Frequency of Floods from a Burned Chaparral Watershed[1]

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Abstract: Effects of brush fire on hydrologic characteristics of chaparral watersheds were analyzed. An unburned chaparral produces moderate surface runoff. The vegetation promotes infiltration by retarding the runoff and providing temporary storage during intense rainfall. The hydrologic characteristics of chaparral watershed, however, are drastically changed by fires. The high rate of runoff following brush fires may result from the combined effects of denudation and formation of a water-repellent soil layer beneath the ground surface. This layer greatly decreases infiltration rates and reduces the hydrologically active portion of the watershed. Infiltrometer tests were performed on burned and unburned watersheds with similar soil types. The test results for the selected sites showed that for simulated rainfall intensities of one-inch per hour or more, the average ratio of runoff rate to rainfall intensity could be two times as great for the burned as for the unburned condition. To simulate floods following a brush fire, the Stanford Watershed Model was calibrated to a burned watershed using the hydrologic data of the postfire period. The floods were simulated by postulating scenarios that historical storms may occur following a brush fire. The study showed that the moderate storms may produce floods of considerable magnitude under a burned condition.

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Chaparral watersheds in Southern California burn as often as every 30 years (Muller and others 1968). Fire suppression efforts have had partial success in containing the periodic intense wildfires that occur, but the number of fires and the total acreage burned annually remain quite high. The number of fires and the burned acreage for Los Angeles County within the past five years are shown below:

Year:	Number of Fires	Burned areas (acres)[1]
1983	32	3,150
1984	22	17,400
1985	36	9,560
1986	47	10,909
1987	136	12,921

[1]Acre = .405 hectare

An unburned chaparral watershed generally produces moderate surface runoff. The vegetation promotes infiltration by retarding the runoff and providing temporary storage during intense rainfall. High infiltration and the retention capacity of chaparral leave little water available for surface runoff. The hydrologic characteristics of chaparral watersheds, however, are drastically changed by fires. The high rate of runoff following brush fires in the chaparral watershed is attributed to the combined effects of denudation and formation of a water-repellent soil layer beneath the ground surface. This layer greatly decreases infiltration rates and reduces the hydrologically active portion of the watershed from a meter or more to a thickness to only a few centimeters (DeBano and others 1979).

RUNOFF CHARACTERISTICS OF A BURNED WATERSHED

To study the effects of a brush fire on the rate of surface runoff, infiltrometer tests were performed on selected sites of the watershed in La Canada burned by the Crest fire on January 1984. The surface runoff was produced over a controlled plot by simulating rainfall of different intensities. The runoff rates were measured and expressed in terms of runoff coefficient defined as the ratio of runoff rate to rainfall intensity. These tests were repeated on similar soil types in the same area under unburned conditions. In the plot of two sets of runoff coefficients against rainfall intensity (fig. 1), the difference between the two sets of runoff coefficients is quite significant. For rainfall intensities of 1 inch per hour or more, the average runoff coefficients may be two times as great for the burned as for the unburned condition.

To study the hydrologic characteristics of a burned watershed, the Santa Anita Dam watershed with a drainage area of 10.8 square miles (27.47 Km2) and a tributary to the Los Angeles River was selected. From December 27, 1953 to January 3, 1954, the disastrous

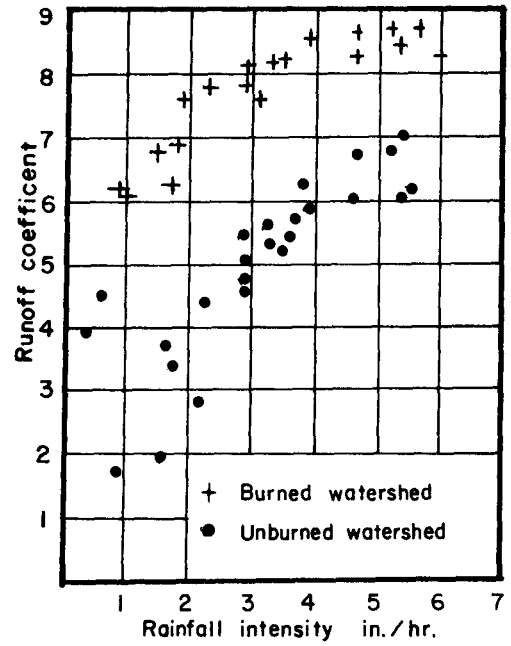

Figure 1 - - Runoff Coefficients under burned and unburned watersheds.

Monrovia peak fire, in the San Gabriel Mountains, burned 97 percent of the drainage area. This nearly complete burn, coupled with relatively good controls and records at the dam site, set the stage for obtaining data on the runoff following a brush fire.

On January 18-19, 1954, a storm produced water and debris flow on the watershed. A week later, on January 24-25, 1954, a second storm also produced water and debris flow, although of smaller magnitude. These two storms were of volume and range of intensities which had occurred in the past, so that some valid comparisons could be made under burned and unburned conditions (tables 1 and 2). The rainfall distributions and the hydrographs produced by the postfire storms of January 1954 and the comparable storms are shown in figures 2 and 3. The comparison of peak flows shows that a burned watershed may produce a peak flow several times greater than that of an unburned watershed.

Table 1 - - Comparison of historical storms with the postfire storm of January 19, 1954.

Storm	Maximum intensities	Storm rainfall	Peaks	Volume of runoff
	in./hr.	in.	cfs	ac-ft.
2-2-36	.76	5.39	185	112
1-7-40	.75	4.63	385	128
1-19-54	.89	5.46	1610	540

Table 2 - - Comparison of historical storms with the postfire storm of January 24, 1954.

Storm	Maximum intensities	Storm rainfall	Peaks	Volume of runoff
	in./hr.	in.	cfs	ac-ft.
12-26-36	1.34	6.42	265	241
11-11-49	.98	6.35	62	5
1-24-54	.83	7.83	1415	530

Hydrologic Modeling of a Burned Watershed

To simulate major floods following the brush fires, the Stanford Watershed Model (Crawford and Linsley 1966) was calibrated to the Santa Anita Dam watershed using the hydrologic data of the postfire period (1953-55). The Stanford Watershed Model is a conceptual model consisting of a series of mathematical expressions which describe the hydrologic processes of a drainage basin. The model uses hourly rainfall and evapotranspiration as input data. Interception, surface retention, infiltration, overland flow, interflow, groundwater flow, and soil moisture storage are simulated to calculate inflow to the channel, and routing is used to simulate the channel system. The model is calibrated by trial until the observed flows are reproduced adequately. Three recording rain gages, one stream gage, and one evaporation station were used in the calibration of the model (fig. 4).

Several runs, each with a different set of parameters, were used to calibrate the model to the watershed under the burned conditions. The first storm following the Monrovia peak fire produced debris flow and surface runoff. Since the model should be calibrated against runoff data, the first storm, which produced debris flow, was excluded from the calibration process. The parameter of the lower zone storage in the model was found to be very small for the burned watershed. This would confirm the theory of formation of a repellent soil layer in a burned watershed.

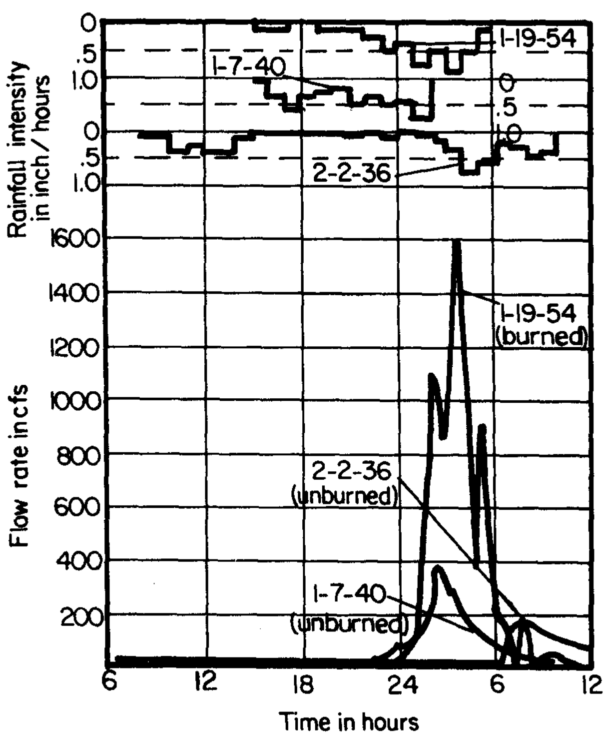

Figure 2 - - Recorded hydrographs under burned and unburned watersheds.

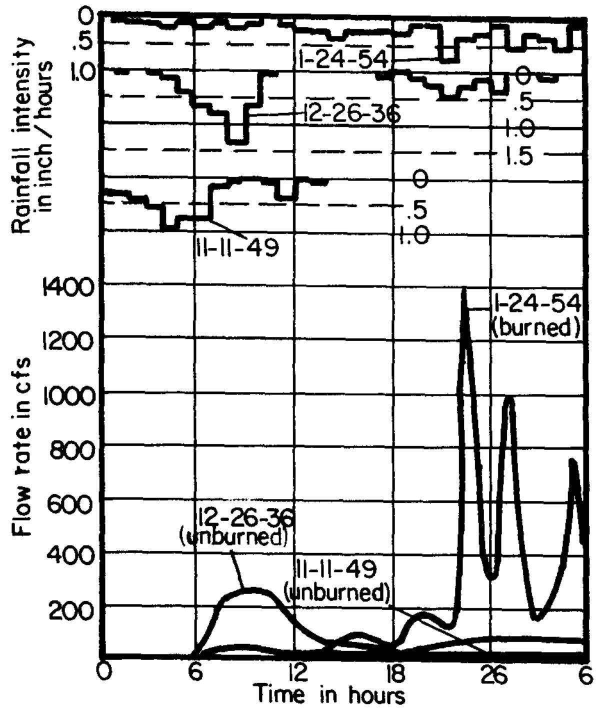

Figure 3 - - Recorded hydrographs under burned and unburned watersheds.

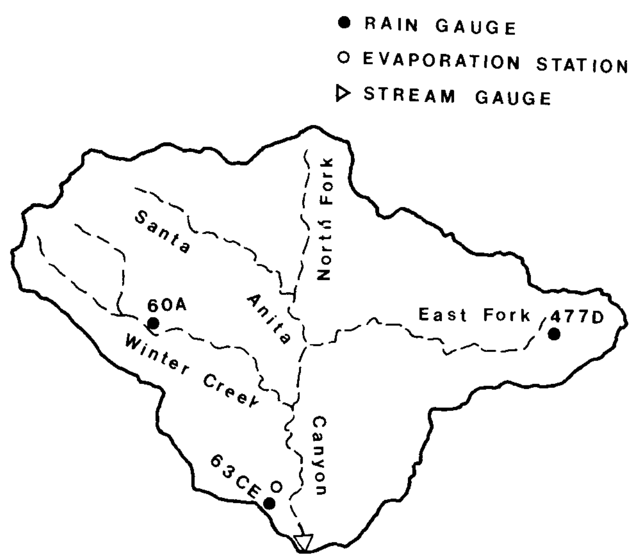

Figure 4 - - Santa Anita Dam watershed with gage location.

Frequency of Floods in a Burned Watershed

Annual peak flow data are available as far as back as 1931. The data were checked for consistency and homogeneity. The data during the recovery period (1954-1963) in which the watershed is under dynamic change were not included in flood frequency analysis. The recovery period for the burned watershed was estimated from historical fires in Los Angeles County drainage area. The Log-Pearson method was used to develop the flood frequency plot (fig. 5) for Santa Anita Dam watershed.

The Stanford Watershed Model along with the flood frequency plot can be used to predict floods from burned watersheds and their corresponding recurrence intervals. To demonstrate the application, two historical storms, one with moderate intensity and volume (storm of 1982-83), and one with extreme intensity (storm 1968-1969), were postulated to occur following a brush fire in the Santa Anita Dam watershed. Records show that these two storms have produced floods of moderate and extreme magnitudes in some areas of Los Angeles County. These two storms were used as input to the Stanford Watershed Model calibrated to the burned watershed and the floods were simulated as output from the model.

To make a probabilistic comparison, the floods resulted from above storms on burned and unburned watersheds were expressed in terms of their recurrence intervals (table 3). The results show that the magnitude of flood from the extreme storm of 1968-69 on burned watershed is not significantly different from the flood from the unburned watershed. However, the increase of six percent in the magnitude of the flood tends to change the recurrence interval from 30 years to 50 years. The moderate storm of 1982-83 appears to react more significantly on the burned watershed. The magnitude of flood from the burned watershed is increased by 200 percent and the recurrence interval changes from six years to 25 years.

Table 3 - - Comparison of floods produced under burned and unburned conditions.

	Unburned watershed		Burned watershed	
Storm	Observed Floods	Return period	Simulated Flows	Return period
	cfs	yr.	cfs	yr.
1-25-69	5,500	30	5,850	50
3-2-83	1,200	6	3,600	25

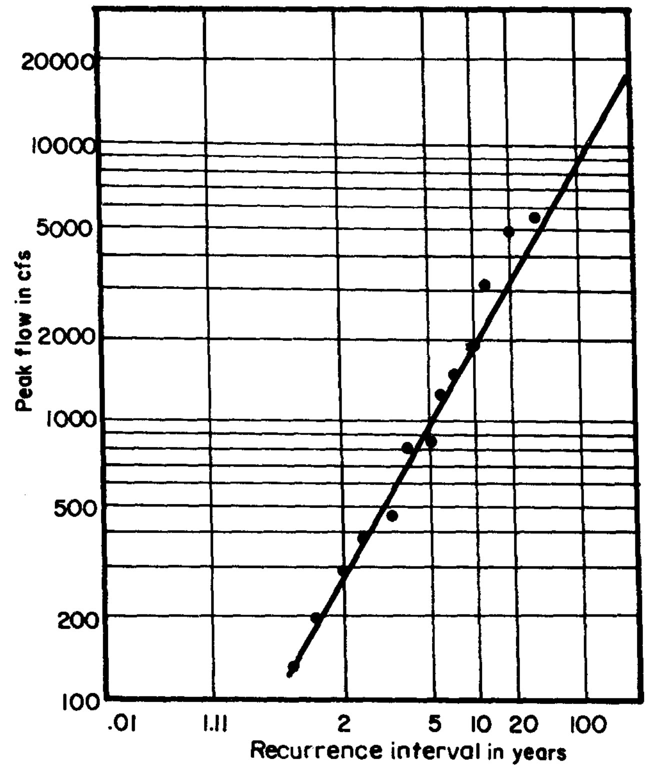

Figure 5 - - Frequency curve of annual floods for Santa Anita Dam watershed.

This study is not yet complete. Our research will continue to define the frequency characteristics of floods under burned conditions. We can draw the conclusion, however, that flood control facilities serving watersheds that experience frequent brush fires should be designed for flow characteristics under burned condition.

REFERENCES

DeBano, Leonard F.; Rice, Raymond H.; Conrad, Eugene C. 1979. Soil heating in chaparral fires: effects on soil properties, plant nutrients, erosion and runoff. Res. paper PSWE-145 Berkley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture.

Crawford, Norman H.; Linsley, Ray K. 1966. Digital simulation in hydrology: Stanford Watershed Model iV. Tech. Rep. 39. Dept. Civil Engineering, Stanford University.

Muller, Cornelius H.; Hanawalt, Ronald B.; McPherson, James K. 1968. Allelopathic control of herb growth in the fire cycle of California chaparral. Bull. Torrey Bot. Club 95(3): 225-231.