Fire Effects on Stream Discharge

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Increased flood potential is a commonly expected result of wildfires in the Southwest, but considerable uncertainty exists in quantifying that increase. Few sites exist in which stream gauges are in place before a fire. Sites with stream gauges that also have a lengthy, detailed precipitation record are more scarce. Where such data do exist, current drought conditions mean that post-fire rainfall intensities are often relatively low, and pre-fire drought precipitation records are needed for a statistically defensible comparison. Further, rigorous comparison of runoff for "similar" pre- and post-fire storms requires consideration of additional factors such as air and soil temperatures, antecedent soil moisture, slope, and aspect. Although a precise comparison of storms and runoff is therefore a challenge, several researchers have collected data that provide insight into the magnitude of changes that occur.

Rainfall Intensity – Runoff Relation

Moody and Martin (2001a) collected data from two mountain watersheds southwest of Denver, Colorado that were burned in 1996. In the Spring Creek watershed, they looked at the rainfall-runoff relation by comparing the peak discharge of a storm per unit area of watershed to the maximum 30-minute rainfall intensity (I_{30}) of that storm, beginning in 1997 and continuing for four years. Their results (see plot at right) show that, particularly for the higher-intensity storms with I_{30} between 10 and 30 millimeters per hour, events in 1999 and 2000 produced lower unit-area peak discharges than did similar events in 1997, suggesting a decrease in extreme flood events with time after the fire.

Moody and Martin (2001b) subsequently expanded their analysis to include two other burned watersheds. Bear Gulch in the Black Hills of South Dakota was burned in 1988 and Rendija Canyon in New Mexico was burned in the 2000 Cerro Grand Fire. In looking at data from all three watersheds, they found that the unit-area peak discharge is related to I_{30} by a power law. Further, above a threshold of about I_{30} = 10 mm/hour, the magnitude of flood peaks increases much more rapidly, suggesting that that intensity could be used to set threshold limits for precipitation gauges in emergency-warning systems in burned areas.

Pre- and Post-Fire Peak Flows

Gottfried and others (2003) presented results from north-central Arizona watersheds burned by wildfires in 2000 and 2003. As with most fires, fire intensity and severity varied among the watersheds. The Workman Creek watersheds were burned by the 9,644-acre Coon Creek Fire from April to May, 2000. A 15-minute rainfall at intensity of 2.6 inches per hour in June 2000 produced a peak flow estimated from field evidence to be more than seven times the 40-year historic high peak flow of 289 cubic feet per second (cfs), which had been measured in October 1972 following a five-day storm that dropped nearly 12 inches of precipitation.

In two relatively flat Stermer Ridge watersheds, Gottfried and others reported that stream discharge measurements were made from 1972 to 1976, after which the flumes were "mothballed" but left in place. The highest peak flow recorded for a summer storm during that time was 0.10 cfs. The Rodeo-Chediski Fire then burned nearly 463,000 acres in June 2002, including the Stermer Ridge watersheds, with one watershed experiencing a high-severity stand-replacing fire and the other a low- to medium-intensity, stand-modifying fire. The flumes were reactivated after the fire, but precipitation gauges were not installed until after two storms had already occurred. However, discharges in the severely burned watershed were estimated

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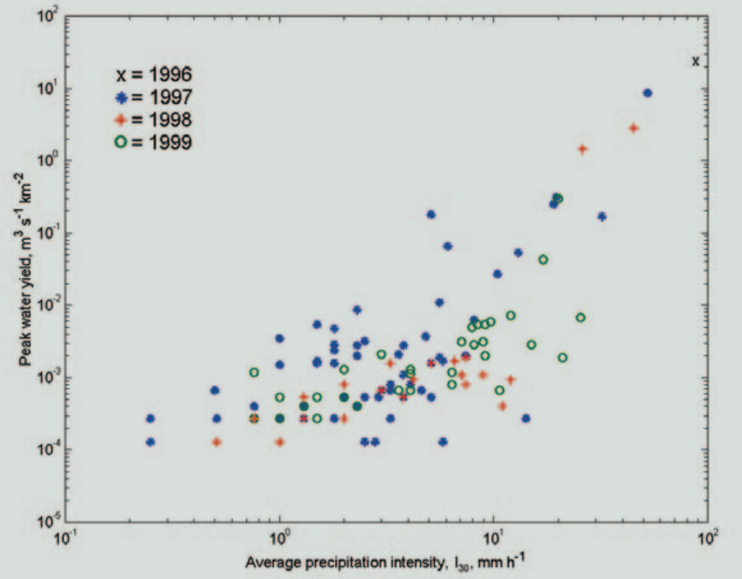
***Top:** View across Buffalo Creek of an alluvial fan deposited after a July 1996 rainstorm over the area burned by the 1996 Buffalo Creek Fire. Photo by R.H. Meade, USGS.*

to be 8.9 cfs and 232 cfs for the two storms.

Veenhuis (2002) studied the effects of wildfires in the Bandelier National Monument area of north central New Mexico. The June 1977 La Mesa Fire burned 15,270 acres, including Frijoles Canyon, and the April 1996 Dome Fire burned 16,516 acres, including Capulin Canyon. Post-fire peak flows, recorded during the year after the fire at the farthest downstream gauging stations in both canyons, were about 160 times the maximum pre-fire floods, at 3,030 cfs for Frijoles Canyon and 3,630 cfs for Capulin Canyon. Pre-fire peak discharge was 19 cfs for Frijoles Canyon and an estimated 25 cfs for Capulin Canyon. In the second year after the fires, peak flows decreased to 10 to 15 times the pre-fire annual maximums, and in the third year they were only three to five times as large as pre-fire flows. However, even 22 years after the La Mesa Fire, flood magnitudes had not receded to pre-fire size. Veenhuis also found that the frequency of larger stormflows increased following fires, particularly in the first three years. In pre-fire Frijoles Canyon, the maximum peak storm flow was 19 cfs; post-fire events exceeding that discharge numbered 15 in 1977 (seven events exceeded 100 cfs), nine in 1978, and five in 1979.



Relation between unit-area peak discharge and 30-minute rainfall intensity (I_{30}) following the 1996 Buffalo Creek Fire (from Moody and Martin, 2001a). Discharge was measured at the mouth of the Spring Creek watershed, and intensity is the average I_{30} intensities from two gauges in the watershed.

Terrain, Soil Make a Difference

Greg Kuyumjian of the Santa Fe National Forest estimates that after the Cerro Grande Fire (43,000 acres, Los Alamos, New Mexico, May 2000) post-fire runoff increased by more than two orders of magnitude. In Pajarito Canyon, with a watershed area of 1,275 acres, seven years of pre-fire data showed a peak flow of 2.4 cfs. In the first major rainfall event following the fire, a flow of 1,020 cfs was recorded, this from 755 acres of high or moderate burn severity. In the 57 years prior to the fire, sediment delivery to Los Alamos Reservoir averaged about 130 cubic yards per year, from a watershed area of just over 4,069 acres. In the first year following the fire, 23,000 cubic yards were delivered to the reservoir, and in the second year, 11,000 cubic yards accumulated, in part from 1,217 acres of high or moderate burn severity.

In areas where terrain is steep and rocky, Kuyumjian found that the magnitude of runoff and sediment load do not increase as dramatically after a fire. Following the 2003 Aspen Fire in southern Arizona, Sabino Creek experienced a post-fire peak flow of 3,140 cfs about a month after the fire ended. That discharge was considerably less than the pre-fire peak flow of 15,400 cfs in 1999. Although precipitation intensity after the fire has never been as high as that which caused the 1999 discharge, for the precipitation events that did occur, the changed watershed conditions caused streams to flow from precipitation at a lower intensity than under pre-fire conditions.

References

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