U. S. FOREST SERVICE
RESEARCH NOTE PSW- 117

PACIFIC SOUTHWEST
FOREST & RANGE EXPERIMENT STATION
P.O. Box 245 Berkeley, California 94701

1966



# Fuel Weight and Removal Costs in Fuel-Break Construction

JAMES L. MURPHY

ABSTRACT: Three major fuel types were sampled during fuel-break construction on the west side of the Sierra Nevada, California. Fuel weight per acre ranged from 120.2 to 420.6 tons per acre on the average. Fuel-break construction removed 27.9 to 40.5 percent of the total fuel; costs ranged from $141.29 to $148.38 per acre and $1.16 to $4.43 per ton.

One of the factors that contributes to a fire's blow-up potential is the amount of fuel that makes up its source of energy. Any system of estimating this potential must consider the fuel. And in mathematical relationships that express quantitatively this blow-up potential, one of the basic elements is fuel weight.[1]

The first phase in evaluating fuel treatment and conflagration control measures calls for a system of rating fuels in terms of fire behavior.[2] To help estimate conflagration potential, it is first necessary to know total fuel weights; variations in fuel weights and weight distribution, by size classes; and the amount of fuel removed in fuel treatment, by size classes.

This note reports, for the first time, the amount of fuel removed and average costs during fuel-break construction for three major fuel types in the westside central Sierra Nevada, California. Within the cover types sampled, fuel weights measured showed wide variability. This variation must be considered when designing a fuel classification system that expresses rates of fire spread and fire intensity.

## The Study

This study was carried out on fuel-break construction sites, on the Stanislaus National Forest, in central California. Aimed at controlling conflagrations by reducing fuel hazards, fuel-break work is being done by this Station and the U.S. Forest Service's California Region, in accordance with established guidelines.[3]

Selected for the study were three timber fire fuel types that are common in California:[4]

Type 3--mature timber, mostly ponderosa pine (*Pinus ponderosa*).

Type 6--timber, medium reproduction and brush: ponderosa pine and manzanita (*Arctostaphylos* sp.).

Type 15--second-growth, medium poles: ponderosa pine.

---

[1] Wendel, G. W., Storey, T. G., and Byram, G. W. *Forest fuels on organic and associated soils in the coastal plains of North Carolina.* U.S. Forest Serv. SE. Forest Exp. Sta., Sta. Pap. 144, p.2. 1962.

[2] Operation Firestop. *Measurement of fuelbed characteristics of grass and chaparral fuels.* U.S. Forest Serv. Progress Rep. 5, p. 2. 1966.

[3] Pacific Southwest Forest and Range Experiment Station. *Guidelines for fuel-breaks in southern California.* Fuel-Break Report 9. 25 pp., illus. 1963.

Murphy, James L., Schimke, Harry E., Sweatt, Bernard, and others. *Guidelines for fuel-breaks in timber.* U.S. Forest Serv., Calif. Region, 23 pp., illus. 1966.

[4] U.S. Forest Service, California Region. *Fireline notebook.* FSH 2, 5135.7, p. 2. 1963.

Type 3 - Mature timber

Type 6 - Timber, medium reproduction, and brush

Type 15 - Second growth, medium poles

Six square-chain plots were located at random in each type before fuel-break construction and the same six plots were relocated after fuel-break construction. Within each square-chain plot, 12 milacre plots were selected because of the large variability in surface fuels found in earlier studies.[5]

For future weight calculations 100-percent cruise was made of all standing trees on the square-chain plots. All other fuels were weighed directly to the nearest pound, using small and large spring scales. All fuels were separated into two classes: > 4 inches average diameter and ≤ 4 inches. Samples of all fuel were oven dried using standard procedures so that all weights could be expressed as standard dry weight. Weight of standing trees was calculated by the formula:

$$W = D \times V$$

in which W= weight; D= density;[6] and V= volume.

Volume was calculated by the formula:[7]

$$V = .2618\ L\ \frac{(D^2 + d^2 + dD)}{144}$$

in which V= volume in cubic feet; L= length in feet; D= diameter of large end (in inches); d= diameter of small end (in inches).

Limb and slash weights were determined from Chandler's Slash Weight Tables for Westside Mixed Conifers.[8]

Costs were computed daily for each specific fuel removal job in each cover type.

## Results and Conclusions

Weight of fuel for each type was as follows:

*Type 3.*--Total fuel weight averaged 420.6 tons per acre (table 1). Most of the material was of relatively large sizes and, therefore, difficult to burn. About 28 percent of the fuel, mostly in size classes greater than 4 inches, was removed during fuel-break construction.

*Type 6.*--Total fuel weight averaged 138.7 tons per acre in this type. Distribution of fuels "less than" and "greater than" 4 inches was relatively uniform. Fuel reduction in this type was about 40 percent--mostly in the brush and larger reproduction (4 to 6 inches). This reduction was made because the stand had to be thinned so that fire would not burn across the fuel-break through the tree crowns.

*Type 15.*--Fuel weight per acre in this fuel averaged 120.2 tons. About 28 percent of the fuel was removed by fuel-break construction. Nearly the same amount of fuel was removed in both size classes (> 4 inches, ≤ 4 inches) because of the large amount of smaller saplings and poles present. The greatest reduction in fire hazard occurred in this type because it has, initially, the greatest amount of smaller, easily ignitable fuel. But this fuel type is reduced to the fuel weight level of other types after fuel-break construction.

Costs per ton of fuel removal were proportional to the amount of handwork (thinning, pruning, piling) that had to be done. Average direct costs that can be identified with an acre of fuel-break constructed were as follows:

---

[5] Operation Firestop. *Op. cit.* p. 10.

[6] Density was derived from: Craig, George A., and Maguire, William P. *The California pine region forest handbook.* p. 85. Sacramento, Calif.: Calif. Div. Forestry. 1949.

[7] Society of American Foresters. *Forestry handbook.* p. 73, sec. 1. New York: Ronald Press Company. 1961.

[8] Chandler, Craig C. *Slash weight tables for westside mixed conifers.* U.S. Forest Serv. Pacific SW. Forest & Range Exp. Sta. Tech. Pap. 48, 21 pp. 1960.

| | Costs[1] | |
|---|---|---|
| | *Per acre* | *Per ton removed* |
| Fuel type:[2] | | |
| 3 | $141.29 | $1.16 |
| 6 | 175.95 | 3.11 |
| 15 | 148.38 | 4.43 |

[1] Includes cost of marking, felling, tractor clearing, brushing, thinning, pruning, piling and burning.

[2] As defined in U.S. Forest Serv., Calif. Region. *Op. cit.*

The findings substantiate the conclusions from fuel studies during Operation Firestop[9] that cover type alone is not a reliable guide to fuel weight because the measured fuel weights showed a wide range of values within a single cover type. Cover type may be a guide to other fuel variables, such as surface area/volume ratio. The results also suggest that because of the variability in distribution of weight by size classes, rate of spread of a fire within a single fuel type may be greater than the difference between types. Since fuels exert a significant effect on fire behavior, this variability must be considered in any fuel weight classification system based upon cover types.

[9] Operation Firestop. *Op. cit.*

Table 1.--*Minimum, average, and maximum weights of fuel removed in fuel-break construction*[1]

| Average diameter size classes (inches) | Fuel type 3 | | | Fuel type 6 | | | Fuel type 15 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min. | Ave. | Max. | Min. | Ave. | Max. | Min. | Ave. | Max. |
| **FUEL BEFORE CUTTING (TONS PER ACRE)** | | | | | | | | | |
| < 4 | 88.4 | 95.8 | 104.5 | 59.5 | 69.3 | 88.7 | 65.2 | 74.6 | 84.7 |
| > 4 | 186.2 | 324.8 | 493.2 | 42.7 | 69.4 | 110.2 | 34.1 | 45.6 | 60.7 |
| Total | 274.6 | 420.6 | 597.7 | 114.9 | 138.7 | 169.8[2] | 99.3 | 120.2 | 134.5 |
| **FUEL AFTER CUTTING (TONS PER ACRE)** | | | | | | | | | |
| < 4 | 77.0 | 82.6 | 87.3 | 38.8 | 54.4 | 73.5 | 45.3 | 55.7 | 72.5 |
| > 4 | 123.2 | 218.7 | 276.5 | 17.2 | 27.7 | 40.3 | 16.5 | 31.0 | 52.1 |
| Total | 200.2 | 301.3 | 360.0 | 68.2 | 82.1 | 99.1 | 67.7 | 86.7 | 96.8 |
| **FUEL REDUCTION (PERCENT)** | | | | | | | | | |
| < 4 | -- | 13.8 | -- | -- | 21.5 | -- | -- | 25.3 | -- |
| > 4 | -- | 32.7 | -- | -- | 60.1 | -- | -- | 32.0 | -- |
| Total | -- | 28.4 | -- | -- | 40.8 | -- | -- | 27.9 | -- |

[1] Based on 12 milacre sub-plots within 6 1-square-chain plots per fuel type.

[2] Totals need not equal sum of < 4 and 54 inches.

*The Author*

JAMES L. MURPHY heads the Station's research on fire control systems planning, with headquarters at the Forest Fire Laboratory, Riverside, Calif. Before joining the Station staff in 1961, he served on several National Forests in California and Idaho. He earned bachelor's (1958) and master's (1959) degrees in forestry at Utah State University, and a doctorate at the University of Michigan (1965).