Fire Effects on Watersheds: An Overview

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Fire has a ubiquitous role in wildland management. It is a frequent visitor to watersheds throughout the world and is of particular concern in the western and southwestern United States. Wildfires are uninvited events that sweep across thousands of acres of watershed areas annually. On the other hand, prescribed fire can reduce the accumulation of dead wood and other fuel that constitutes an ever-present wildfire danger, and thus plays an important role as a management tool on many watersheds. Prescribed fire can also be used to satisfy other management objectives such as seed-bed preparation, increased forage production, and improved wildlife habitats.

The Hydrologic Cycle and Fire Effects

A watershed's response to fire depends upon the effect that fire has on the individual components of the hydrologic cycle operating on the watershed. Not all processes and pathways in the hydrologic cycle are equally affected by fire; for example precipitation is not affected at all. Those processes and pathways most affected by fire are those that are controlled by vegetation and the soils of the watershed: they include interception, infiltration, evapotranspiration, soil moisture storage, and overland flow of water.

Forest and soil damage is much less from low-severity ground fires (background) than from high-severity crown fires (inset).

Fire can substantially reduce interception by destroying both the vegetation canopy and the organic litter on the soil surface, thereby exposing the soil to raindrop impact and subsequent runoff and erosion. Fire can reduce infiltration into the soil by forming a water-repellent soil layer or plugging soil pores with fine ashy material. Percolation through the soil can also be reduced this way. Reduced infiltration and percolation in turn can increase surface runoff and sedimentation. Increases in streamflow also may occur following fire because the removal of vegetation reduces transpiration losses by plants.

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Watershed Responses to Fire

The major factors affecting the hydrologic response of a watershed to fire are fire severity and the magnitude and timing of precipitation following fire (DeBano and others, 1996). Fire severity, classified as low, medium, or high, describes the change that fire causes in particular ecosystem resources such as vegetation or soils. Wildfires, having greater severity than prescribed fires, prompt the greatest watershed response, particularly for large-magnitude hydrologic events. The inability to predict the magnitude and timing of precipitation that will follow a fire is a significant challenge to assessing potential damage from it: a 100-year event could cause extensive runoff and erosion, depending on local topography and soil conditions, whereas gentle rains could have minimal impact. Although general climatic rainfall patterns are known, rain distribution and intensity varies widely, so probability distributions can at best serve as guides for assessing potential damages.

Varying techniques for assessing fire severity in terms of canopy loss and

soil changes have been developed along with descriptive terminology that can be used in the field following fire (Neary and others, 2008). Fire severity in soils is determined by field examination after a fire and rated according to the amount of surface litter that is charred and consumed and the amount of white and dark ash. Large amounts of white ash on the soil surface indicate a high-severity fire. Likewise, the plant canopy's appearance following fire is rated in terms of scorch and the amount of the green plant material consumed. Complete consumption of both dry fuels and green plant material indicates high fire severity. Fire-severity levels are combined with the effects of precipitation events after the fire to determine the hydrologic response (or performance) of watersheds following fire. Post-fire damages are tied to the adverse soil and vegetation changes in watershed performance.

Mitigating Fire Effects on Watershed Performance

Neary and others (2008) reviewed a large number of burned-area emergency rehabilitation (BAER) treatments (both physical and vegetative) used to mitigate the impacts of fire on watershed hillslopes and channel structures with respect to their effect on runoff and erosion following fire. Their recommendations were:

- Rehabilitation should be done only where risk to life and property is high, since significant resources must be invested to ensure improvement over natural recovery.
- Seeding treatments may not be needed as frequently as previously thought because seeding has a low probability of reducing erosion the first wet season following fire, when erosion rates are highest.
- Mulching can be an effective tool, but is expensive and should be limited to the most critical areas of the watershed.
- Channel treatments, such as straw-bale check dams, should be considered secondary mitigation treatments although they can temporarily store sediment and desynchronize its release with stormflow events.
- A monitoring program should be initiated to evaluate the overall effectiveness of the applied treatments.

The most effective way to reduce overall watershed damage by high-severity wildfires is to implement programs that effectively reduce the accumulation of fuels and therefore the probability of subsequent severe wildfires.

The effectiveness of treatment programs in reducing fire severity was demonstrated in ponderosa pine (*Pinus ponderosa*) forests during the 2002 Rodeo-Chediski fire in Arizona. This wildfire burned 468,000 acres and exhibited the most extreme fire behavior ever seen in the Southwest. Prior to the fire, long-term fuel reduction treatments were implemented on the White Mountain Apache Tribal lands and on the nearby Apache-Sitgreaves National Forest. These treatments involved thinning, timber harvesting, prescribed burning, or a combination of these. The purpose of these treatments was to transform a forest structure having dense forest floor fuels, ladder fuels, and canopy fuels to a more open forest structure characteristic of presettlement conditions. These treatments help limit natural or man-made ignitions to low-severity ground fires rather than high-severity crown fires (see photos). An evaluation of these treatments indicated that the severity of the burn was reduced substantially on the treated plots and that the beneficial effects of the treatments on stand structure characteristics were projected to persist for several decades (Finney and others, 2005; Strom and Fulé, 2007).

In conclusion, fire severity and post-fire weather significantly affect watershed performance. Although some remedial treatments can be applied after wildfires, enacting a regular program of fuel reduction by the use of forest thinning, timber harvesting, prescribed fire, or a combination of these can provide natural resource managers with a viable long-term option for protecting watershed performance.

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