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FUEL MOISTURE--A GUIDE FOR EVALUATING SEVERITY OF FIRE SEASONS

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ABSTRACT

Field personnel in all forest fire protection agencies need some simple but reasonably accurate method for evaluating severity of the fire season as it progresses and of comparing severity of the current season with that of preceding fire seasons. This paper proposes use of records of average fuel moisture percentages cumulated continuously for 5-day periods throughout successive fire seasons. Records for all seasons must start on the same calendar day. Beginning and closing dates should be selected so as to enable complete recording of buildup to and recovery from the peak of each season's severity.

The paper describes two systems for graphing cumulated fuel moisture percents so as to facilitate comparison. It also tells how to interpret the resulting curves--the relation of segments within a curve, and the relation of the current season's curve to earlier records--and points out unavoidable limitations of the proposed systems.

INTRODUCTION

For many years fire control personnel have been attempting to devise methods for comparing severity of successive fire seasons. As values of forest and range lands increase, fire control becomes correspondingly more important. As any fire season advances, some measure of its development and increase of severity becomes extremely important in anticipating problems and preparing to solve them. Also, some measure of seasonal severity is useful in evaluating the efficiency of the fire control organization. For several years, Intermountain area fire protection agencies have used the Model-8 Burning Index Meter to predict and evaluate daily burning conditions and a component of this meter, Severity Index, to arrive at a measure of relative buildup.[1] Other regions have danger rating systems that perform similar functions. In using any danger rating system, judgment must be exercised in making many decisions related to fire presuppression and suppression activities.

[1] Buildup: Cumulative effects of drying (during preceding period) on current fire danger.

OBJECTIVES

This paper outlines and explains a system for evaluating fire season development and for rating severity. The system was originally designed to supplement the Intermountain Fire-Danger Rating System; however, the principles and methods discussed can be applied to most existing danger rating systems. The system described here can be used in conjunction with the National Fire-Danger Rating System when it is adopted locally. The specific capabilities and intent of this system are:

1. To provide a simple, practical guide that may be used by field personnel to:

    a. Assist in tempering judgment.

    b. Aid in accurately comparing one fire season to another.

    c. Aid in evaluating fire season buildup and potential.

2. To provide a longer and more nearly adequate period of season rating coverage.

3. To utilize available records with the minimum of conversion and calculation.

METHOD

Fuel moisture percents, as obtained from the $\frac{1}{2}$-inch fuel-moisture-indicator sticks,[2] are the basic component. Fuel moisture percents determined by other methods may also be used. The basic assumption of this system is that the drier the fuel condition and the more fuel that is available to burn, the greater is the potential severity of a given season. A potentially severe season becomes a reality only if natural or human agents start fires.

Fuel moisture percents, as recorded from daily measurements throughout the fire season, are cumulated by 5-day groups. Then, using measurements from as many years as possible, an average[3] 5-day cumulated fuel moisture can be computed. Increments of 5 days are used in cumulating fuel moisture percents to reduce the total number of figures. Larger increments could be used; however, doing so decreases sensitivity. Ideally the period of May 1 through October 31 would cover the fire season in the Intermountain area, showing both buildup and recovery. For this presentation, fuel moisture percents for the period of June 1 through September 30 are used.

A graph of the computed average 5-day cumulative fuel moisture percent shows a climbing curve; this is to be expected when plotting successive cumulated totals. Each fire-weather station would have its own characteristic curve. Figure 1 shows these curves for four selected fire-weather stations in Forest Service Region 1. An easy method of comparing the severity of any season to that of the computed average season would be to draw curves for both seasons on the same graph; this would show whether the cumulated moisture for the year in question was above, below, or about the average. The chief drawback to this method is that it requires a comparatively large graphic scale to show changes for each 5-day period.

An alternate method of graphing, which seems better suited for general administrative use, requires that the average 5-day cumulative fuel moisture percent be plotted as a straight horizontal line and that the average be considered as 100 percent. The period being compared is then related as a percent of the

[2] Specially prepared sticks or sets of sticks of known dry weight continuously exposed to the weather and periodically weighed to determine changes in moisture content as an indication of changes in moisture in forest fuels.

[3] The term "average" as used in this paper is the arithmetic mean. The arithmetic mean was chosen because it is the most commonly used average, the most easily understoood, the easiest to compute, and requires only total values and numbers. The disadvantage of this method is that its value may be greatly distorted by extreme values; therefore, it may not be typical. This is why it is extremely important to use as many years' data as are available to help avoid overinfluence by unusually wet or dry years. Including more years' data in the average tends to reduce the effect of any extremes.

average. To represent the computed relationship graphically, the horizontal axis of the graph represents calendar date; the vertical axis represents percent. The curve immediately tells whether the current cumulated fuel moisture for the present season is above or below average, whether the season is getting wetter or drier, and at what rate changes are occurring. In figure 2, the curves for percent of average are shown for 1960, 1961, and 1962 for the same four fire-weather stations shown in figure 1.

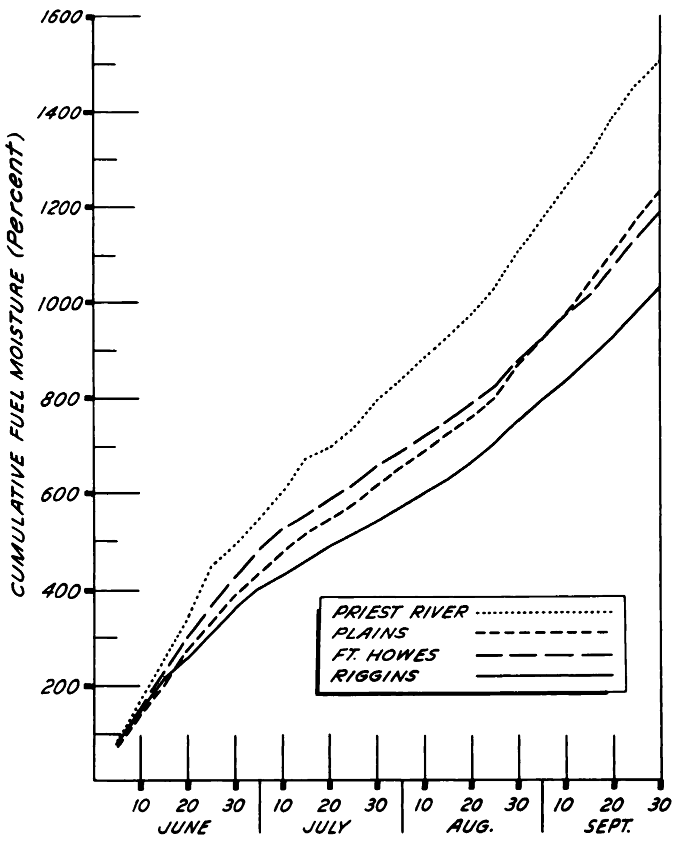


Figure 1.--Average 5-day cumulative fuel moisture curves for four fire-weather stations in Forest Service Region 1.

INTERPRETATION AND APPLICATION

Once the 5-day cumulated fuel moisture as a percent of average has been calculated, what can be done with it, and how can it be used?

Some interpretation is necessary before any application can be made. The percent-of-average curve has three basic characteristics that are tempered by curve position. The curve for any year being compared to the average is either climbing, falling, or parallel to the average line; and is either above, below, or on this line. Each of these conditions has a definite meaning and can be interpreted. The position of the curve at any point in relation to the average line is determined by antecedent conditions of fuel moisture. If the curve is above the average line, the cumulated fuel moisture has been greater than is usually expected under average conditions. Thus, when the curve falls below the average line, the cumulated fuel moisture has been less than average.

Generally, in any fire season anywhere in the Intermountain West, high fuel moistures in the spring are followed by a drying period during the summer. In the fall, rain and snow cause a wetting or recovery from the summer drying. Figure 3 shows the relation of fuel moisture to season that usually exists in the area represented by the four stations shown in figures 1 and 2.

Local relations of season to fuel moisture must be considered when evaluating the percent-of-average curve for any year. Such relations necessarily vary by locations. The percent-of-average curve indicates not only the difference in cumulated fuel moisture but also the rate at which this difference occurs.

A climbing curve, regardless of whether it is above or below the average line, indicates that fuel moisture is cumulating at a rate faster than normal (see fig. 4, left). This tells us that the location being observed is going through a wetting period or a period when the fuel is drying at a slower rate than is usually expected for that period. Steepness of the slope of the curve must also be considered; the steeper the climb the more rapid the wetting or the slower the drying as related to average.

A falling curve indicates the opposite of a climbing curve (see fig. 4, right). The greater the drop the greater the drying; or, depending on the general season, the slower the wetting as compared to the average. Here again, steepness of slope of the curve is important. The steeper the slope, the faster the change as related to normal.

A parallel curve shows that the recording location is experiencing a period when the rate of fuel moisture cumulation is the same as the average rate. Either the loss or gain of moisture during the period when the curve parallels the average line is the same as the rate normally experienced for that same time of year. Whether the parallel portion of the curve is above or below the average line is determined by the moisture situation preceding the period being compared.

The position of the curve at the beginning of the season is important because it indicates whether the season started above, below, or at normal (average) fuel moisture conditions. The trend of succeeding readings is also important because it indicates how the season is progressing, whether the potential fire danger is increasing, and how severity of the present season compares with the average severity for the given location.

This type of information about severity trends can be very useful to fire control agencies. If the current season's curve starts at a point below average and continues to drop, an early and a long fire season is indicated <u>unless</u> something happens to reverse the trend. On the other hand, if the curve for the current season starts at a point above average and continues to rise, it indicates a shorter or less severe season. Some unusual weather condition is necessary to bring the cumulative moisture curve back to normal once it has been established above or below the average line. When any segment of the current season's curve falls or rises markedly or closely parallels the "average" line, the preceding section of curve must be evaluated to aid in weighting the effect of the latest trend. For example, if the curve during July dips downward sharply and the preceding portion of the curve was climbing above the average line, the present situation is less critical than if that same dip were occurring following a downward trend below average.

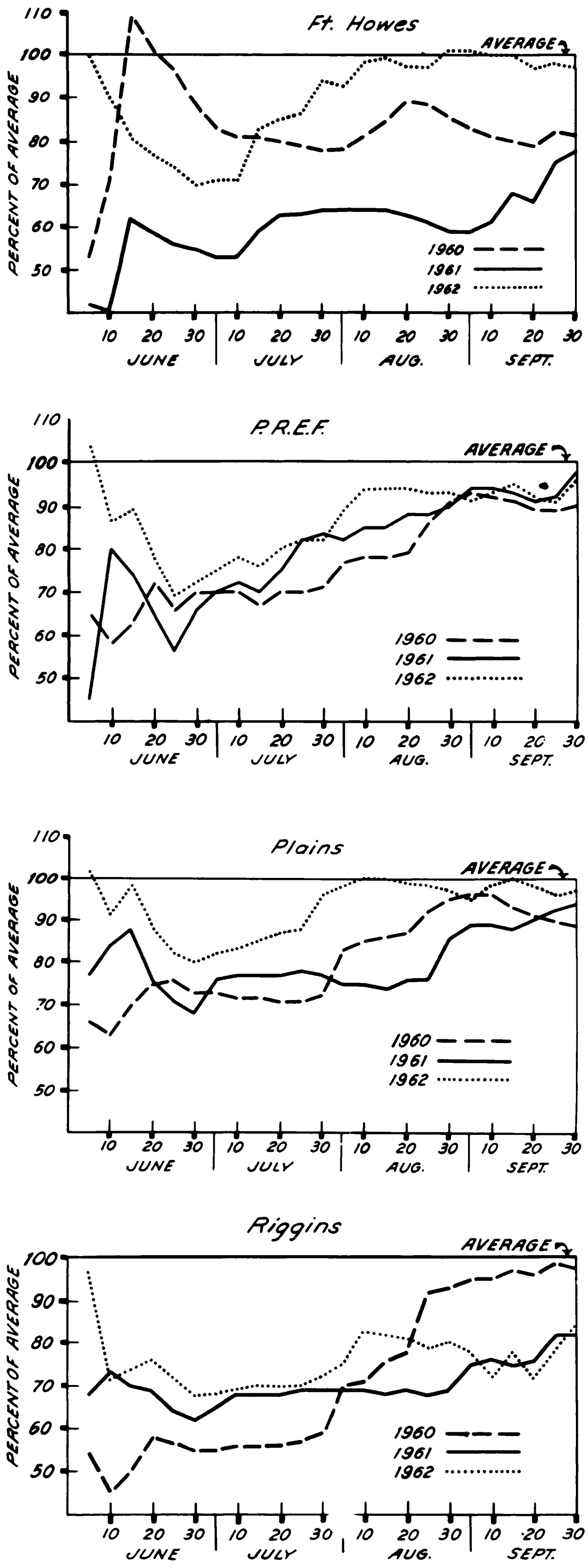
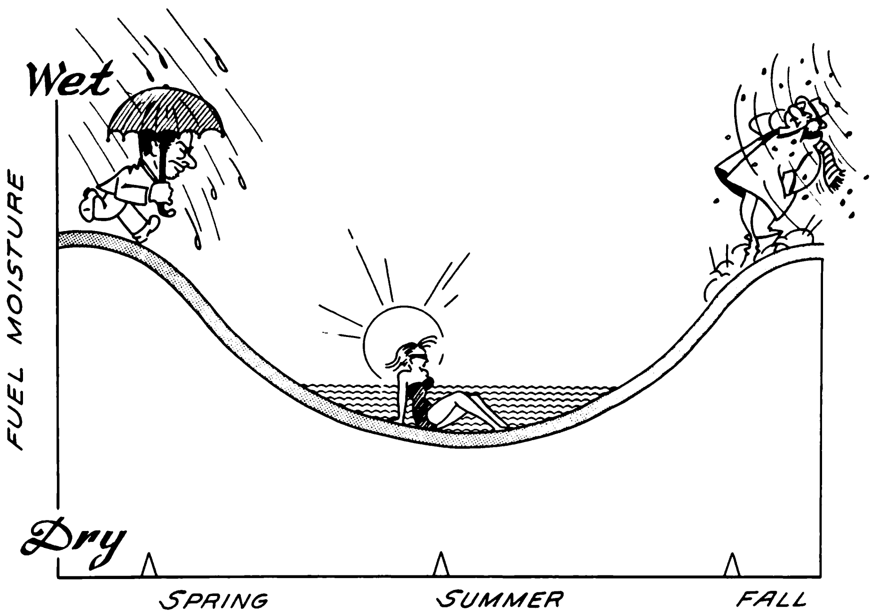


Figure 2.--Five-day cumulative fuel moisture as a percentage of average for four fire-weather stations in Forest Service Region 1.

Figure 3.--Relation of season to fuel moisture in Forest Service Region 1.



The period being compared to the average may be any length desired--10 days, 2 weeks, 1 month, or 3 months. Figure 5 shows a comparison on a monthly basis. A word of caution: the seasonal trend should be evaluated in order to temper the results of this type of comparison.

SUMMARY

As stated above in "Objectives," this system is intended merely to aid in situations where personal judgment must be exercised in making fire-control decisions. The system is based on the assumption that potential severity of any fire season is related directly to cumulated moisture; the corollary assumption is that the drier the season the greater is its potential severity. We cannot now prescribe limits to show when a certain percentage of average is "critical" or "easy." However, the curves point out buildups, recoveries, and their rates, all of which might be unnoticed in using other methods. When fuel moisture percents are below average at the beginning of a season and continue to drop, a potentially bad season is imminent. The season becomes severe only if high natural and human risks are in evidence. It is also easy to tell how far above or below average a season is on any given date. Also, the curve for a season might start below average and parallel the average line, indicating that the trend is similar to normal but that the season started in drier condition. This suggests that the area of the recording station will have a longer than usual dry period if no rain falls before the latter part of the fire season.

This system should be used only as a means for evaluating severity of the current season as basis for making decisions. Spread index alone does not necessarily show early or late buildup or the drying of forest

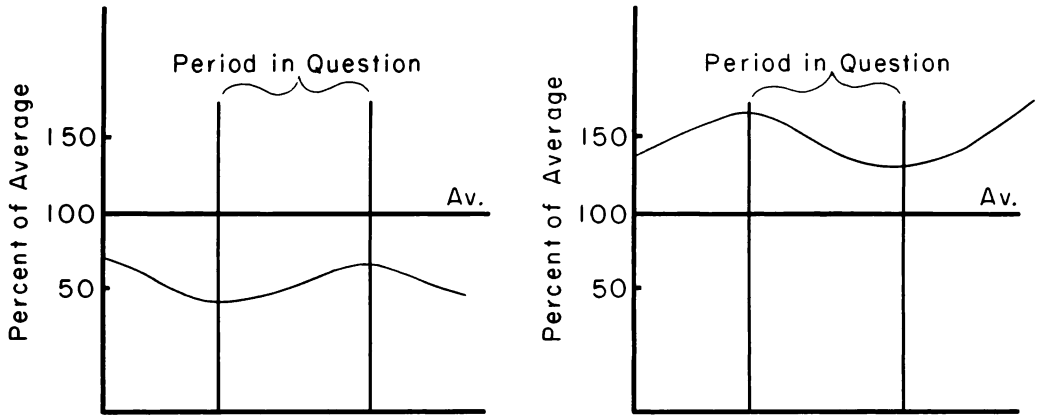


Figure 4.--Comparison of an individual time period to the cumulated fuel moisture as a percent-of-average curve: Left, Drier than average year with wetter than average period; right, wetter than average year with drier than average period.

and range fuels. An early buildup indicates that all fuels are drying. The additional drying of larger fuels increases the amount of total fuel readily available for burning. No quantitative measure of the exact amount of fuel increase is now available. However, a graphic presentation similar to figure 2, showing that the small fuels are drier than average and by how much, indicates that the larger fuels are also relatively drier. This concept is often overlooked.

PROCEDURES FOR CALCULATIONS

For those who desire to make their own comparisons to a computed average on a 5-day seasonal or other periodic basis, the following explanation covers the necessary procedures.

Average 5-day cumulated fuel moisture percent.--To determine the long-term average, 5-day cumulated fuel moisture percents for identical periods must be computed for as many years as complete data are available. Measurements must begin on the same date of each year. (For this paper, June 1 was selected.) Ideally, the starting date should be early enough in the year to include the entire buildup period. Sufficient length of coverage should be allowed in order to avoid terminating ratings before any fire season is over. If a given year's set of data ends before the end of the fire season, it can be used; however, if a station does not begin recording cumulated moisture until after the predetermined common starting date, the data for that entire year cannot be used. Missing fuel moisture percents for 1 or 2 days can be estimated as outlined in regular observational procedures.

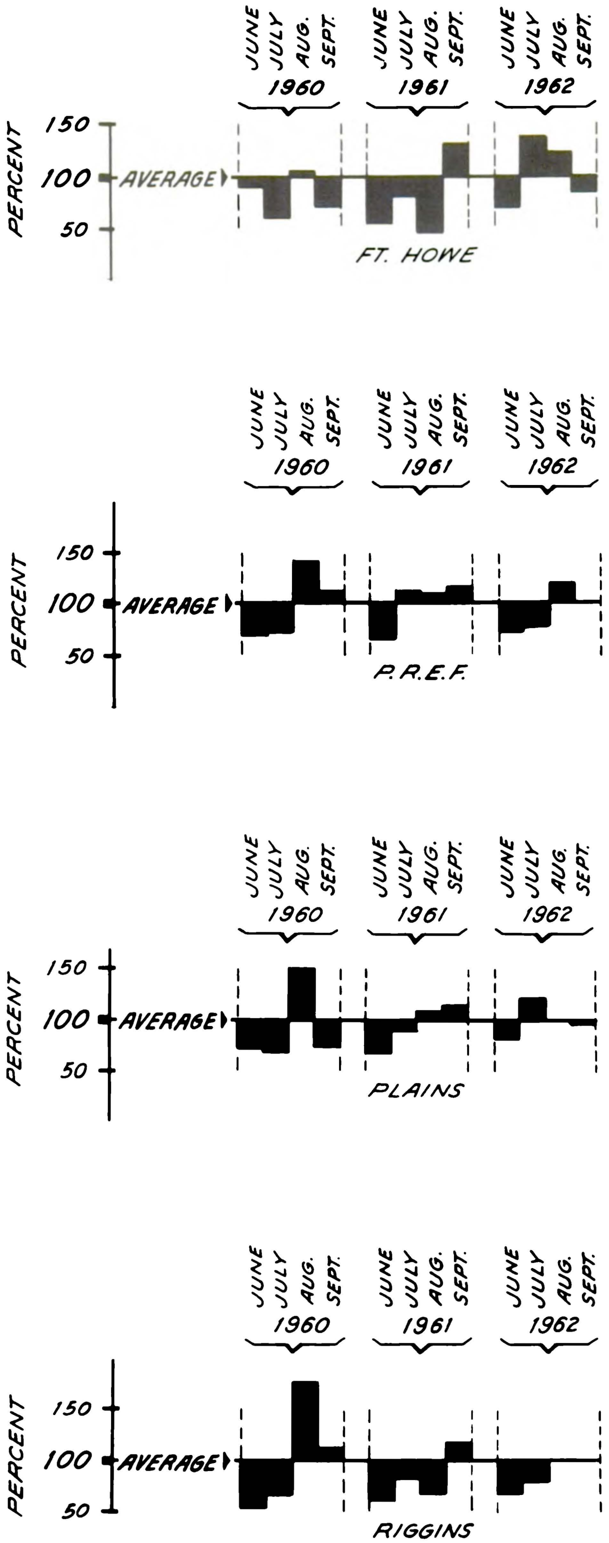


Figure 5. --Monthly cumulated fuel moisture as a percentage of average for four fire-weather stations.

The following table illustrates the procedure for computing the average. It illustrates recording and computing procedure for only the month of June, but the procedure would be the same for all other months in a fire season. Notice that the 1959 data had to be discarded because observations did not start on the common date, June 1. The 1960 and 1962 data in the example could be used for the entire period. Data for the first 20 days of June 1961 can be used. As long as records of fuel moisture percents begin on the proper date and are continuous, they can be used even though they do not cover the entire fire season. Using even these incomplete data strengthens the earlier part of the season's average.

Determining average percents of 5-day cumulations of fuel moisture

	Daily fuel moisture percents				5-day cumulated fuel moisture percents				Average 5-day cumulated fuel moisture percents
June	1959	1960	1961	1962	1959[1]	1960	1961	1962	
1	--	13	9	12					
2	--	11	10	14					
3	--	25	14	25					
4	--	25	21	12					
5	--	26	23	12	*	100	77	75	84
6	--	16	14	11					
7	--	13	12	10					
8	--	9	9	8					
9	--	14	9	10					
10	--	12	10	25	*	164	131	139	145
11	--	9	8	14					
12	--	10	10	21					
13	17	17	20	50					
14	19	24	17	33					
15	15	28	8	20	*	252	194	277	241
16	17	18	8	15					
17	13	11	8	12					
18	10	9	7	9					
19	9	8	6	10					
20	8	8	7	8	*	306	230	331	289
21	8	8	6	8					
22	7	8	6	7					
23	8	7	7	7					
24	6	6	--	7					
25	5	7	[2] --	7	*	342	--	367	[3] 355
26	7	7	--	7					
27	8	9	--	7					
28	7	8	--	7					
29	6	7	--	10					
30	7	7	--	11	*	380	--	409	[3] 395

[1] Data for 1959 could not be used because starting date was not common to other years in the series.
[2] Only June 1-20 can be used for 1961.
[3] The 5-day cumulated fuel moisture percent is averaged from only 2 years' data.

It must be remembered, however, that when computing the average one must divide by the number of years used. For example, in this table the average fuel moisture percents (last column) for the periods June 1-5, 6-10, 11-15, and 16-20 are computed from 3 years' data, but the averages for June 21-25 and 26-30 are based on only 2 years' data. In months that have 31 days, the last period is 6 days instead of 5.

This extra day does not upset calculations when it is used throughout the computations and is plotted in the same manner each time. The figures in the right-hand column are long-term averages and should be recomputed about every 5 years. Continuity of records is essential because any year that does not have complete records must be disregarded when computing the long-term averages.

Percent of average.--Once a long-term 5-day cumulated fuel moisture average has been established, comparison to any desired year is made by using the following formula:

$$\text{Percent of average} = \frac{\text{Current 5-day cumulated fuel moisture percent}}{\text{Average 5-day cumulated fuel moisture percent}} \times 100.$$

The percent of average must be computed for each successive 5-day period throughout the period of coverage (e.g., June 5, 10, 15; September 20, 25, 30). When this is completed, calculated values are plotted graphically on a convenient scale (as in fig. 2).

Comparison by period.--To arrive at a fuel moisture comparison for any given period, the procedure is similar to that for computing the cumulated percent of average shown above. First, using the average cumulated fuel moisture percents previously computed, find what the average cumulated fuel moisture is for the period of time desired. The following tabulation shows how to compute this average on a monthly basis.

Date	Average 5-day cumulated fuel moisture (Percent)	Calculation		Average cumulated fuel moisture by month (Percent)
June 30	395			395
July 31	607	607-395	=	212
Aug. 31	872	872-607	=	265
Sept. 30	1,350	1,350-872	=	478

The procedure is the same for computing the current period's cumulated fuel moisture percent. To arrive at a percent-of-average figure for comparison, the following formula is used:

$$\underset{\text{(by period)}}{\text{Percent of average}} = \frac{\text{Cumulated fuel moisture percent of current period}}{\text{Cumulated fuel moisture percent of average period}} \times 100.$$

This information can then be represented graphically as desired. Figure 5 shows one method of presentation, but other methods are equally suitable.

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