FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
507 — 25th Street, Ogden, Utah 84401

USDA Forest Service
Research Note INT-229

September 1977

PRELIMINARY GUIDELINES FOR PRESCRIBED BURNING UNDER STANDING TIMBER IN WESTERN LARCH/DOUGLAS-FIR FORESTS

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ABSTRACT

Guidelines are offered for safe, effective fire treatments in western larch/Douglas-fir forests. Describes procedures for estimating and limiting the scorching of tree crowns. Provides a method for predicting percentage of the forest floor that will be burned down to mineral soil.

KEYWORDS: fire management, prescribed fire, fire prescriptions, understory burning, firing techniques.

To successfully conduct a broadcast prescribed fire beneath standing trees, some means must be found to limit fire intensity and yet provide a desired treatment. By using a form of firing that will control the release of heat along with careful selection of burning conditions, a safe and successful fire beneath standing timber is possible. In a typical western larch/Douglas-fir forest (SAF-212), considerable care must be taken when planning the ignition pattern and when selecting and waiting for the correct burning conditions. Less care may be required in other forest situations such as in large, widely spaced ponderosa pines, with light fuel loadings beneath, or perhaps in a western larch seed tree cut where the residual trees are massive, fire-resistant old veterans. Even in these cases, control of fire intensity and attention to burning conditions are advisable. In yet other forests types, such as lodgepole pine or spruce stands, extreme care must be used if the residual stand is to be kept alive. The guidance offered here is most suitable for old-growth western larch/Douglas-fir stands, either in natural condition or where harvested by partial cutting. The duff reduction information applies equally well on clearcut, uncut, or partially cut areas that are broadcast burned.

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HOW TO BURN UNDER STANDING TIMBER

Burning Patterns

Heat can be dispersed by means of a firing pattern that consumes fuel in controlled amounts and that releases heat slowly and evenly. Probably the best means of firing in the understory in the western larch/Douglas-fir types is a series of strictly limited strip headfires. As the name suggests, strips of fuel are ignited and burned out, beginning at the upslope end of the fire area, or the downwind end if the terrain is flat. Once a strip has burned out to a low level of fire activity, the next strip is ignited, and so forth, until the fire treatment is completed. In proper fuels a backing fire is at least as good as strip headfiring; however, fuel continuity, fuel size class distribution, and fuel moisture content are usually unfavorable for a backing fire in western larch/Douglas-fir forests. Strip headfires, *properly conducted*, are much more flexible.

Hazards

To reap the benefits of strip headfiring, two rules must be followed. First, a strip must be allowed to burn until fire intensity markedly drops before proceeding to the next strip. Second, strip width must be small enough to prevent the full flame height and width of a free-burning, forward-spreading fire from developing. If either rule is violated, damage to the stand in the form of tree-crown scorch will increase, sometimes dramatically, along with more frequent crown fires and the danger of spot fires.

Research shows that when broadcast burning in western larch/Douglas-fir stands with down, dead woody fuel loadings from 5- to 50-tons/acre, 15- to 20-foot strips is the limit for consistent control of the fire intensity. These limits should be observed and adopted where similar fuels are to be burned in this forest type. (Strips can be narrower if fire behavior indicates the need for tighter control or limitation.)

Successful understory burning in heavy down, dead, woody fuels requires patience. A strip must be allowed to burn up before another is ignited, and impatience must not lead to wider and wider strips. Patience is also needed when waiting for the correct prescribed conditions for burning.

Avoiding Crown Scorch

One means to determine the need for narrower strips is the flame height in a stand. Preliminary data indicate that Douglas-fir with 60 percent of the crown scorched will probably not survive. Western larch and ponderosa pine can apparently stand more scorch than Douglas-fir; the exact amount is unknown. Little is known about other species in the Rocky Mountains. Until studies give more explicit guidance, crown scorch in Douglas-fir should be less than 60 percent of crown length.

Albini (1975) has presented a crown scorch model (fig. 1) that relates flame length to scorch height on a standard (77° F) day. The curves represent different windspeeds. To use the curves, estimate maximum length of the flames, measure windspeed, and look up the maximum scorch height on the chart. Measure the temperature and go to figure 2 to estimate the scorch height that is occurring. For example, if the temperature is 60° F and the estimated flame length is 4 feet with a 5 mi/h wind, the maximum scorch height is about 18 feet. At 60° F, the actual scorch height is about 0.75 of maximum or about 13.5 feet. If this scorch height is less than about 60 percent of the crown of the desirable Douglas-firs, flame height is acceptable. If more than 60 percent of the crowns are being scorched, it may be possible to reduce the flame height by taking narrower strips of fuel in each strip headfire. The model will estimate scorch height for any tree species, but the limit of scorching is often not known. The author has used this technique repeatedly on fires and found it useful and sound.

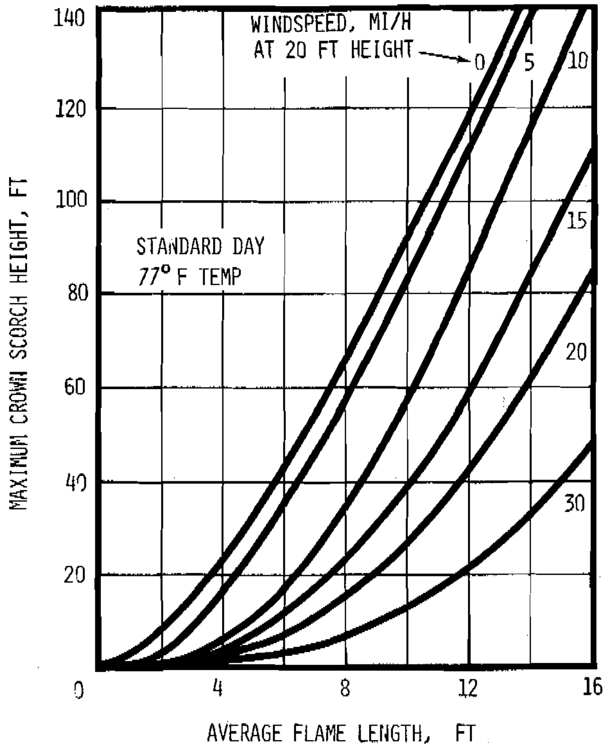


Figure 1.--Maximum height of crown scorch versus flame length on a 77° F day.

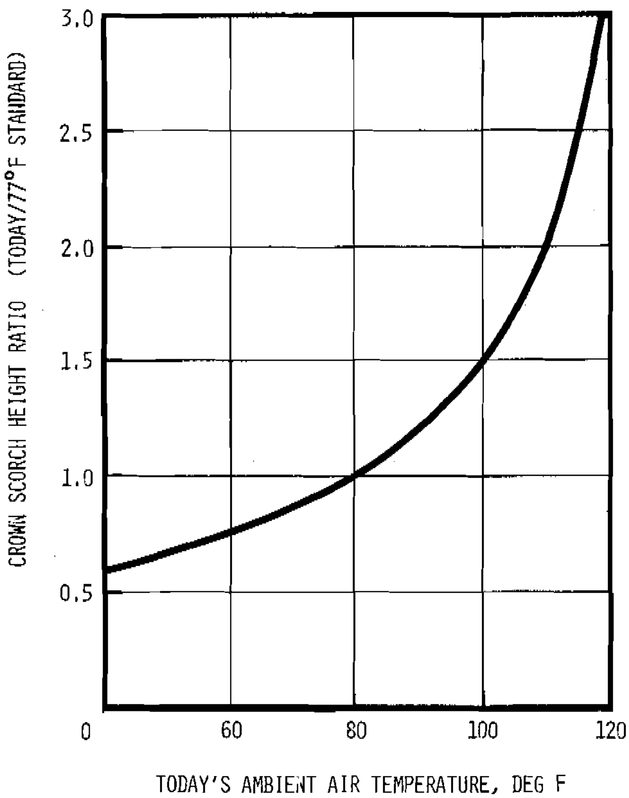
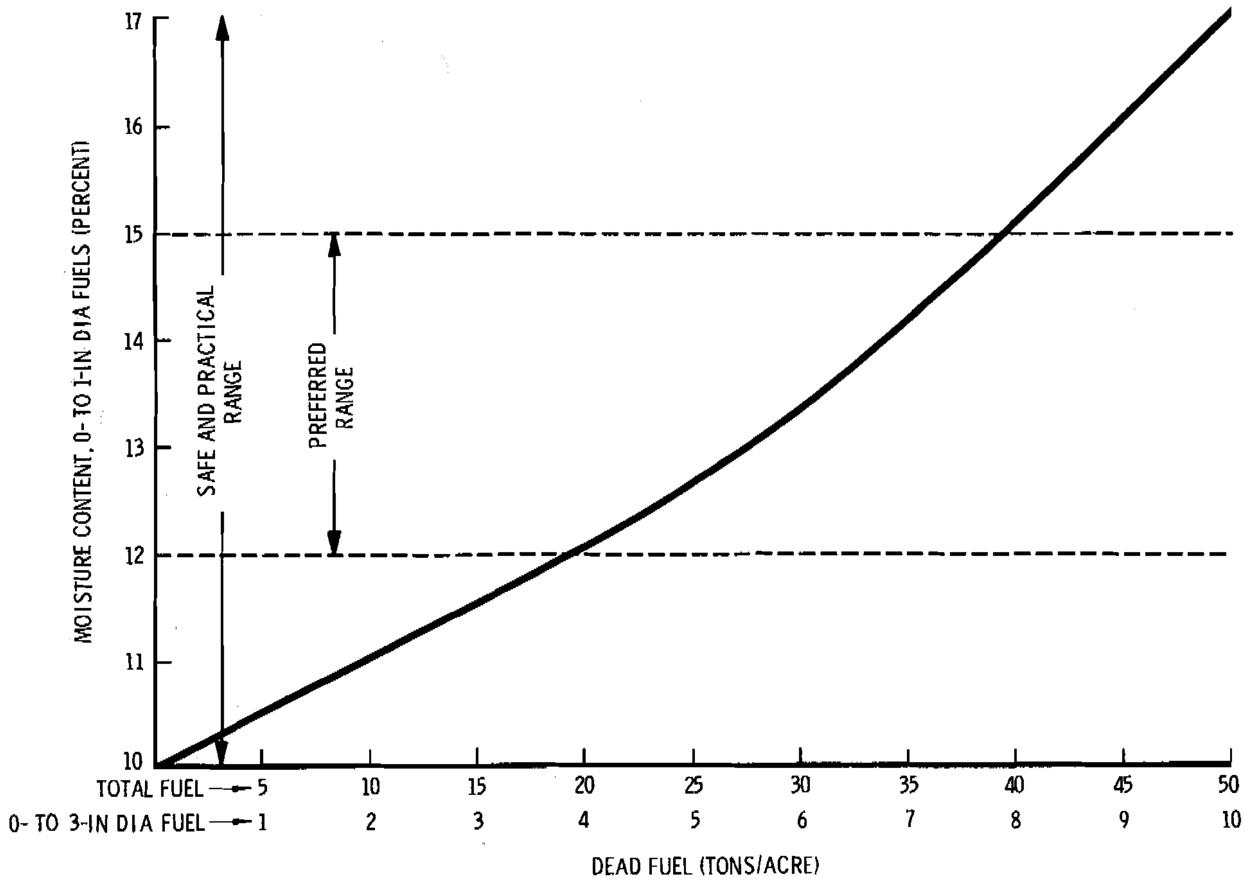


Figure 2.--Relationship of scorch height to burning-day ambient temperature.

When To Burn

Fuel moisture determines the degree to which a fire accomplishes the land manager's objectives. We must first know the range of burning conditions over which it is possible to burn, yet completely control the fire. To help answer this question, we compiled the graph in figure 3 from our experience in burning under standing timber in a large number of western larch/Douglas-fir stands. The diagonal, curved line gives various sets of fuel moistures and fuel loadings for a spreading fire that is readily controllable and not unduly damaging to overstory trees if other conditions are favorable. The fuels should be reasonably well distributed and uniform over the area. Windspeed should be below 10 mi/h, and preferably below 5 to 7 mi/h if directly upslope. At 10 percent fuel moisture content, the fire will be fairly intense and will spread readily. At 17 percent moisture content, a continuous bed of fine fuel (preferably cured, needle-bearing slash) is necessary to prevent a ragged fire treatment. This kind of burning is easiest and safest within the preferred range of fuel moisture content shown in figure 3, especially if the heavier fuel loadings are burned at or near the 15 percent level of moisture content and lighter fuel loadings around the 12 percent mark.



Fuel Moisture Content

The fuel moisture values indicated in figure 3 are for the actual fuels to be burned. Because the range of desired fuel moisture is quite narrow and highly influential, the moisture content must be taken only from fuel samples. Half-inch fuel moisture sticks tested over a period of 2 years during the burning of 24 stands were frequently in error by as much as 5 percent moisture content from that of the actual fuels. An error of this size can have a pronounced effect on fire behavior and results. Fuel moisture sticks should not be used for this kind of understory burning.

Fuel moisture can be estimated by means of conventional ovendrying techniques. Fuel moisture can also be calculated within 30 minutes of ignition by means of a microwave oven powered by a portable generator, at the site to be fired. Both techniques are outlined in the appendix. A detailed research paper on microwave oven technique is being prepared by the author. If fuel moisture cannot be estimated, the fire should not be conducted. Too much is at stake. Figure 3 lists fuel moisture for 0- to 1-inch-diameter down, dead, and woody fuels. A sampling procedure similar to the one described in the appendix should be followed.

Fuel Loadings

The fuel loading values shown in figure 3 are estimated by a planar intersect fuels inventory. The sampling density and procedure are described by Brown (1974). Two fuel load scales are shown in figure 3. If the fuel is recently created slash, logged to a 4-inch top and utilized for sound logs and poles, the total fuel load value can be used. For other cases, the 0- to 3-inch-diameter fuel load should be relied upon. (When in doubt, use the 0- to 3-inch value.)

It is not intended that only those values falling on the line in figure 3 be considered as good conditions for burning, but rather to show where burning is most safe and effective. Above 30 tons/acre total fuel load, or 6 tons/acre of 0- to 3-inch material, fuel moisture contents from 13 to 17 percent are advisable. Below these fuel loadings, the 10- to 13-percent range will give the best fires.

The foregoing describes conditions when burning under standing timber is possible and controllable without destroying a mature stand of moderately to highly fire-resistant tree species. Most trees with thin bark will be killed in any of these fires. This is true whether a tree is a young western larch or an old lodgepole pine. The fires can be safe and burn well, yet kill trees. Most Douglas-fir, ponderosa pine, and western larch larger than about 5 inches d.b.h. will survive. Most Engelmann spruce, subalpine fir, lodgepole pine, and trees smaller than about 5 inches d.b.h. will not survive. Even this will vary. The key is bark thickness and the percentage of the crown that escapes scorching temperatures.

Duff Reduction

The reduction of duff, and the baring of some mineral soil is often one of the objectives of fire treatment, especially where a seedbed receptive to certain species of trees is desired. When the duff is sufficiently dry it will burn, although quite slowly. Most often, especially during the usual seasons of prescribed burning, the duff is much too wet to burn unless a considerable amount of heat is applied from larger fuels burning above the duff. The duff is dried, ignited, and consumed to a degree dependent on how wet the duff is and how much fuel is available.

Experimental results show that duff consumption can be predicted if moisture content of the duff and fuel consumption or fuel availability can be estimated. Figure 4 shows the relationship between the percentage of duff removed and the moisture content of the lower half of the duff. Note that below about 30 percent moisture content, duff

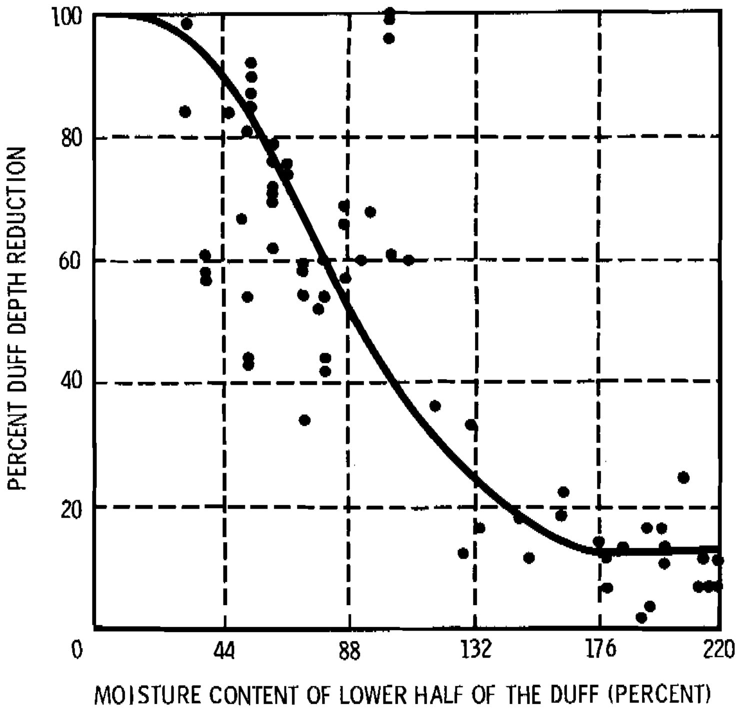


Figure 4.--Percentage of preburn duff depth reduced by broadcast fires versus the moisture content of the lower half of the duff. Curve fitted to experimental data.

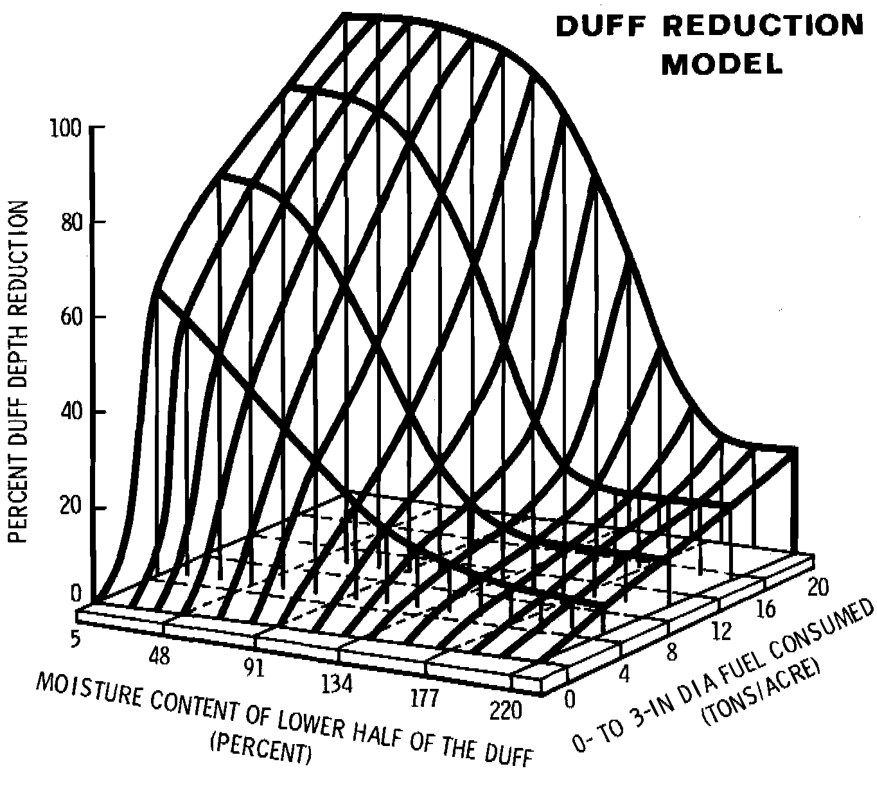


Figure 5.--Percentage of duff reduction as it varies with combinations of moisture content of the lower half of the duff and the amount of 0- to 3-inch-diameter down, dead, and woody fuels consumed.

is almost completely consumed. This agrees with the moisture of extinction value used by Albini (1976) for the closed timber litter fuel model. Presumably this is where duff will burn unassisted. As moisture content rises, the amount of duff consumed drops until, at about 150 percent, the curve flattens out, suggesting that only about 15 percent of the duff can be removed. Note also that some of the points fall well above the curve and some well below. This is a reflection of the influence of the fuels burning above the duff.

The influence of fuel consumption is more easily understood by viewing the three dimensional diagram in figure 5. This diagram was developed by fitting a mathematical model to measured data, following the procedures described by Jensen (1973). Note that the third axis is the amount of 0- to 3-inch-diameter surface fuels that burned. At any given value of moisture content in the lower duff, an increased amount of 0- to 3-inch surface fuel consumed gives an increased amount of duff consumption. This reflects the influence of the heat from fuels burning above the duff. However, as the duff gets wetter, an increasing amount of fuel is needed to reduce an equal amount of duff. When the duff is very wet, the amount of fuel burned has a severely decreased effect on how much duff will be removed.

For the convenience of the user, the relationships among the amount of duff removed, the moisture content of the lower half of the duff, and the amount of 0- to 3-inch surface fuel consumed have been tabulated in table 1. To use the table, one needs to know the moisture content of the lower half of the duff (ovendrying technique) and how much 0- to 3-inch-diameter down, dead, and woody fuel will be burned. The latter information is obtained by inventorying the fuels: the combined preburn weight of the 0- to 1/4-inch, 1/4- to 1-inch, and 1- to 3-inch size classes, as described by Brown (1974). In the range of safe and practical moisture contents shown in figure 3, the amount of 0- to 3-inch fuels consumed is estimated with surprisingly reliable accuracy by multiplying the preburn weight by 0.78. Enter the table with that value along the line entitled "0 to 3 inch fuel loss" and stop at the value closest to your result. Then read down that column for combinations of percentage of duff moisture and percentage of duff reduction. The figure indicates percentage of preburn duff depth that will be burned away.

One further finding leads to a useful means for estimating the percentage of the area that will be bared to mineral soil. Although not strictly true, the duff tends to be removed in an even layer all across a broadcast burned area in western larch/Douglas-fir stands. Anyone who has done much burning knows that some spots will burn hotter than the surrounding area. However, an analysis of several thousand duff reduction measurements on 61 broadcast-burned clearcuts and 24 broadcast fires under standing timber in western larch/Douglas-fir stands revealed that only five fires had a standard deviation in duff depth reduction greater than 1.25 inches, and that 70 percent of the fires had less than a 0.8 inch standard deviation in duff depth reduction. The assumption of a uniform layer of removed duff appears to be sound.

Table 1.--*Percentage of duff depth reduction*

Moisture content, lower half of duff	0-to 3-inch fuel loss (tons/acre)				
	0	5	10	15	20
	Percent				
5	0	61	79	90	100
10	0	59	78	90	100
15	0	58	78	90	100
20	0	56	78	90	100
25	0	53	77	90	100
30	0	51	76	90	100
35	0	49	75	90	100
40	0	46	73	90	100
45	0	44	71	89	100
50	0	42	68	88	100
55	0	39	65	87	100
60	0	37	62	85	100
65	0	35	58	83	99
70	0	32	54	81	99
75	0	30	50	78	99
80	0	28	45	74	98
85	0	26	41	69	97
90	0	25	37	65	96
95	0	23	33	59	94
100	0	21	29	53	92
105	0	20	26	48	89
110	0	18	23	42	86
115	0	17	20	36	83
120	0	16	18	31	78
125	0	15	16	27	74
130	0	14	14	24	68
135	0	13	13	21	62
140	0	12	12	19	56
145	0	11	12	18	50
150	0	10	11	17	44
155	0	10	11	16	39
160	0	9	11	16	34
165	0	9	11	16	30
170	0	8	11	16	27
175	0	8	11	16	25
180	0	7	11	16	23
185	0	7	11	16	22
190	0	7	11	16	22
195	0	6	11	16	21
200	0	6	11	16	21
205	0	6	11	16	21
210	0	6	11	16	21
215	0	5	11	16	21
220	0	5	11	16	21

The author has had good success in predicting the percentage of the area burned to mineral soil by using the following process. First, measure duff depth at many points scattered about the planned burn unit (100 points is a good number). Decide the percentage of the area you desire to have bare to mineral soil. Call this "Percent Bare": for example, Percent Bare = 60 percent. List preburn duff depths measured. For example:

Preburn duff depths (Inches)
4
3
2
1
0
6
5
3
4
3

For simplicity, this example has only 10 measurements, so set n = 10. To have 60 percent of the area bare to mineral soil, six sample points must be reduced to zero duff depth.

Because duff tends to be removed in an even layer, examine the list to see how thick a duff layer must be burned off to bare 60 percent of the points. Proceed as follows:

1 point is zero, or 10 percent of the area sampled.
2 points are 1 inch or less, or 20 percent of the area sampled.
3 points are 2 inches or less, or 30 percent of the area sampled.
6 points are 3 inches or less, or 60 percent of the area sampled.

Therefore, we must burn away a layer 3 inches thick. Of course, some points do not have 3 inches of duff, but if we prescribe the fire to burn away 3 inches of duff, those with less than 3 inches will be bare along with those that have 3 inches.

Compute the percentage of loss for each point if 3 inches is removed, and average the result. If the preburn depth is less than 3 inches, award 100 percent.

	Percent
$3 \div 4 = 0.75 \times 100 =$	75
$3 \div 3 = 1.0 \times 100 =$	100
2	100
1	100
0	100
$3 \div 6 = 0.5 \times 100 =$	50
$3 \div 5 = 0.6 \times 100 =$	60
$3 \div 3 = 1.0 \times 100 =$	100
$3 \div 4 = 0.75 \times 100 =$	75
$3 \div 3 = 1.0 \times 100 =$	100
Total =	860

$$\text{Average} = \text{Total}/n = \frac{860}{10} = 86 \text{ percent} = \text{needed percentage of duff loss.}$$

You can now determine if the fuel loading on the area will create a fire hot enough to burn away the desired amount of duff. As stated previously, you can estimate this by multiplying the 0- to 3-inch fuel weight by 0.78. Enter table 1 under "0- to 3-inch Fuel Loss" in the column closest to your result. For our example, assume a preburn 0- to 3-inch fuel weight of 20 tons/acre. Multiplying 20 tons × 0.78 = 15.6 tons, so enter the table under the column headed 15 tons/acre. We see that it is possible to remove 90 percent of the duff if it is at 5 percent moisture content. Our computed percent duff depth reduction was 86 percent, which would be achieved at a duff moisture content between 50 and 55 percent if we burned when the 0- to 1-inch fuel moistures are within the 10 to 17 percent range discussed earlier.

SUMMARY

For many managers, understory burning is a new experience. Mistakes are often made during first attempts because some of the fire effects are not obvious at the time of the fire. In particular, the scorching of the crowns does not become apparent until days or even weeks after the fire. The fire may have all of the appearances of going nicely, only to show a severely scorched stand a few days later. The procedures described for estimating the scorch are strongly recommended. Using these estimates the fire manager can adjust the fire as described and achieve the desired objectives with minimal damage to the stand. Ignoring these details will often lead to needless damage. Burning when the 0- to 1-inch fuels are within the recommended range will yield fires that are effective and safe. Selecting a duff moisture content of the right value will give the added benefit of removing the desired amount of the duff layer.

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APPENDIX

Sampling Fuels and Duff for Moisture Content

To use the prediction models given in this paper, the moisture contents of the 0- to 1-inch-diameter down, dead, and woody fuels and the lower half of the duff must be determined. Several samples should be taken from locations distributed across the fire areas. The 0- to 1-inch samples should be taken from about the midpoint of the depth of the fuel bed, and should be about equally divided between the 0 to 1/4 inch and 1/4 to 1 inch size classes in each sample. They should, in every way possible, represent the fuels that exist. The duff should be collected from the lower half of the duff, regardless of duff depth. Be careful to exclude any mineral soil from the duff sample. Roughly a large handful of material should be collected for each sample.

If a standard oven at 100° C is to be used to dry the fuels, a period of 24 hours is needed to determine the moisture content. Therefore, the fuels should be sampled each day for several days ahead of the fire day, taken at about the same time of day that ignition is planned. By doing so, a drying trend can be plotted on a graph, and a reasonable estimate of the fuel moisture can be projected. This scheme is frustrated if the weather conditions change during the night before or the day of the fire, but if the daily weather pattern remains consistent the procedure is reliable. As a last resort, the fuels should be sampled at least once, 24 hours before the fire, and ovendried to determine their moisture content. If the weather does not cause rapid wetting or drying, the estimate will be reasonably accurate.

A suggested procedure follows:

1. Go to the unit to be burned at about the time of day you expect to burn.

2. Collect one sample of 0- to 1-inch-diameter down and dead woody fuel from each of 10 points spread out across the unit. Ten points on a diagonal through the unit is a good pattern. Take the samples from the midpoint of the depth of the fuel bed. Put the sample in a container and seal it tightly.

3. At each point collect a sample of the lower half of the duff, avoiding mineral soil. Place in a container and seal it.

4. Transport the samples to a drying and weighing facility and weigh the wet samples. If the collection containers are deep and narrow (like a test tube), it is advisable to transfer the samples to wider, more open containers before weighing and drying. Record the weight of the container of wet fuel to an accuracy of 0.1 gram.

5. Dry the fuels in a 100° C oven overnight (approximately 24 hours).

6. Remove the dried samples from the oven, one at a time, and quickly weigh again to an accuracy of 0.1 gram. Record the weight of the container of dry fuel.

7. Discard the fuels, weigh the drying container and record it as "tare" weight.

8. Calculate the fuel moisture content as follows:

   a. Subtract the tare weight of the container from the weight of the container of wet fuel and call this "wet weight"; wet + tare - tare weight = wet weight.

   b. Do the same for dry weight: dry + tare - tare weight = dry weight.

   c. Calculate moisture content:

$$\%\text{ moisture content} = \frac{\text{wet weight-dry weight}}{\text{dry weight}} \times 100$$

Figure 6 shows a sample form for calculating moisture content of fuels.

FUEL MOISTURE CONTENT
UNIT __________

DATE __________
NAME __________

Sample I.D.	Wet + tare	tare	Wet wt.		Dry wt. + tare	tare	A Dry wt.		B Diff	C M.C.		$C = \frac{B}{A}$		

Figure 6.--Sample form for calculating ovendry moisture content of fuels.

The procedure for using a microwave oven is similar, but certain precautions are necessary. Further, because the drying can be accomplished in about one-half hour, the fuels can be sampled shortly before ignition is planned, and the decision to burn can rest on the results.

The weighing procedure is the same as described before, as are the calculations. To dry the samples, place them in weighed, *nonmetallic* containers. Wide, flat glass containers work well. Place the samples in the microwave oven. It is also very important that you place 3 or 4 moistened sponges in the oven in order to avoid damage to the oven as the samples become dry. Turn the oven on for 3 minutes. Turn the oven off and stir each sample, using a piece of wire or a glass rod. Be careful that no sample material spills from the container or sticks to the stirring rod. Repeat the process seven or eight times to be sure all moisture is driven off. Keep the sponges damp throughout the process. Proceed with the weighing procedure and calculations as previously discussed for standard ovendrying.

The following safety precautions should be observed.

Medical authorities feel that microwave ovens may interfere with the normal operation of medical electronic devices, such as cardiac pacemakers. Consequently, people using such devices should not operate microwave ovens.

Other safety practices recommended are:

1. Have oven tested at least once a year for radio frequency leakage.

2. Do not use the oven if the door does not close and latch firmly against the oven front.

3. Periodically check door for worn hinges, torn or twisted door seal, and any other visible sign of damage.

4. Do not try to use the oven with the door open and do not attempt to defeat any interlocks.

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