PACIFIC NORTH WEST FOREST AND RANGE EXPERIMENT STATION

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EARLY EFFECTS OF FOREST FIRE ON STREAMFLOW CHARACTERISTICS

by

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ABSTRACT

A comparison of streamflow records from three small mountain streams in north-central Washington before, during, and after a severe forest fire showed three immediate effects of destructive burning. These were:

Flow rate was greatly reduced while the fire was actively burning.

Destruction of vegetation in the riparian zone reduced diurnal oscillation of flow rates.

Flow rates quickly increased to points above protracted normal depletion rates but to varying degrees.

No drastic immediate change in stream temperatures was noted.

Keywords: Forest fire, alteration of flow, riparian water loss, diurnal distribution, evapotranspiration, depletion.

During the early morning hours of August 24, 1970, much of north-central Washington was swept by an intense dry-lightning storm. This heralded the beginning of what would prove to be one of the most serious fire disasters ever to occur in the region. Ultimately about 115,000 acres of timber were devastated in this single lightning-fire sequence. This area included the Entiat Experimental Forest where water yields, climate, and other environmental variables have been observed for nearly 10 years on three small watersheds. Study installations were restored and reactivated to extend preburn data into a long-range study of the effects of fire on the environment, and the alteration of these effects by vegetative succession. This paper reports some effects of the forest fire that were immediately noticeable in streamflow characteristics.

STUDY AREA

The Entiat Experimental Forest was set aside in 1957 as a study area representative of much of the forested lands east of the Cascade Crest. It was intended for studies of the integrated hydrologic response to specific forest management practices. Three watersheds--1,168, 1,270, and 1,393 acres in size--were instrumented for study.

The experimental drainages are within the Entiat River basin, an area of generally bold and rugged relief dissected by many tributary streams. Much of the river was occupied by a valley glacier during the Wisconsin stage of the Pleistocene Epoch. As the glacier advanced, downcutting the valley, tributary streams were relatively unaffected. As a result, the study watersheds are hanging valleys above the main valley floor. Elevations range from 1,800 feet at the river to more than 7,000 feet at the headwaters. Mean slope is about 50 percent, but slopes as steep as 90 percent are common. Drainage is generally southwest, with aspects ranging from southeast to northwest.

Base rock is an extensive formation known as the Chelan Batholith, a mesozoic intrusive granodiorite with biotite and hornblende as accessory minerals. A medium to coarse-grained massive rock, the gray granodiorite weathers deeply where exposed. Since the glacial period, most of the area has been overlain by volcanic ash and pumice originating from Glacier Peak volcanism about 12,000 years ago. As amounts of deposition vary, soil depths range from extremely shallow, with numerous rock outcrops, to deposits of unconsolidated material many feet deep. Soils are therefore characterized by loose, poorly developed mixtures of decomposed granodiorite and pumice overlying bedrock.

Prior to the fire, vegetation was almost entirely undisturbed mature forest, with only small areas of subalpine grass-forb and bare rock. About 75 percent of the area was classed as ponderosa pine (*Pinus ponderosa*) saw-log type, with Douglas-fir (*Pseudotsuga menziesii*) as the main associated species. Stocking density ranged from medium to poor, with medium to dense understory of ponderosa pine and Douglas-fir reproduction, snowbrush ceanothus (*Ceanothus velutinus*), bitterbrush (*Purshia tridentata*), pinegrass (*Calamagrostis rubescens*), and numerous forb species.

Climate is typical of the east slope of the Cascade Range (fig. 1). For the period of record available, at 3,000-foot elevation the annual mean temperature is 44.3° F., and average annual precipitation is 18.14 inches. Moisture-laden Pacific storms cross the area mainly during winter. Winters are moderately cold and relatively wet, with precipitation generally occurring as snow from November to May. Summers are warm and dry, with only about 10 percent of annual precipitation occurring from June to September.

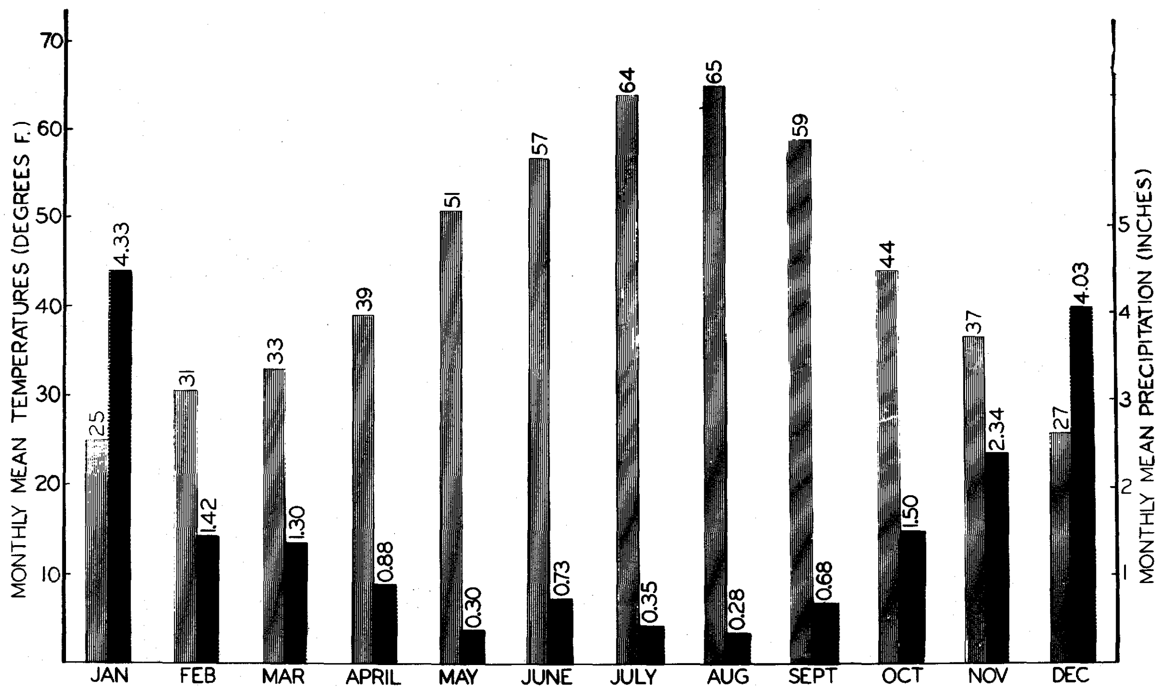

Figure 1.--*Monthly mean temperature and precipitation, Entiat Experimental Forest.*

Streamflow characteristics strongly reflect regional climate (fig. 2). Early winter storms occasionally occur as rain through November. Snow then accumulates throughout the winter, interrupted occasionally by minor melting during brief warm periods. Maximum snowpack is attained in late March or early April. During the spring snowmelt period, streams rise to a peak flow normally occurring in mid-May. Runoff then declines rapidly to a low and fairly steady flow by August or September. Pronounced diurnal fluctuations in runoff rates are evident during the snowmelt season and during summer when evapotranspiration rates are high (fig. 3). During spring snowmelt, maximum daily flow rates occur during the day as a result of maximum insolation. In the summer season, daily minimum flow rates occur during the period of maximum insolation when evapotranspiration is at its peak.

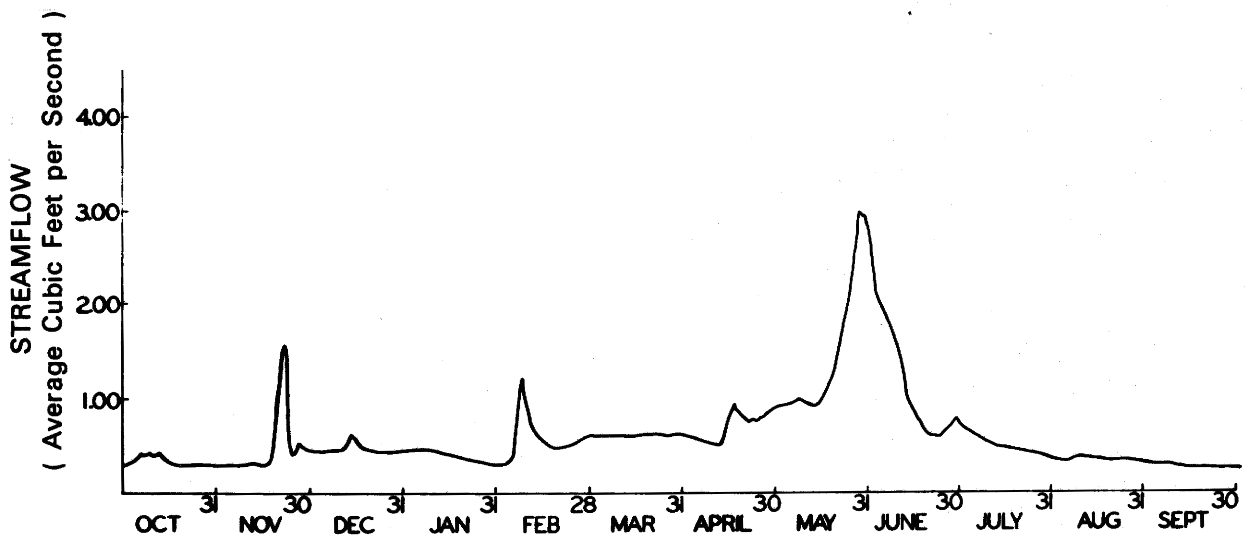

Figure 2.--*McCree Creek streamflow, October 1962 to September 1963, Entiat Experimental Forest.*

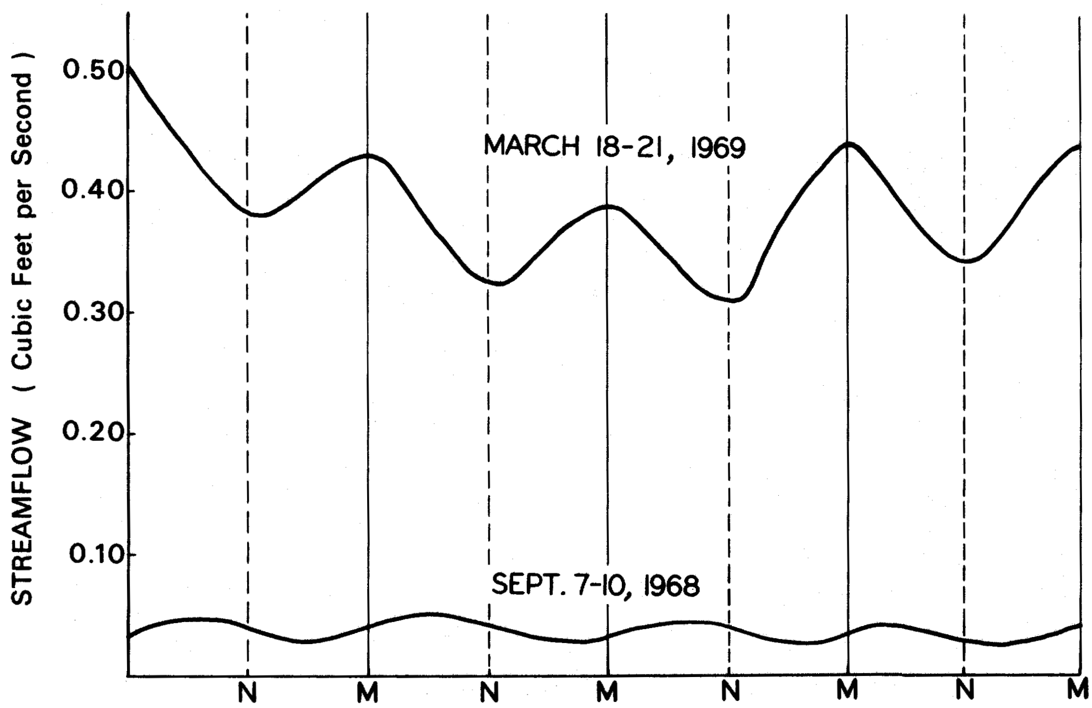

Figure 3.--*Hydrographs showing typical diurnal fluctuations in flow rate during snowmelt period (above) and late summer (below), McCree Creek, Entiat Experiment Forest. N = noon, M = midnight.*

Instrumentation

Streamflow is measured at the outlet of each watershed by continuously recording flow depth over a 120° V-notch sharp-crested weir. Though some icing is experienced for short periods through the winter, the usable record of these installations is essentially year-long. Volume of sediment loss is measured in the weir ponds. Precipitation is sampled along the general centerline of the study area by a recording precipitation gage near 3,000-foot elevation and a non-recording storage-type gage near 7,000-foot elevation. In addition to hydrologic input and output, records of air temperature and relative humidity have been maintained at the 3,000-foot level. Continuous records of stream temperature at all stream gaging stations were begun 2 years prior to the fire.

THE FIRE

A primary factor contributing to the 1970 north-central Washington fire disaster was fuel conditioning by antecedent weather. The period February through August was the driest recorded on the east slope of the Cascades in more than 40 years. During May-August only 0.08 inch of precipitation was recorded on the study area. Daily maximum temperatures in excess of 90° F. were f[illegible] luring August, and streamflow was near the sea[illegible]

Ignition resulte[illegible] g storm which formed in southern Washington a[illegible] ward during the early morning of August 24 [illegible] nt. The storm was characterized by hot, [illegible] roduced essentially no precipitation. A tot[illegible] were set in the Entiat River basin, includin[illegible] al Forest.

As the burning period progressed, efforts of hand crews were overwhelmed. By early afternoon the fast-spreading fronts of several fires began to merge. When the situation became desperate, all vital data and most of the threatened instruments were removed from the study site. Because the risk of the fire's destroying one stream gaging shelter installation (McCree Creek) appeared slight, water level and stream temperature recorders were left in operation at that location.

By 8:00 p.m. the entire Entiat Experimental Forest had been severely and uniformly burned (fig. 4).

Inspection of installations after the fire burned out revealed that the installation where instruments had not been removed was not damaged. Only one of the evacuated installations required major reconstruction. By August 30, instruments had been reinstalled, and extension of preburn data was begun on a plan to evaluate the effects of forest fire and subsequent vegetative succession on hydrologic characteristics.

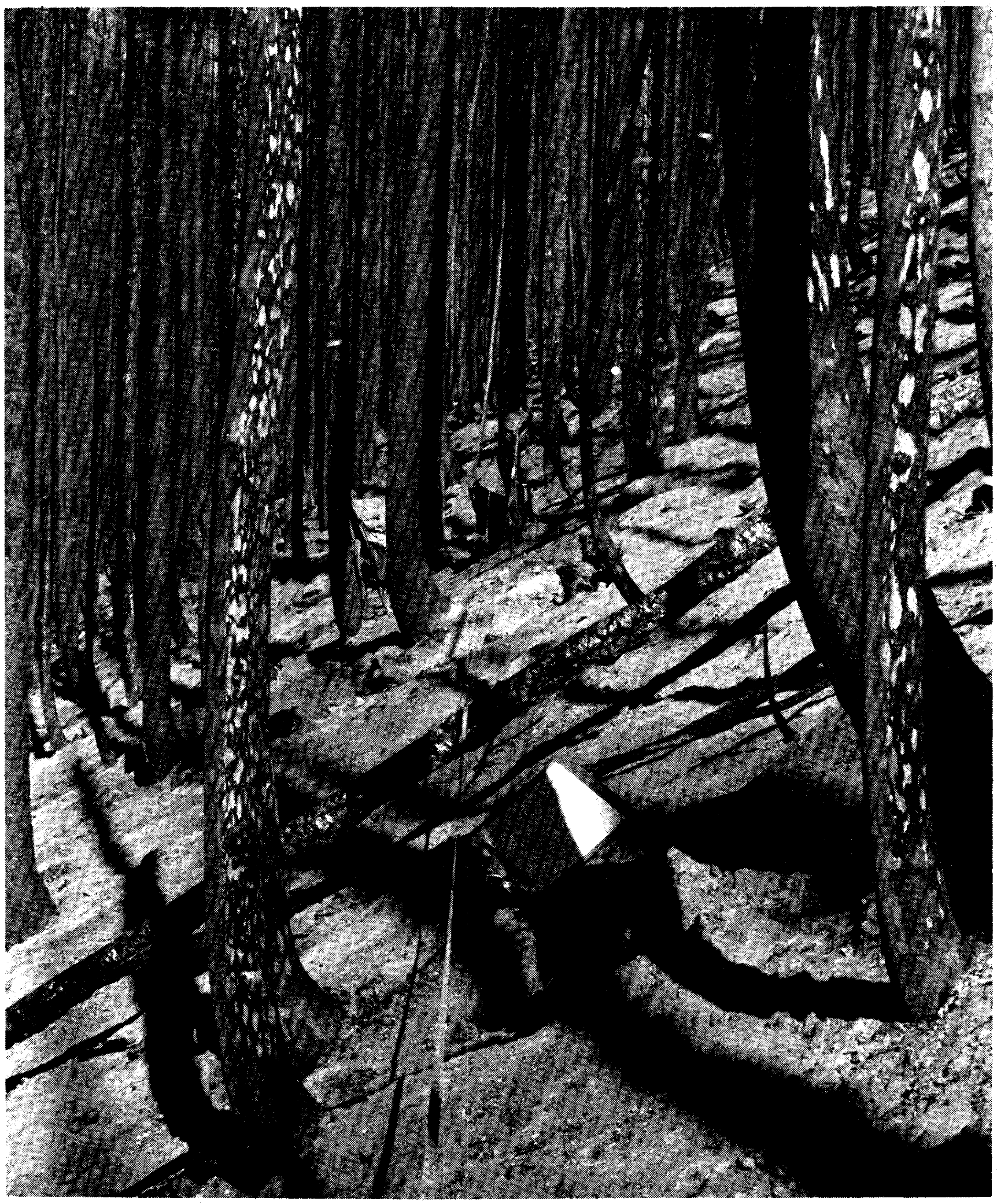

Figure 4.--*View on Fox Creek watershed after the fire. Note that bark burned to the cambium on many stems.*

RESULTS AND DISCUSSION

Hydrographs obtained immediately before and after the forest fire on all three streams are illustrated in figure 5. These reveal several interesting flow phenomena. The most immediate effect on McCree Creek, where continuous instrumentation was maintained, was greatly reduced flow coincident with peak burn intensity and extending into the early morning hours of August 25. This is presumed to be a result of vaporization of water from live stream surface ventilated by strong convection currents.

The manner in which this drainage burned was dramatic. During evacuation of records and instruments, it was observed that McCree Creek was essentially free from fire at about 5:30 p.m. Burns Creek drainage, immediately adjacent to the west, was entirely aflame at that time. At 8:00 p.m. aerial reconnaissance of the general fire area disclosed that fuels over all of McCree Creek were burning fiercely. The timing of this event is reflected in the hydrograph. Flow rate began to drop sharply at the time when daily stream recovery from transpiration loss would normally have begun.

A second and more persistent change in flow characteristics after the fire was the marked reduction of diurnal oscillation in flow rates on all streams.

Streamflow patterns displayed just prior to ignition are striking illustrations of the effects of transpiration by vegetation rooted in the streamside capillary fringe. Because of close correlation with energy availability, transpiration reduces the amount of water entering the channel with daily regularity. The net result is an oscillating flow, characteristic of small headwater or tributary streams in late summer. The forest fire eliminated transpiration draft within the riparian zone of these drainages for the remainder of the 1970 growing season. Only minor daily variations were observed after August 24.

A third change in flow pattern concerned the general elevation of flow rates above extended normal depletion curves.

In the upland areas, beyond the streamside fringe, vegetation derives water from the soil reservoir. There is no nighttime recovery of streamflow from transpiration draft in these zones. Rather, there is a steady decline, or normal depletion, in moisture available for streamflow until recharge by precipitation occurs. Within a week after the fire, flow rates of all three streams were generally above protracted normal depletion curves to some degree. Flows of two streams (Burns and Fox Creeks) were slightly elevated. But the flow of McCree Creek rose sharply for 15 days after the fire to a point considerably higher than normal depletion level. Only a trace of precipitation was recorded until after September 13.

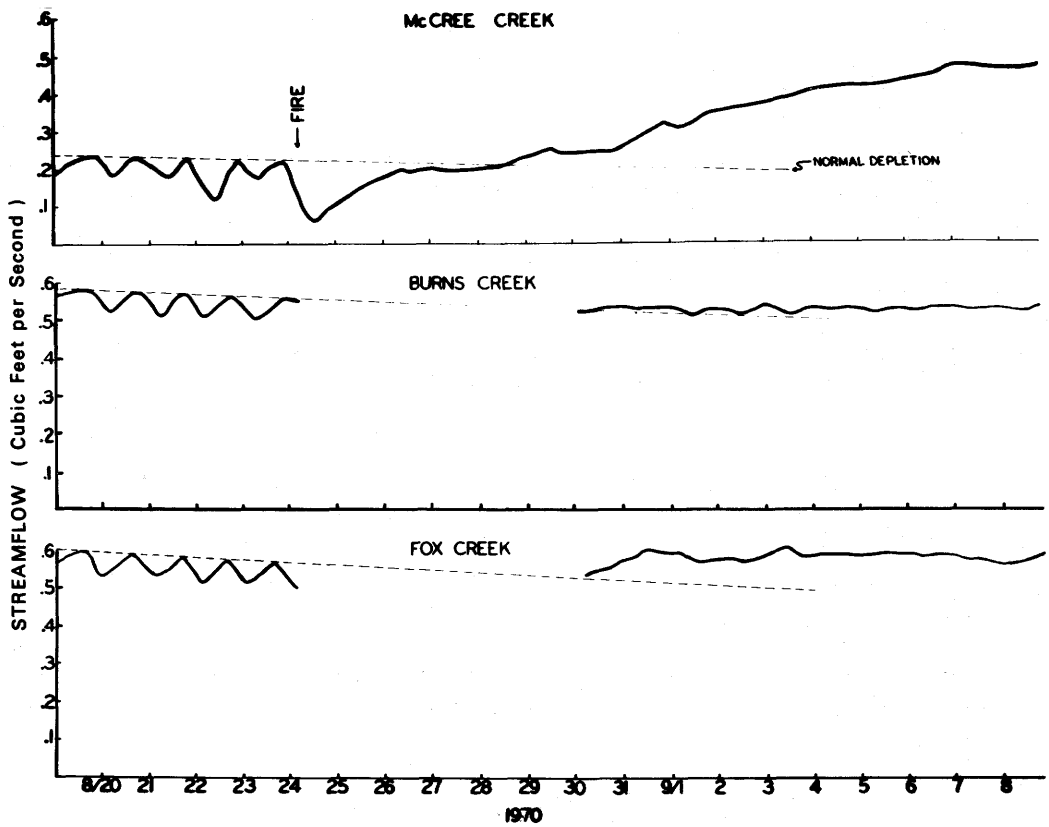

Figure 5.--*Streamflow of the Entiat experimental watersheds, August 20 to September 8, 1970.*

This difference in response may be partly due to prefire differences in vegetative composition. Timber stands on Burns and Fox Creeks were similar in volume and about equally divided between ponderosa pine and Douglas-fir. On the other hand, Douglas-fir comprised nearly 70 percent of the timber on McCree Creek, with 12-percent greater volume. Studies of moisture relations of these species[1/] suggest that the Douglas-fir was transpiring more at the time of the fire. Expected release from transpiration draft would therefore be greatest on McCree Creek.

There is some possibility that reduction of evaporation from the soil by a deep ash mulch could have influenced streamflow after the fire. However, evaporation from the soil surface would likely be only a minor component in the daily water balance during late summer.

[1/] William Lopushinsky. Stomatal closure in conifer seedlings in response to leaf moisture stress. Bot. Gaz. 130(4): 258-263, 1969.

Higher flows after the fire may also be an effect of soil heat flux. Moisture migrates from surface layers to lower zones in response to transient thermal gradients produced by the daily temperature cycle.[2] A massive heat flux could be anticipated during the fire and following sudden removal of shade and protective ground cover.

Stream temperatures fluctuated surprisingly little after the fire. The record of McCree Creek water temperature, presented with daily air temperatures in figure 6, shows a brief rise of 1° F. on the third day. Water temperatures then decreased normally as the summer season ended.

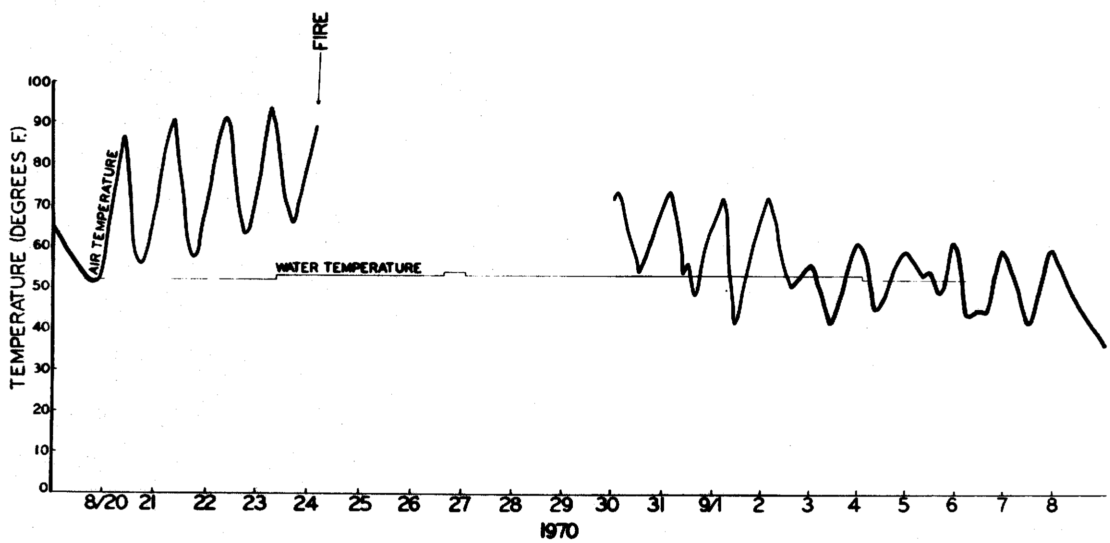

Figure 6.--*Air and water temperatures, McCree Creek, August 20 to September 8, 1970.*

[2] J. W. Cary. Soil moisture transport due to thermal gradients: Practical aspects. Soil Sci. Soc. Amer. Proc. 30: 428-433, 1966.

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