volume scorched between 1-79% (mortality probability 2-40%) (1)
- Crown volume scorched between 80-95% (mortality probability 41-75%) (2)
- Crown volume scorched between 96-100% (mortality probability 76-83%) (3)

f. For trees 38 in. dbh:

- Crown volume scorched between 1-81% (mortality probability 2-41%) (1)
- Crown volume scorched between 82-96% (mortality probability 42-75%) (2)
- Crown volume scorched between 97-100% (mortality probability 76-82%) (3)

g. For trees \geq **40 in.** dbh:

- Crown volume scorched between 1-81% (mortality probability 2-40%) (1)
- Crown volume scorched between 82-97% (mortality probability 41-75%) (2)
- Crown volume scorched between 98-100% (mortality probability 76-81%) (3)

8. **Bole Char at Ground Level** (Ryan 1990; Ryan and Frandsen 1991; Wagener 1961; Schmitt and Spiegel 2002)

(To ensure accurate interpretation of the following criteria, the cambium at the root collar should be sampled from 4 areas of equally spaced quadrants from around the bole on all trees in the recesses between the main lateral roots (do not sample on the roots themselves). The numbers enclosed in parentheses following the bole scorch or char criteria are the numbers of sampled quadrants with **dead** cambium out of the 4 quadrants sampled)

- a. Bole scorching (blackening of the bole with no change in bark structure) (0)
 absent or light, with no bark consumption at the root collar and/or lower stem.
 Phloem and cambium not fire-killed.
- b. ≤75% circumference of the bole cambium and phloem at the root collar is dead (i.e., 1-3 quadrants with dead cambium); bole scorch, and bark consumption and char (any alteration of bark thickness and visibly changed bark structure) at the root collar and/or lower stem has occurred and may have killed most, but not all, of the cambium at the root collar. Cambium on the upper surfaces of the main lateral roots adjacent to the bole may be dead. Sampling cambium and phloem at 4 sites around the root collar in the recesses between the main and lateral roots (do not sample on the roots themselves) indicates that at least 25% of the circumference at the root collar is alive. If marking is delayed more than 1 year after the fire, other indicators such as woodpeckers and bark beetles may indicate a portion of killed root collar or bole circumference. A tree characterized with these conditions can be expected to survive for the short-term if other factors have not contributed lethal effects.
- c. >75% circumference of the bole cambium and phloem at the root collar is dead (4 quadrants with dead cambium); bole scorch and bark consumption at the root collar and/or lower stem is extreme, with bark consumption occurring around the entire root collar and/or lower stem. Sampling the cambium at 4 sites around the root collar in the recesses between the main

lateral roots indicates that less than 25% of the circumference at the root collar is alive. A tree characterized with these conditions is not expected to survive, having evidence of lethal root and/or bole damage, even though the crown may remain green for the short-term.

9.		Scorch Height (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988) Learest diameter below to diameter of tree being evaluated)	
	,	No visible scorching	(0)
		8	(-)
	f.	For trees 21 in. dbh:	
		Total scorch height between 1-74 ft. (mortality probability 6-41%)	(1)
		Total scorch height between 75-84 ft. (mortality probability 42-75%)	(2)
		Total scorch height between 85-104 ft. (mortality probability 76-93%)	(3)
	g.	For trees 24 in. dbh:	
		Total scorch height between 1-81 ft. (mortality probability 5-41%)	(1)
		Total scorch height between 82-92 ft. (mortality probability 42-75%)	(2)
		Total scorch height between 93-111 ft. (mortality probability 76-91%)	(3)
	h.	For trees 26 in. dbh:	
		Total scorch height between 1-86 ft. (mortality probability 4-42%)	(1)
		Total scorch height between 87-98 ft. (mortality probability 43-76%)	(2)
		Total scorch height between 99-116 ft. (mortality probability 77-89%)	(3)
	i.	For trees 28 in. dbh:	
		Total scorch height between 1-90 ft. (mortality probability 3-39%)	(1)
		Total scorch height between 91-103 ft. (mortality probability 40-75%)	(2)
		Total scorch height between 104-121 ft. (mortality probability 76-88%)	(3)
	j.	For trees 30 in. dbh:	
		Total scorch height between 1-95 ft. (mortality probability 3-40%)	(1)
		Total scorch height between 96-109 ft. (mortality probability 41-75%)	(2)
		Total scorch height between 110-126 ft. (mortality probability 76-87%)	(3)
	k.	For trees 32 in. dbh:	
		Total scorch height between 1-100 ft. (mortality probability 3-41%)	(1)
		Total scorch height between 101-115 ft. (mortality probability 42-76%)	(2)
		Total scorch height between 116-131 ft. (mortality probability 77-85%)	(3)
	1.	For trees 34 in. dbh :	
		Total scorch height between 1-104 ft. (mortality probability 2-39%)	(1)
		Total scorch height between 105-120 ft. (mortality probability 40-75%)	(2)
		Total scorch height between 121-136 ft. (mortality probability 76-84%)	(3)
	m.	For trees 36 in. dbh:	
		Total scorch height between 1-109 ft. (mortality probability 2-40%)	(1)

	Total scorch height between 110-126 ft. (mortality probability 41-75%)	(2)
	Total scorch height between 127-141 ft. (mortality probability 76-83%)	(3)
0	T	
f.	For trees 38 in. dbh :	(1)
	Total scorch height between 1-114 ft. (mortality probability 2-41%)	(1)
	Total scorch height between 115-132 ft. (mortality probability 42-75%)	(2)
	Total scorch height between 133-146 ft. (mortality probability 76-82%)	(3)
g.	For trees \geq 40 in. dbh:	
	Total scorch height between 1-118 ft. (mortality probability 2-40%)	(1)
	Total scorch height between 119-137 ft. (mortality probability 41-75%)	(2)
	Total scorch height between 138-151 ft. (mortality probability 76-81%)	(3)
10 Dff (Congruention (Dyon 1000) Dyon and Francisco 1001; Dyon and Nagto 1005)	
	Consumption (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985) No leaf litter or duff scorched or consumed	(0)
		(0)
D.	Leaf litter charred or consumed; upper duff charred, but not altered over entire depth.	(1)
c.	Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered.	(2)
d.	Litter and duff completely consumed, and top layer of mineral soil	(3)
u.	visibly altered, often reddish.	(3)
	Subtotal Rating Score for Part B:	
	Composite Rating Score Part A+B:	
Suggest	ted Decision Classes:	

(Refer to Rating Range Determinations Below)

Large Diameter Ponderosa Pines

<u>High</u> Probability of Tree Surviving = Composite Rating Score Ranging from	1-7
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from	8-15
<u>Low</u> Probability of Tree Surviving = Composite Rating Score Ranging from	16-24

Rating Range Determinations for Ponderosa Pines

(High, Moderate, and Low Survival Up To One Year After Fire)

Composite Rating Ranges

By Survival Decision Classes

	<u>High</u>	Moderate	Low
a ar	0.2	1.0	1.0
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	1-1
Arrangement/Distribution of Down Woody Material	0-0	0-1	1-1
Dwarf Mistletoe Occurrence	0-1	0-2	0-2
Root Disease Occurrence	NA	NA	NA
Bark Beetle Pressure	1-1	2-2	2-3
Crown Volume Scorch	0-0	1-1	2-3
Bole Scorch	0-2	2-2	6-6
Total Scorch Height	0-0	1-2	1-3
Duff Consumption	0-1	1-2	2-3
Totals	1-7	8-15	16-24

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