1985 International Symposium on Urban Hydrology, Hydraulic Infrastructures and Water Quality Control
(University of Kentucky, Lexington, Kentucky — July 23-25, 1985)

Hydrologic Effects of Shrubland Watershed Fires on Urban Areas

by

J.J. DeVries, Dept. of Civil Engineering University of California, Davis, CA

T.V. Hromadka, II, U.S. Geological Survey, Water Resources Division, Laguna Niguel, CA

A. J Nestlinger, Orange Co. Environmental Management Agency, Santa Ana, CA

Abstract. Increased urban development is taking place in and below watersheds covered by chaparral and other types of shrubs in California and other Western states. The management policy for these areas has been to suppress fire to the greatest extent possible. However, fire is a natural feature of the shrubland ecosystems, and fire suppression results in a build-up of fuels that produces larger and lore intense fires when they eventually occur.

The immediate direct effect of fire is to substantially increase storm runoff, to accelerate watershed erosion, and to greatly increase sediment transport to downstream urban areas. This paper reviews procedures for hydrologic analysis of these watersheds and lists research needs to provide additional information to allow the hydrologic effects of fires on watersheds in and adjacent to urban areas to be accurately assessed.

Introduction

Large areas of the western United States have rainfall that is sufficient to support only grass and shrub species. During the dry season in these arid areas fires are a major problem. Urban development in California and other Western states in these shrubland areas is being affected to an increasing degree due to damage and destruction of property resulting from high storm runoff and sedimentation. Increased storm runoff and accelerated erosion can be directly linked to processes resulting from fires on the watersheds above the developed areas. The problems are due in part to the increased human use of shrubland watershed areas, and in part to the effects of long-term fire suppression policies in these areas.

This paper gives a description of this problem and summarizes some of the current knowledge of the effects of fire on the watershed on its hydrologic response. Research needs for dealing adequately with this problem are listed also.

Effects of Fire on Shrubland Watersheds

In the arid West large areas are covered by vegetation types known as "chaparral," "brushland," or "shrubland." The climate in these areas is usually characterized by winters with sufficient precipitation to develop extensive vegetation growth, but with extremely little or no precipitation in the summer. The high stand productivity and relatively short plant life combine to produce large volumes of potential fuel on shrubland watersheds. In addition many of the shrubs have oils or resins which add to their flammibility. The shrub species are adapted to fire, and in many cases depend on it for reproduction.

Under natural conditions shrubland stands become extremely flammable within 30 to 60 years following a fire, and before fire control was begun in the last century, the natural fire process was continually recuring. From historical records and by observation of uncontrolled areas[10], it is noted that natural burns, usually ignited by lightning strikes, tend to burn limited areas because the fires are extinguished when they reach a more recently burned area where sufficient fuel to sustain the fire is not available.

In many areas (especially Southern California) fire suppression has been a public policy for nearly 100 years. Concern over damage to property has lead to a philosophy of watershed management which regards all fire as something to be completely avoided. Complete fire suppression has produced a different set of problems, however. The absence of fire has resulted in a buildup of fuels over very large areas. The natural mechanism controlling the spread of fire to the edge of a recent burn is no longer present. As a consequence the fires which occur usually burn with very high intensity and spread over very large areas because

Rowe's approach is based on six factors, three of which relate to runoff and three to erosion and sediment production. Rowe determined these factors for specific storm zones to account for meteorological effects on watershed hydrology. He then selected key watersheds in each storm zone assuming that the characteristics of these watersheds could be used to describe the other watersheds in the region. He also used physiographical, geological, and fire-history data for the individual watersheds to develop watershed parameters for the determination of watershed response to fire. The six factors are: 1) frequency and magnitude of "normal" runoff, 2) effect of fire on changing magnitude of normal and peak discharges, 3) residual effects of past fires on runoff, 4) normal annual erosion rates, 5) effect of fire on the erosion rates, and 6) residual effects of past fires on erosion.

Research Needs

The basic hydrologic mechanisms of the processes involved in the response of watersheds to fire are adequately understood. Some data are available for specific watersheds for various types of fire conditions. Techniques do not exist, however, for applying the existing data base to the prediction of the long term effects of fire on individual watersheds, taking into account specific responses of the watershed to such variables as fire temperatures, size and season of burn, and variations in vegetation and prefire conditions in the watershed.

There is a need for models of the hydrologic behavior of watersheds which accurately reflect the response of the basin to changes produced by fire. The models must account for changes in hydrologic processes such as surface runoff, infiltration, and movement of water through the soil in ways that permit the changing response of the basin with time to be analyzed as vegetation is regenerated and changes in character.

References

1. Agee, J.K., Prescribed Fire Effects on Physical and Hydrologic Properties of Mixed-Conifer Forest Floor and Soil. Contribution No. 143, Water Resources Center, University of California, Davis, California, 1973.

2. Anderson, H.W., M.D. Hoover, and K.G. Reinhart, "Forests and Water: Effects of Forest Management on Floods, Sedimentation, and Water Supply." General Technical Report PSW-18, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA, 1976.

3. Andre, J.E. and H.W. Anderson, "Variation of Soil Erodibility with Geology, Geographic Zone, Elevation and Vegetation Type in Northern California Wildlands," Journal of Geographical Research, Vol. 66(10), pp. 3351-3358, 1961.

4. Curry, R. "Water Yield and Water Quality in Shrubland Watersheds," In: DeVries, J.J., ed. Shrublands in California: Literature Review and Research Needed for Management," Contribution No. 191, Water Resources Center, University of California, Davis, California, 1984.

5. Davis, J.D., "Southern California Reservoir Sedimentation," in Fall Meeting and Exhibit, American Society of Civil Engineers, Washington, D.C., 1977.

6. DeBano, L.F., "Water Repellent Soils: State-of-the-Art," General Technical Report PSW 46, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California, 1981.

7. DeBano, L.F., R.M. Rice and C.E. Conrad, "Soil Heating in Chaparral Fires: Effects on Soil Properties, Plant Nutrients, Erosion and Runoff," Research Paper PSW 145, PSW Forest and Range Experiment Station, USDA, US Forest Service, Berkeley, California, 1979.

8. Hydrologic Engineering Center, "Users Manual," HEC-1 U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, California, 1985.

9. MacArthur, Robert C., "Watershed Sedimentation Investigation For The Mentone Dam," Special Projects Report No. 83-4, The Hydrologic Engineering Center, Davis, California, 1983.

10. Minnich, R. and L. Howard, "Biogeography and Prehistory of Shrublands," In: DeVries, J.J., ed. Shrublands in California: Literature Review and Research Needed for Management, Contribution No. 191, Water Resources Center, University of California, Davis, California, 1984.

11. Rice, Ray M., "The Hydrology of Chaparral Watersheds," In: Proceedings, Symp. on Living with Chaparral, 1973, pp. 27-34, Sierra Club, Riverside, Calif., 1974.

12. Rowe, P.B., C.M. Countryman, and H.C. Storey, "Hydrologic Analysis Used to Determine Effects of Fire on Peak Discharge and Erosion Rates in Southern California Watersheds," U.S. Department of Agriculture, U.S. Forest Service, California Forest and Range Experiment Station, U.C. Berkeley, Berkeley, California, 1954.

13. Rowe, P.B., H.C. Storey, and E.L. Hamilton, "Some Results of Hydrologic Research." In: Some Aspects of Watershed Management in Southern California, pp. 19-29, USDA Forest Service, Calif. Forest and Range Experiment Station, 1951.

14. Savage, S.M., J. Osborn, J. Letey and C. Heaton, "Substances Contributing to Fire-Induced Water Repellency in Soils," Soil Science Society America Proceedings, Vol. 36, pp. 674-678, 1972.

15. Welling, R., M. Singer, and P. Dunn, In: DeVries, J.J., ed. Shrublands in California: Literature Review and Research Needed for Management," Contribution No. 191, Water Resources Center, University of California, Davis, California, 1984.

16. Wells, Wade G., "Erosion and Seidment Transport in Pacific Rim Steeplands," I.A.H.S., Public Notice 132, Christchurch, New Zealand, 1981.