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Prepared in Cooperation with the California Geological Survey

Southern California—Wildfires and Debris Flows

Introduction

Wildland fires are inevitable in the western United States. Expansion of man-made developments into fire-prone wildlands has created situations where wildfires can destroy lives and property, as can the flooding and debris flows that are common in the aftermath of the fires. Fast-moving, highly destructive debris flows triggered by intense rainfall are one of the most dangerous post-fire hazards. Such debris flows are particularly dangerous because they tend to occur with little warning. Their mass and speed make them particularly destructive: debris flows can strip vegetation, block drainages, damage structures, and endanger human life.

Photograph of a typical burned hillslope in southern California. Photograph by Sue Cannon.

The U.S. Geological Survey's Landslide Hazards Program is participating in a multi-agency cooperative effort to investigate debris flows in burned areas of southern California and other parts of the western United States. Participating agencies are the U.S. Department of Agriculture (USDA) Forest Service, the Natural Resources Conservation Service, and the California, Colorado, and Montana Geological Surveys. The objective of this project is to develop methods needed to estimate the locations, probability of occurrence, and size of potentially destructive debris flows. Public officials can use this information to plan and execute emergency response and post-fire rehabilitation.

Analysis of data collected from studies of debris flows following wildfires can answer many of the questions fundamental to post-fire hazard assessments—what and why, where, when, how big, and how often?

What We Know About Post-Fire Debris Flows

What and Why? Post-fire debris flows generally are triggered by one of two processes: surface erosion caused by rainfall runoff, and landsliding caused by infiltration of rainfall into the ground. Runoff-dominated processes are by far the most prevalent because fires commonly reduce the infiltration capacity of soils, which increases runoff and erosion. Infiltration processes are much less common, but prolonged heavy rains may increase soil moisture even after a wildfire. The wetted soil then may fail, producing infiltration-triggered landslides.

Where? Although debris flows can occur in areas underlain by nearly any rock type, the areas most likely to produce debris flows are those underlain by sedimentary or metamorphic rocks that have more than about 65 percent of the area burned at moderate to high severities. In addition, debris flows are most frequently produced from steep (> 20°),

tightly confined drainage basins with abundant stored material, and are unlikely to extend beyond the mouths of basins larger than about 25 square kilometers (~10 square miles) in area.

When? Post-fire debris flows are most common in the 2 years after a fire; they are usually triggered by heavy rainfall. Flooding and increased runoff may continue for several years, but it is unusual for post-fire debris flows to be produced beyond the second rainy season. Some of the largest debris-flow events have been triggered by the first intense rainstorm of the storm season. It takes much less rainfall to trigger debris flows from burned basins than from unburned areas. In southern California, as little as 7 millimeters (0.3 inches) of rainfall in 30 minutes has triggered debris flows, and any storm that has intensities greater than about 10 millimeters/hour (0.4 inches/hour) is at risk of producing debris flows.

Campground in Cable Canyon, southern California, where a debris flow on December 25, 2003, killed two people. A wildfire during the previous October burned hillslopes in the area, and heavy rains triggered the deadly debris flows. Photograph by Sue Cannon.

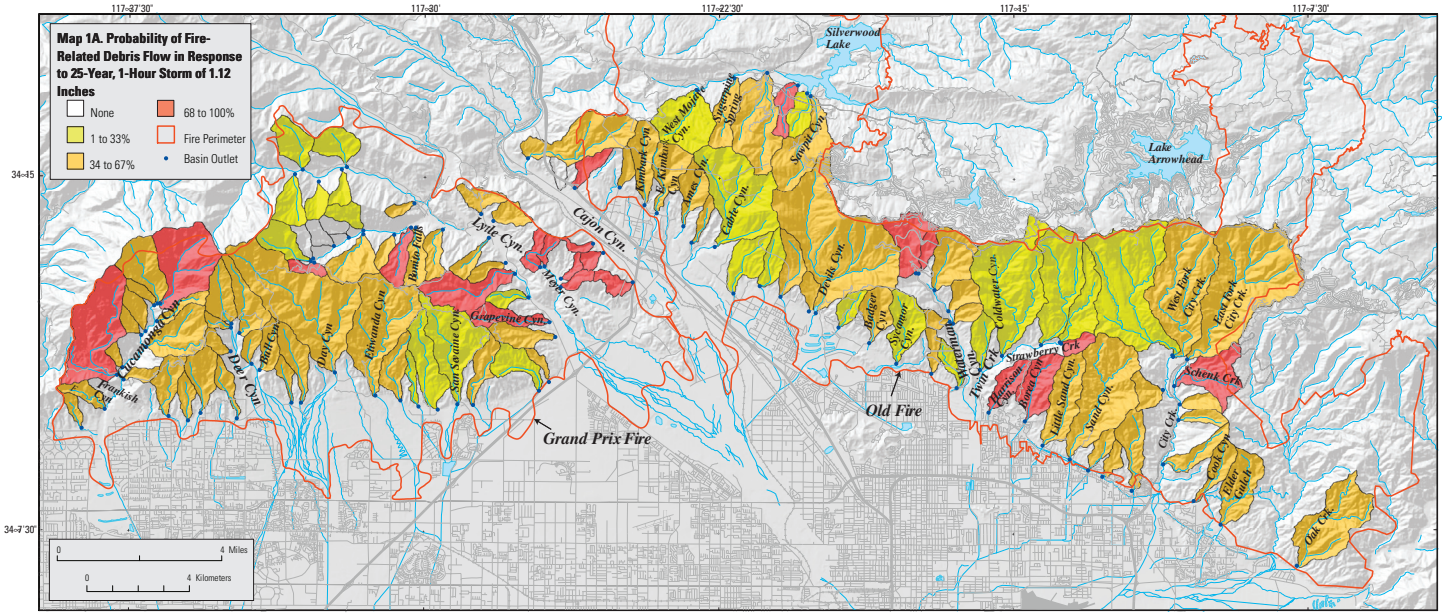
How big? Documented debris flows from burned areas in southern California and the western United States have ranged in volume from as small as 600 cubic meters to as much as about 300,000 cubic meters. This larger volume is enough material to cover a football field with mud, rocks, and debris to about 65 meters deep.

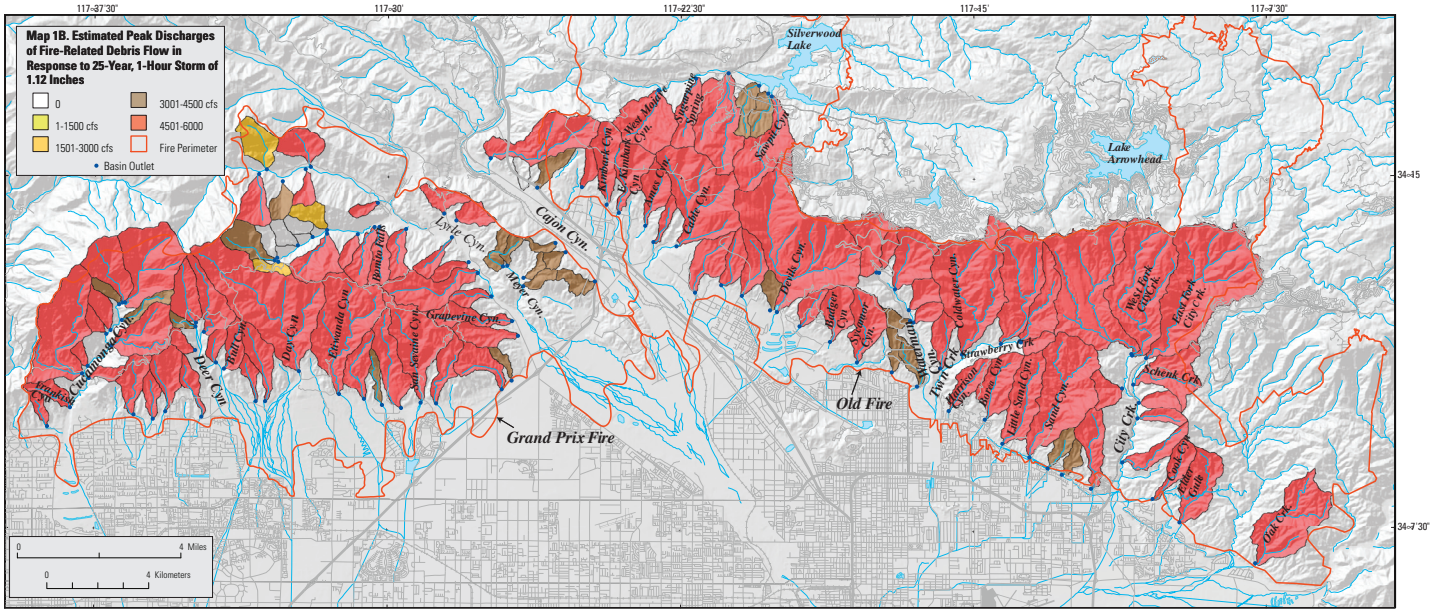
How often? Basins slopes covered only by a thin layer of soil and loose rock and channels that contain only minimal deposits generally produce debris flows only in response to the first intense rainfall of the season. Basins that contain thick channel-fill deposits and slopes mantled with thick layers of soil and loose rock rubble commonly produce numerous debris flows throughout the rainy season. Once the sediment supply has been depleted, debris-flow activity wanes, but water floods are still possible.

Debris-flow hazard maps: In 2003, large areas in San Bernardino, San Diego, and Ventura Counties burned; debris flows are now a hazard in these burned areas. The U.S. Geological Survey (USGS) has published a series of maps of these counties that show the basins most likely to produce the largest debris flows. These maps show the potential for debris flows that might occur in response to 25-year, 10-year, and 2-year rainstorm events; the maps are based on models derived from data collected from recently burned basins throughout the western United States. The models take into account the combined effects of the area of the basin burned, basin gradient, soil properties, and storm rainfall conditions. USGS scientists continue to refine ways to assess the risk of debris flows in recently burned areas, so that more timely information can be provided to emergency response agencies.

Rapid-Deployment Data-Collection Networks (RDNs)

RDN rain gages installed immediately after a wildfire provide valuable data for researchers studying the erosive response of burned basins, and they form the basis for post-fire flood and debris-flow warnings in some areas. Scientists use rainfall data from the RDNs to define rainfall intensity-duration thresholds that identify those conditions most likely to result in post-fire debris-flow activity. Rain gage data are used to develop models for estimating the probability and magnitude of debris-flow activity. Data collected by these RDNs are rapidly becoming an integral element of the Federal government mission of protection of life and property following wildfires.





Maps of basins burned by the October 2003 Old and Grand Prix wildfires in San Bernardino County, California, showing the probability of debris-flows (Map 1A), and potential peak discharges that can issue from a basin outlet (Map 1B), in response to 25-year-recurrence, 1-hour-duration storms. Source given in reference 5 under "For more information."

What Can You Do If You Live Near A Recently Burned Area?

Before a Storm:

1. Watch the patterns of storm-water drainage near your home, and note the places where runoff water converges, increasing flow in channels. These are areas to avoid during a storm.
2. Contact your local authorities to learn about the emergency-response and evacuation plans for your area. Develop your own emergency plan for your family or business.

During Heavy Rainfall:

1. If you are in an area that is susceptible to flooding or debris flow (or has experienced flooding or debris flow in the past), consider leaving if it is safe to do so. Remember that driving during heavy rainstorms can be hazardous.
2. Stay alert and stay awake! Many debris-flow and flood fatalities occur when people are sleeping. Listen to the radio for warnings of intense rainfall. National Oceanic and Atmospheric Administration (NOAA) Weather Radio All Hazards tone alert will let you know of hazards in your area. Be aware that intense bursts of rain may be particularly dangerous, especially after longer periods of heavy rainfall.
3. If you are near a stream or a channel, listen for any unusual sounds that might indicate moving debris, such as trees cracking or boulders knocking together. A trickle of flowing mud or debris may precede larger flows. Be alert for any sudden increases or decreases in water flow and for a change from clear to muddy water. Such changes may indicate debris-flow activity upstream, so be prepared to move quickly. Don't delay! Save yourself, not your belongings.
4. Keep in mind that during flash floods and debris flows water may rise much faster and much higher than it would if the watershed were not burned.
5. Be particularly alert when driving. Bridges may be washed out, and culverts overtopped. Do not cross flooding streams!! Embankments along roadsides are particularly susceptible to landsliding. Watch the road for collapsed pavement, mud, fallen rocks, and other indications of debris flow.

Debris-flow deposits produced during a Christmas day 2003 storm in Waterman Canyon, San Bernardino County, California. Photograph by Sue Cannon.

For more information

1. *http://landslides.usgs.gov/research/wildfire/*

2. Gartner, J.E., Bigio, E.R., and Cannon, S.H., 2004, Compilation of post-wildfire runoff-event data from the western United States: U.S. Geological Survey Open-File Report 2004–1085. *http://pubs.usgs.gov/of/2004/1085/*

3. Cannon, S.H., Gartner, J.E., Rupert, M., and Michael, J.A., 2004, Emergency assessment of debris-flow hazards from basins burned by the Piru, Simi, and Verdale fires of 2003, southern California: U.S. Geological Survey Open-File Report 03–481. *http://pubs.usgs.gov/of/2003/ofr-03-481/*

4. Cannon, S.H., Gartner, J.E., Rupert, M.G., and Michael, J.A., 2004, Emergency assessment of debris-flow hazards from basins burned by the Cedar and Paradise fires of 2003, southern California: U.S. Geological Survey Open-File Report 2004–1011. *http://pubs.usgs.gov/of/2004/1011/*

5. Cannon, S.H., Gartner, J.E., Rupert, M.G., Michael, J.A., Djokic, Dean, and Sreedhar, Sreeresh, 2004, Emergency assessment of debris-flow hazards from basins burned by the Grand Prix and Old fires of 2003, southern California: U.S. Geological Survey Open-File Report 03–0475. *http://pubs.usgs.gov/of/2003/ofr-03-475/*

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This fact sheet is available on-line at
http://pubs.usgs.gov/fs/2005/3106

Publication layout by Margo L. Johnson