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INCREASES IN MAXIMUM STREAM TEMPERATURES AFTER SLASH BURNING IN A SMALL EXPERIMENTAL WATERSHED

by

Al Levno, *Forest Research Technician*

and

Jack Rothacher, *Principal Hydrologist*

ABSTRACT

The first year after slash was burned on a 237-acre clearcut watershed in the Cascade Range of Oregon, average maximum water temperatures increased 13°, 14°, and 12° F. during June, July, and August. A maximum stream temperature of 75° F. persisted for 3 hours on a day in July.

A previous report[1/] describing changes in maximum water temperature was prepared after all logs were removed but before slash was burned on a 237-acre clearcut watershed in the H. J. Andrews Experimental Forest. The present report summarizes changes that occurred in maximum stream temperatures during the first year after the slash was burned. Although slash may be left unburned or other methods used to dispose of this waste material, broadcast burning is still the commonest method for slash disposal after logging.

1/ Levno, Al, and Rothacher, Jack. Increases in maximum stream temperatures after logging in old-growth Douglas-fir watersheds. Pacific Northwest Forest and Range Exp. Sta. USDA Forest Serv. Res. Note PNW-65, 12 pp., illus. 1967.

THE STUDY

The clearcut watershed was logged during 1962 to 1966. Logging slash was broadcast burned in October 1966 (fig. 1). Weather conditions were favorable for burning, and virtually all the smaller slash and understory vegetation was consumed by the fire. After the slash fire, larger logs remaining in the lower third of the main stream channel were hand cleared from the immediate streambed (fig. 2), leaving the stream channel exposed to direct sunlight.

Figure 1.—Clearcut watershed after slash burning, H. J. Andrews Experimental Forest.

Figure 2.—Stream channel after slash burning and hand clearing, H. J. Andrews Experimental Forest.

The characteristics of this and two other watersheds being studied on the H. J. Andrews Experimental Forest are covered in detail by Rothacher et al.[2] The watersheds originally supported a dense stand of old-growth Douglas-fir forest on steep northwest-facing topography. Wet winters and dry summers are typical on the west slopes of the Cascade Range of Oregon. Summer air temperatures

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[2] Rothacher, Jack, Dyrness, C. T., and Fredriksen, Richard L. Hydrologic and related characteristics of three small watersheds in the Oregon Cascades. USDA Forest Serv. Pacific Northwest Forest & Range Exp. Sta., 54 pp., illus. 1967.

occasionally exceed 100° F. Average maximum air temperature increases from 80° F. in June to 93° F. in July and August and drop again to 74° F. in September. The average numbers of full sunny days for June, July, August, and September are 18, 24, 20, and 21, respectively. Most of the area is below 3,000 feet in elevation and generally receives the major portion of the annual 90 inches of precipitation as rain.

Although the narrow stream channels have been cut to bedrock along most of their length, the rock, under undisturbed forest conditions, is generally covered with a thin veneer of gravel, woody debris, and vegetation. High winter flows, which may occasionally exceed 50 cubic feet per second (c.f.s.), drop to under 0.05 c.f.s. in late summer. Although the streambed gradient is steep and contains sharp rises which obstruct fish passage, trout are found in the lower reaches of some of the streams in the area. Downstream obstructions exclude anadromous fish.

Weekly maximum and minimum water temperatures have been recorded at the gaging station at the mouth of each experimental watershed since 1959, a period including both before and after harvesting conditions. Beginning in October 1966, water temperatures were recorded hourly on punched tape. Weekly maximum water temperatures were determined from the hourly data.

Data on water temperature increases, based on a linear regression relationship computed between two watersheds while both were undisturbed, is shown in figure 3. This relationship permits prediction of water temperatures on one watershed from temperatures measured on the other. After one watershed was modified (logged and burned in this case), measured water temperatures were compared with predicted temperatures based on a still undisturbed control watershed.

Standard error of the estimate for the after-burning regression was 3.3° F., considerably higher than the error of 1.3° F. for the before-logging regression. Since stream temperature is controlled primarily by direct sunlight, the increased variation indicates greater fluctuation in solar radiation received by the stream in the burned watershed. The shaded, unlogged stream receives more nearly the same amount of radiation on a bright, sunny day as on a cloudy day.

Figure 4 presents the average maximum temperatures measured the year following burning and a predicted curve of temperatures that would have been expected had the watershed not been logged or burned.

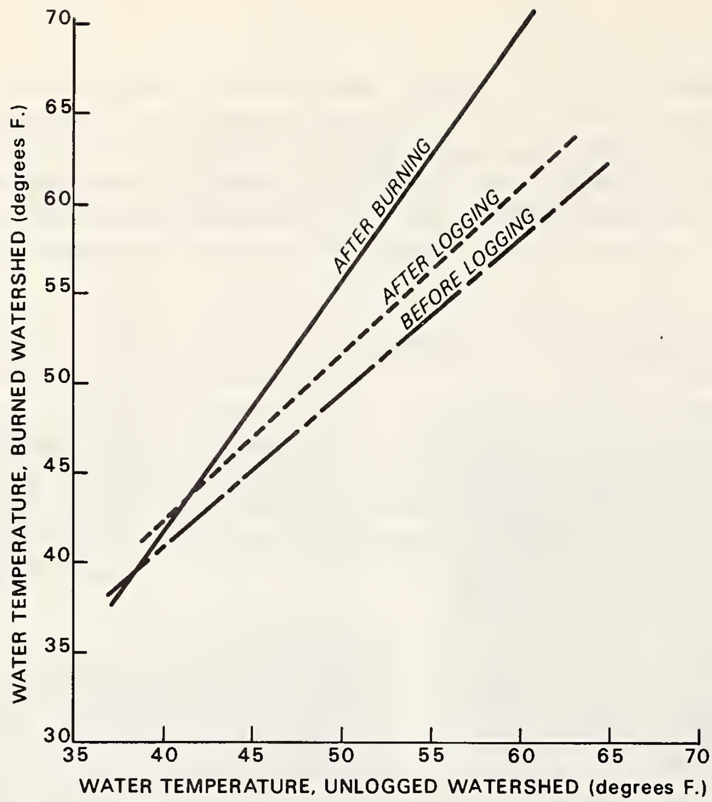

Figure 3.—Maximum weekly water temperatures on the burned watershed before logging, after logging, and after slash burning in relation to temperatures recorded on the unlogged watershed.

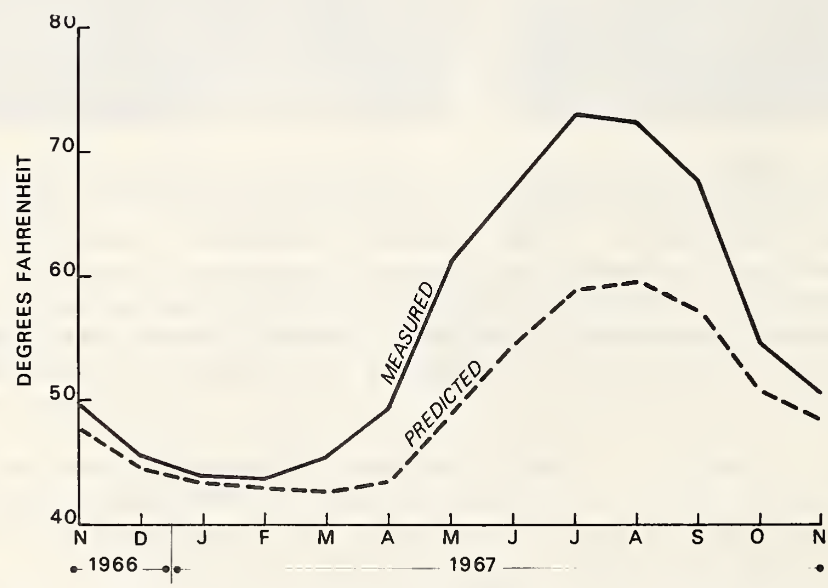

Figure 4.—Measured and predicted average maximum water temperatures on a clearcut watershed following logging and burning, H. J. Andrews Experimental Forest.

Average maximum water temperatures were highest during June, July, and August, 67°, 73°, and 72° F., respectively. This is an increase of 13°, 14°, and 12° F. over the predicted average of 54°, 59°, and 60° F. for the same period.

The maximum water temperature that had been recorded in the burned watershed before logging was 65° F. On June 15, the first year following slash burning, water temperatures in excess of 65° F. began occurring and, except for 6 cloudy days, continued daily until September 22, a total of 86 days. The average duration of temperatures over 65° F. was 10.2 hours per day. Total number of hours at 66° F. and above was 889. The maximum temperature attained, 75° F., persisted for 3 hours on July 3, 1967, during a very warm period when maximum air temperatures varied from 97° to 107° F. Total number of hours for water temperatures from 66° to 75° F. are presented in figure 5.

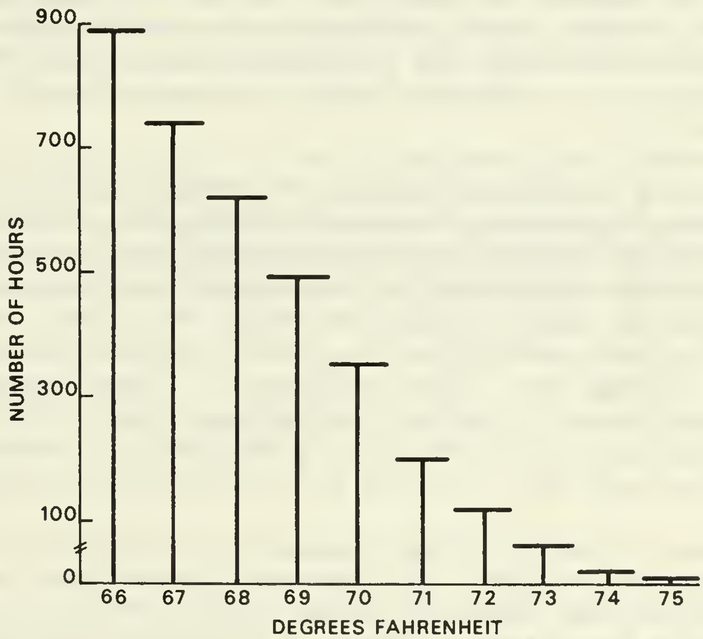

Figure 5.—Total number of hours of high water temperatures (66° to 75° F.) during the first year following slash burning on the H. J. Andrews Experimental Forest.

The longest period of temperatures continuously above 65° F. was 17 hours. This occurred several times during early July, beginning about 9 o'clock in the morning and lasting until 1 or 2 o'clock in the morning of the next day. Temperature would then drop to 62° to 64° F. and begin rising sharply when sunlight again reached the water surface.

DISCUSSION

Data from this and other studies clearly indicate that the water temperature regime may be changed when timber harvest removes the shade provided by streamside vegetation. Temperature increases are directly related to the amount of shade removed and the surface area of stream exposed to direct sunlight. This is due primarily to the energy increase created when the low-intensity, diffuse light of a stream under the forest is changed by canopy removal to direct solar radiation.

Surviving understory shrub vegetation and logging debris adjacent to a stream may provide shade which will cushion the solar radiation impact after canopy removal and lessen the rise in stream temperature. As reported in the previous note (see footnote 1), clearcut logging increased maximum water temperature only 4° F. after all merchantable logs had been removed but before slash burning and stream clearance. In a patch-cut watershed, no significant increase in maximum water temperature was recorded after logging until a debris slide in a section of the channel destroyed all streamside vegetation. The resulting exposure to direct solar radiation caused increases of 12° F. in the stream's temperature.

Burning, which removes all protective stream cover, also increases solar radiation on the stream, causing a marked rise in water temperature. Maximum water temperature increases recorded in this study compare closely with those measured in the Oregon Coast Ranges.[3/] After the 175-acre clearcut Needle Branch Watershed was burned, Brown and Krygier found the mean-monthly maximum water temperatures were 70°, 71°, and 72° F. during June, July, and August. These temperatures were 14° F. above those in the adjacent unlogged watershed. On the H. J. Andrews Experimental Forest, the after-burning increases in water temperature were 13°, 14°, and 12° F. for the same months.

Temperatures of small streams respond very quickly to solar radiation. Brown and Krygier, in discussing temperature change processes, pointed out that exposure of the stream surface to direct solar radiation is the principal cause of high water temperature. In the study on the H. J. Andrews Experimental Forest, water temperature began to increase immediately after sunlight reached the water surface in the morning and to cool again as soon as direct sunlight left the water surface in the afternoon. Although greater exposure of the

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3/ Brown, George W., and Krygier, James T. Changing water temperatures in small mountain streams. J. Soil & Water Conserv. 22(6):242-244, illus. 1967. Also, personal communication with the authors.

study stream after the slash was burned drastically increased the maximum stream temperatures, the duration of the highest temperatures was relatively short. The maximum temperature of 75° F. persisted for only 3 hours. Water temperatures above 65° F., the prelogging maximum, persisted for 17 hours several times in July.

During June through September, water temperature in the burned watershed was above 65° F. for 889 hours. Thus, the stream exceeded the previously recorded maximum of 65° F., measured before logging and burning, for 30 percent of the time during the summer period, or about 10 percent of the total time during the year. Water temperature did drop below the preburning maximum each night. Daily minimums were 64° F. or below, averaging 60.8° F. during the June through September period.

The large increases reported in this study may not be as great in downstream areas. As a consequence of the patch-cut logging system used in the Pacific Northwest, streams from forested areas mingle with those from exposed areas and flow into larger streams, thus diluting the warmed water. Also, water cools some as it passes from an exposed area into a shaded stretch (see footnote 1).

The principal effect of land management practices may be largely in upstream areas, often important fish habitats. The consequences of these practices require further study in terms of the stream ecosystem. As yet, their effect on algal growth, on insect and fish habitat, and on other aspects of water resources is not completely understood.