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Landslides in the Northern Colorado Front Range Caused by Rainfall, September 11–13, 2013

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During the second week of September 2013, nearly continuous rainfall caused widespread landslides and flooding in the northern Colorado Front Range (fig. 1). The combination of landslides and flooding was responsible for eight fatalities and caused extensive damage to buildings, highways, and infrastructure (fig. 2). Three fatalities were attributed to a fast moving type of landslide called debris flow (fig. 3). One fatality occurred in Jamestown, and two occurred in the community of Pinebrook Hills immediately west of the City of Boulder. All major canyon roads in the northern Front Range were periodically closed between September 11 and 13, 2013. Some canyon closures were caused by undercutting of roads by landslides and flooding, and some were caused by debris flows and rock slides that deposited material on road surfaces (fig. 4). Most of the canyon roads, with the exceptions of U.S. Highway 6 (Clear Creek Canyon), State Highway 46/Jefferson Co. Rd. 70 (Golden Gate Canyon), and Sunshine Canyon in Boulder County, remained closed at the end of September 2013. A review of historical records in Colorado indicates that this type of event, with widespread landslides and flooding occurring over a very large region, in such a short period of time, is rare.

What did the U.S. Geological Survey do?

Between September 13 and September 26, the U.S. Geological Survey (USGS) Landslide Hazards Group in Golden, Colorado, (1) conducted ground reconnaissance to locate and characterize the nature and timing of landslides; (2) took three flights, two in a fixed-wing aircraft and one in a helicopter, to determine the areal extent of landslides; and (3) evaluated ongoing landslide hazards caused by the rainfall event.

Findings

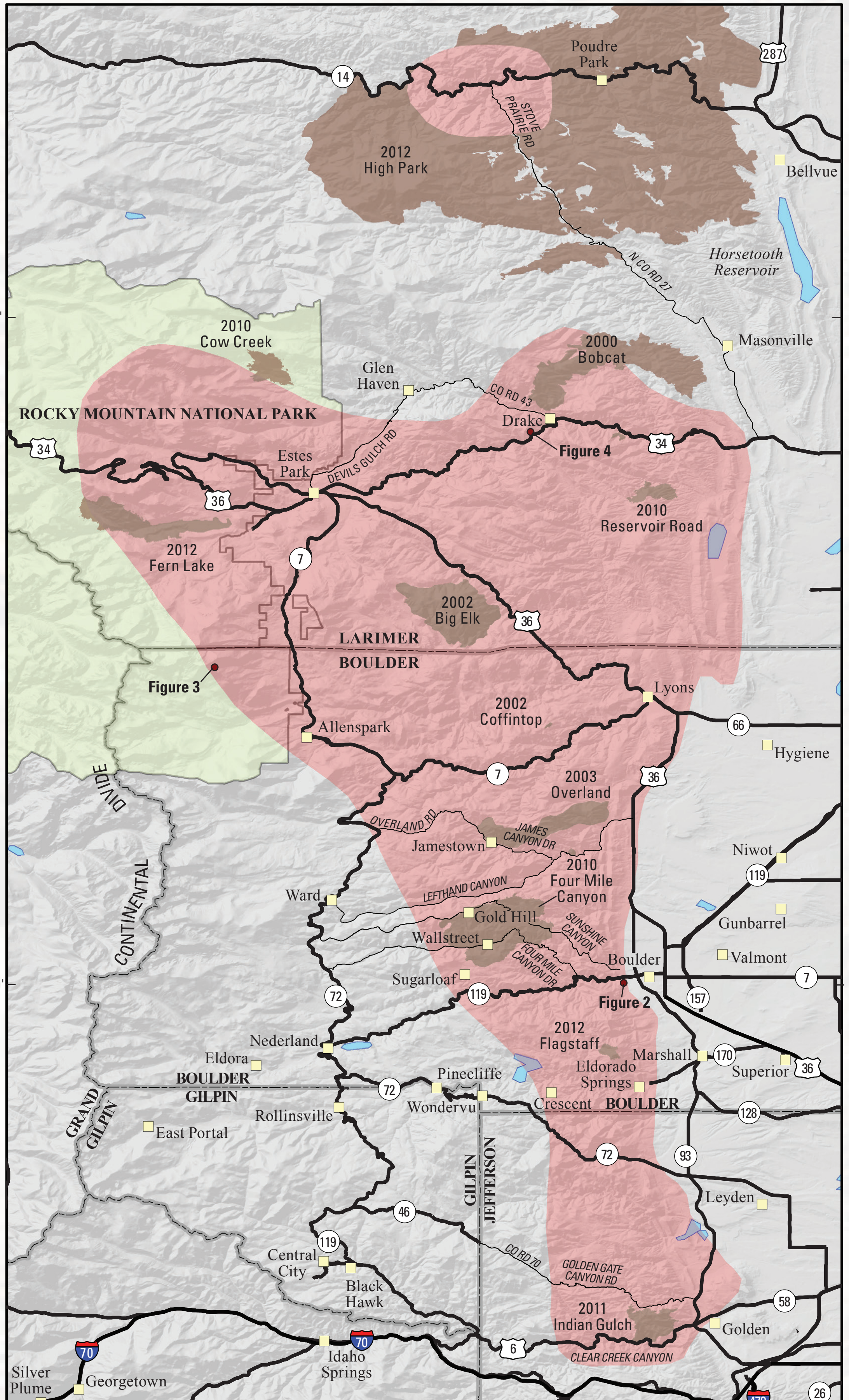
USGS field observations indicated that the area having the greatest density of landslides was roughly the shape of an inverted triangle with the southern apex near Golden and widening north of Boulder (fig. 1). Debris flows were the most common type of landslide observed. These debris flows occurred across a large elevation and climatic gradient extending from the high plains to the alpine environment. Debris flows occurred in soils formed on a wide range of geologic units from the Pennsylvanian through Cretaceous sedimentary sequence of folded sandstones and shales at the range front to Precambrian gneissic and granitic rocks to the west. The types of vegetation where debris flows occurred also were diverse. Some debris flows occurred above tree line and in recent burn areas having little to no vegetation (fig. 3). Other debris flows occurred on grass-covered slopes, and still others occurred on slopes covered by thick, mature conifer trees. The common link between nearly all debris flows observed was that they began as discrete sliding masses that moved downslope as a fluidized mixture of sediment and water. Thicknesses of these initial slides ranged from about 30 centimeters to more than 5 meters. Travel distances of resulting debris flows ranged from tens of meters to about five kilometers (fig. 3). In general, debris flows that entered drainages having flowing water had the longest travel distances and those that occurred on open grass-covered slopes had the shortest travel distances. Part of the reason for this difference in travel distances was that debris flows that entered drainages increased their size by eroding and incorporating additional material into the flow, whereas debris flows on open slopes were limited in size to the volume of the initial landslide.

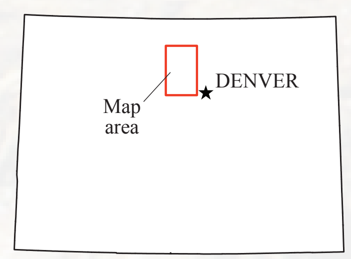
USGS interviews with homeowners, business owners, highway personnel, and local government officials indicated that debris flows and floods occurred together from late Wednesday night (September 11) until mid-day on Friday (September 13). These interviews, as well as field observations, indicated that debris flows exacerbated flooding by supplying sediment to stream valleys. This sediment was mobilized by floods and in some cases caused surging flood pulses that destroyed buildings and infrastructure. The size of this sediment ranged from clay up to 3-meter diameter boulders.

Ongoing Hazards

After the rain stopped, rock fall continued at a higher than normal frequency through the end of September. Field observations indicated that soils, fractured bedrock, and boulders on many slopes, particularly canyon walls, were disturbed and loosened by the September rainfall. These areas may be susceptible to catastrophic failure during rainstorms and snowmelt for several years. Motorists, cyclists, and pedestrians should be aware of this potential hazard from rock slopes and use caution when traveling in Front Range canyons.

Fact Sheet 2013–3114
January 2014





EXPLANATION

- Burn area and year of fire
- Approximate extent of landslides

Figure 1. *Extent of landslides in the northern Colorado Front Range. Areas burned by wildfires between 2000 and 2012 are shown with fire names and dates.*

Figure 2. *Building on Arapahoe Avenue in Boulder that was broken in two by impact from a landslide (Photograph by J.A. Coe, U.S. Geological Survey, September 18, 2013).*

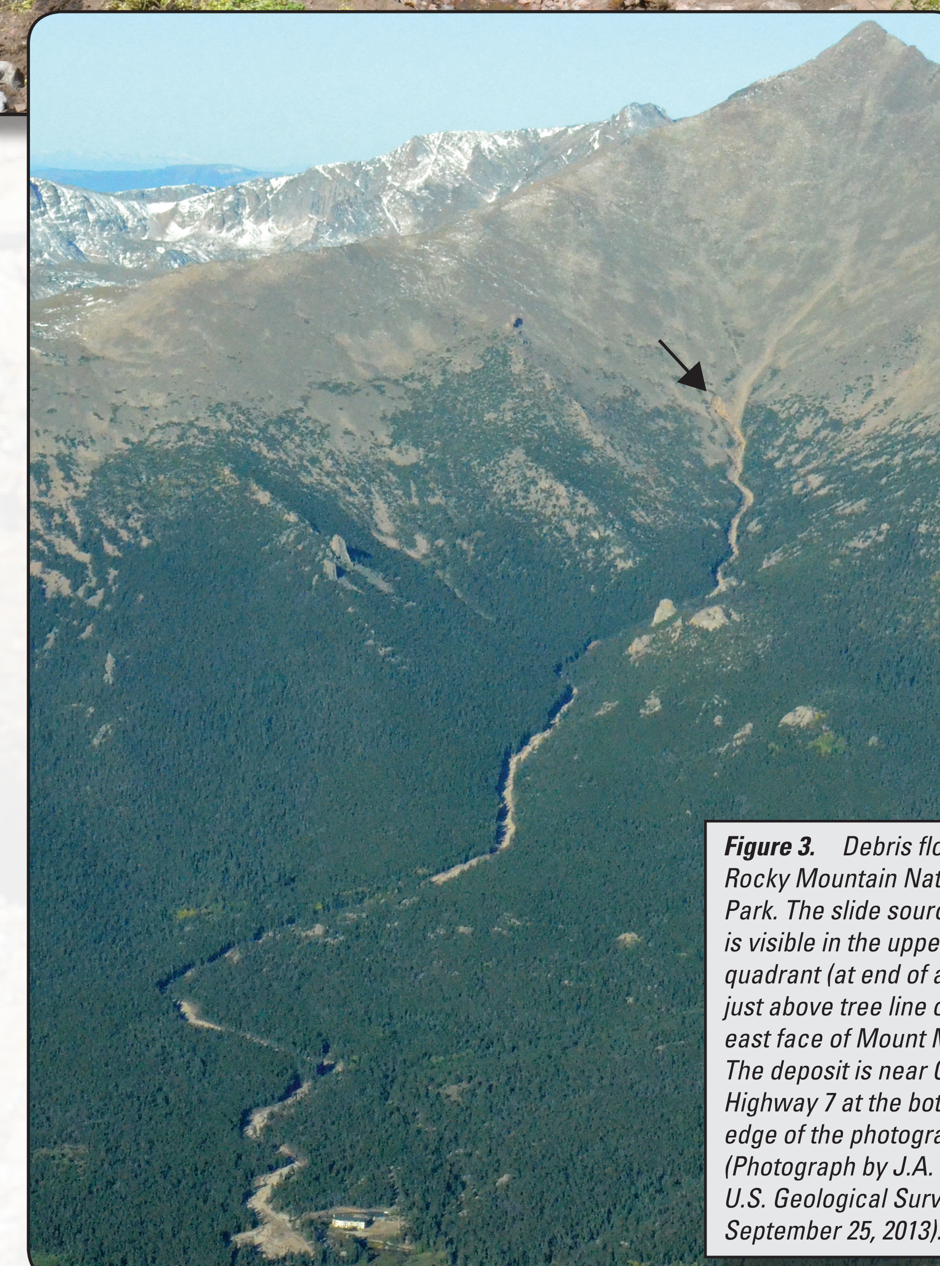


Figure 3. *Debris flow in Rocky Mountain National Park. The slide source area is visible in the upper right quadrant (at end of arrow), just above tree line on the east face of Mount Meeker. The deposit is near Colorado Highway 7 at the bottom edge of the photograph (Photograph by J.A. Coe, U.S. Geological Survey, September 25, 2013).*

Figure 4. *House damaged by debris flow in Big Thompson Canyon; deposit (foreground) covers U.S. Highway 34 (Photograph by J.W. Godt, U.S. Geological Survey, September 20, 2013).*

For More Information

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2327-6916 (print)
2327-6932 (online)
http://dx.doi.org/10.3133/fs20133114