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1998 Debris Flows near the Yakima River, Kittitas County, Washington—Some Geomorphic Implications

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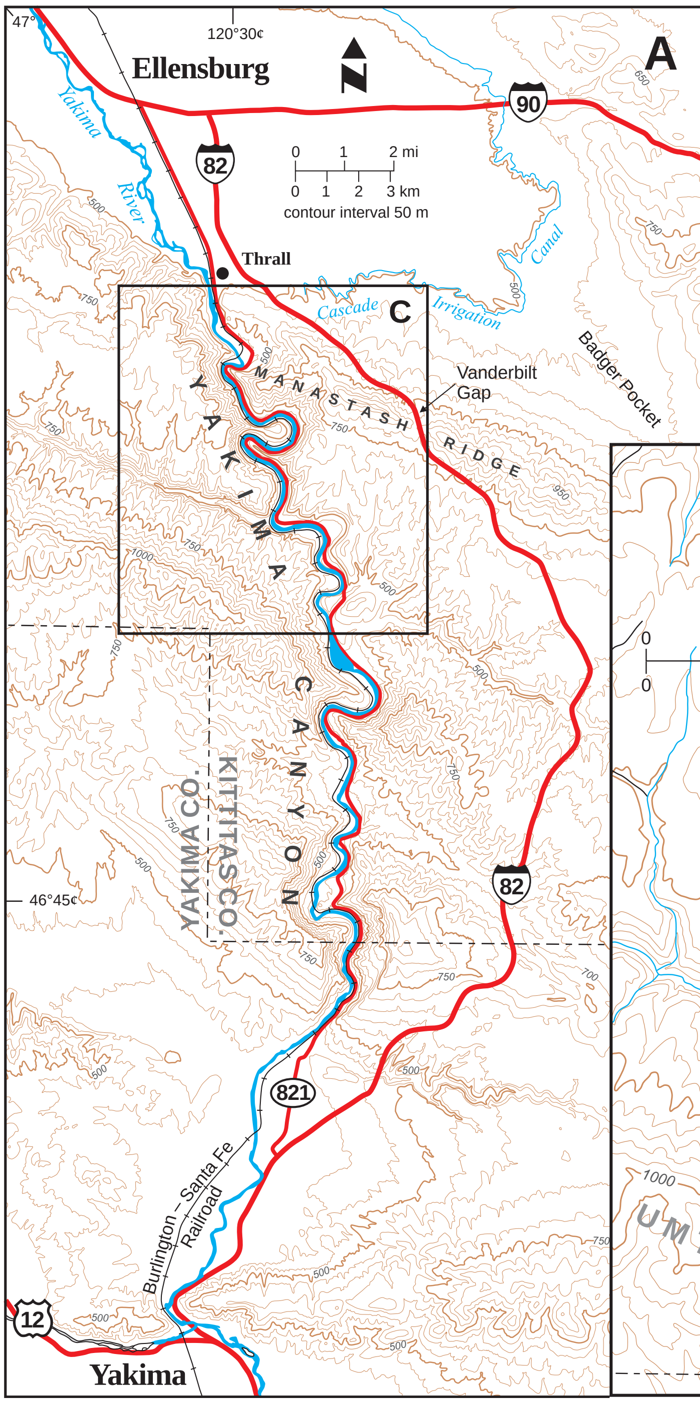
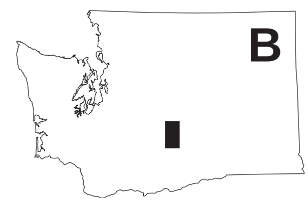
INTRODUCTION

The geomorphic consequences of debris flows and their associated storms have been documented in many parts of the United States. Few, if any, have been studied and documented in central Washington (Fig. 1). The importance of recurrent debris flows in sculpting Washington landscapes has not been generally recognized compared to other processes. Arid and semi-arid regions are particularly vulnerable to debris flows triggered by sudden intense thunderstorms. Most such areas are sparsely populated and eyewitnesses are uncommon. By contrast, semi-arid central Washington is relatively well populated, and there are likely to be people who have observed the storms. Such witnesses can help provide a better understanding of the role played by these storms in molding the landscape. What follows is an example.





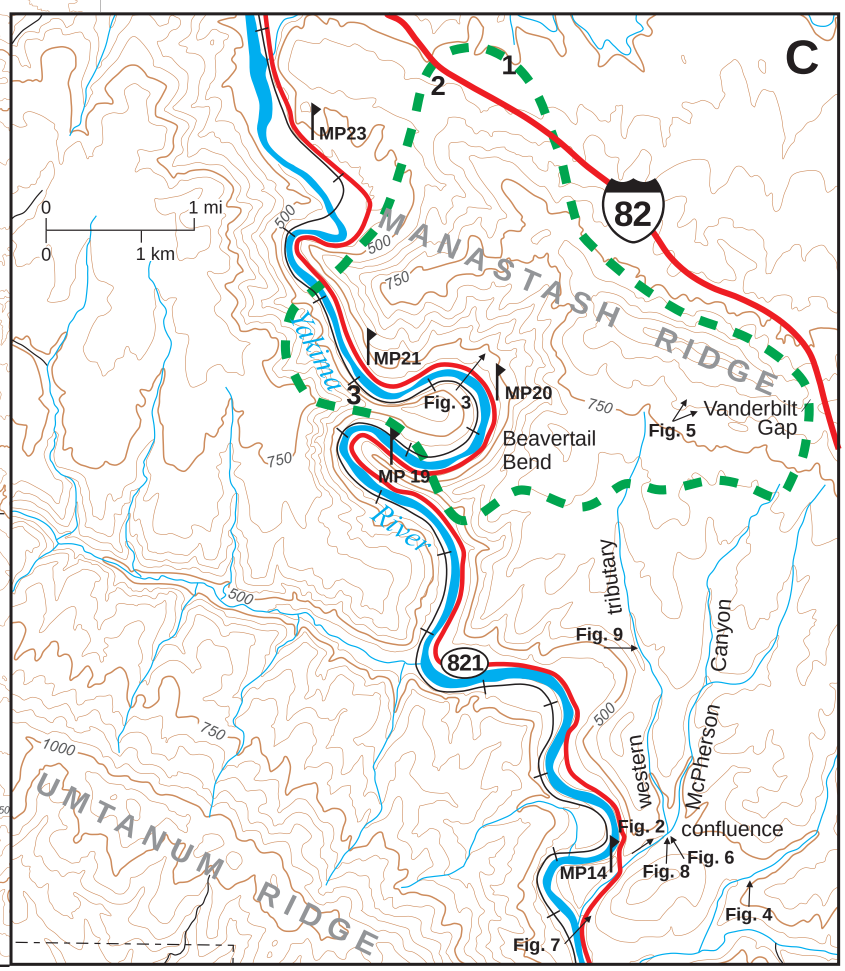


Figure 1. **A**. Map of the area between Ellensburg and Yakima within which the storm and most of the debris-flow damage occurred. **B**. Its location within the state of Washington. **C**. A close-up of the study area. Figure locations are shown with arrows indicating the direction of view. MP, milepost. Dashed outline approximates the boundary of the stagnated storm cell. Numbers are damage sites mentioned in the text.

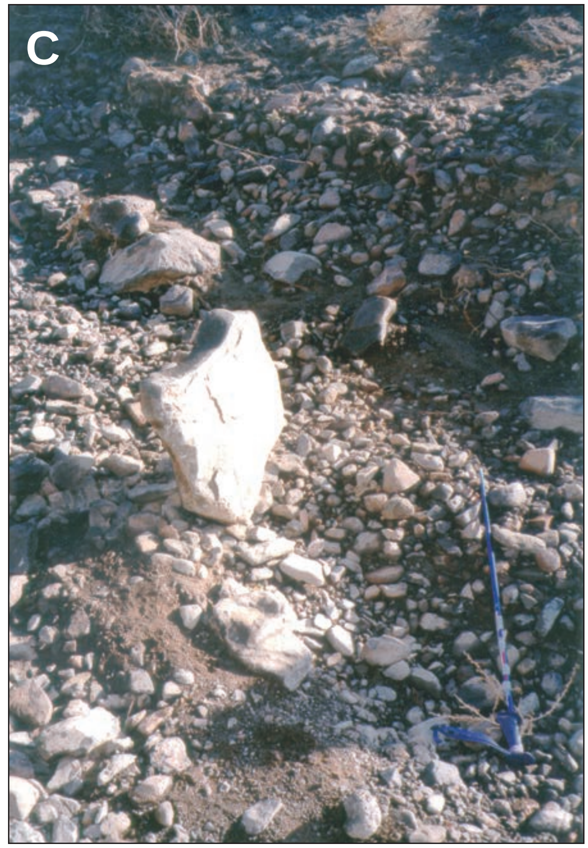


Figure 2. **A**. Imbricated rock in debris channel in lower McPherson Canyon. Note the size of the material entrained. **B**. Perched boulders a short distance downstream from A. **C**. Upended slab left by waning flow.

THE STORM

Between 2:00 and 3:00 p.m. on July 3, 1998, a severe thunderstorm from the west-northwest stalled intermittently over part of southeastern Kittitas County, Washington (Fig. 1). During the cloudburst, Ellensburg recorded 0.87 inches (2.21 cm) of rain in less than an hour. At about 2:15 p.m., witnesses southeast of Ellensburg in the Badger Pocket area reported a tornado-like cloud that appeared to touch down in the vicinity of Thrall near the north entrance to the Yakima River canyon. Some observers also reported an apparent convergence of winds from the northeast and southwest that may have preceded the funnel-like cloud. One observer said "the storm seemed to come in three waves, starting at about 2:30 p.m. Strong winds and rain out of the west hit the area first, and then very strong winds came. . . from the north, followed by a ten minute lull. . . then winds, rain and hail cascaded out of the southwest" (*Ellensburg Daily Record*, July 7, 1998).

As the generally southward-moving storm cell began ascending Manastash Ridge (Fig. 1), it intensified, probably from the uplift. When the cell reached the ridge top, it straddled the ridge and stalled for nearly an hour. Records from the automated weather recorder at Interstate 82 (I-82) on the northeast flank of Manastash Ridge indicate that more than 3 inches (7.6 cm) of rain fell in less than one hour. Much of one orchard was covered with an estimated 5 inches (13 cm) of hail (Fig. 1C, no. 1), and fruit was hail-damaged in several others. Had the hail been rain, it would have added measurably to erosion. Winds in excess of 21 mph were recorded on an agricultural anemometer 6.5 feet (2.1 m) above ground level.

When the storm lifted, it left the remainder of the upland surface rainless from about 1 mile south of the Manastash Ridge crest all the way to Yakima, 25 miles (40 km) farther south. There the cell touched ground and again stalled. In less than an hour, 3.2 inches (8 cm) of rain fell over the Yakima city area. The previous one hour record was 2.03 inches (5.16 cm).

According to the Pendleton National Weather Service office (Joe Solomon, Pendleton National Weather Service Meteorologist, oral commun., 2001), the atmospheric conditions on July 3 were as follows. Convection developed along west-to-east-oriented ridges of the east slopes of the Cascades west of Ellensburg around midday. A large upper-level low east of the Cascades was moving northwesterly upslope into the mountains. The presence of the low helped to facilitate an eastward push of marine air from western Washington through the passes. The marine push eventually overcame thermally produced upcanyon wind patterns associated with the mountain topography. The advancing marine air began to counter the flow pattern of the upper level low. Individual storm cells began to merge. As they combined, they stagnated into a single major cell that hovered for close to an hour over the steep terrain south of the Kittitas valley near the Yakima River canyon. Torrential rainfall, totaling 3 to 4 inches (8–10 cm), fell in a little over an hour.

Figure 3. Debris flows along the north side of Beavertail Bend of the Yakima River burying State Route 821 and debouching into the river. Note the small catchment areas of the ravines and their steep scoured channels. *Photo courtesy of the Washington State Department of Transportation.*

The boundary between the surfaces that experienced torrential precipitation and those that remained almost completely dry was especially well-defined on the southwest flank of Manastash Ridge. Here the edge of the less than 4-square-mile (10.6 km^2) catchment area was marked by rills and flattened grasses next to undisturbed surfaces.

DEBRIS FLOW DAMAGE

Undoubtedly there were variations in the amount and duration of the precipitation over the principal storm area on the flanks of Manastash Ridge, but the quantity and intensity of precipitation that occurred over very limited surface areas was impressive. The rate of precipitation vastly exceeded the rate of infiltration, producing damaging debris flows. The ratio of the supply of water to the supply of regolith determined flow viscosity, and, together with channel gradient and channel roughness, determined the speed of the debris flows. Surges or pulses in the flows were associated with significant sediment additions from undercut channel banks and temporary pondings of the flow. The downstream volume of debris flows is generally proportionate to the area drained, but the channels descending Manastash Ridge varied enough in some instances to make the gradient and the supply of debris available more determinant. (See discussions of debris flow characteristics in Costa, 1984, and Johnson and Rodine, 1984.)

The summit area of Manastash Ridge and the drainages south of the summit have a cover of discontinuous loess and relatively thin colluvium, with many outcrops of weathered basalt bedrock (see Figs. 5 and 6). Storm-induced torrents raced down northeast-facing ravines on the flank of the ridge between Yakima River and Vanderbilt Gap (where I-82 crosses the ridge) (Fig. 1). The ensuing debris flows overtopped ditches and damaged irrigation canals and roads. The Kittitas Reclamation District Mainline Cascade Irrigation Canal suffered one 40-foot (12 m) and one 12-foot (3.6 m) washout (Fig. 1, no. 1). Part of a 50-foot (15-m) long, 4.5-foot (1.6 m) square irrigation tunnel beneath I-82 was plugged with debris (Fig. 1, no. 2). Roadside ditches overflowed, piling debris on to the roads.

West of the Yakima River, a small area that received less sustained precipitation extends a short distance upslope, but not far enough upslope to provide a catchment capable of producing the scale of debris flows that occurred east of the river. The one exception is a flow that buried the Burlington–Santa Fe railroad tracks (Fig. 1, no. 3). On the left bank of the river, concentrated and sustained rainfall flushed out several ravines, some of whose drainage basins are better measured in acres (hectares) than square miles (kilometers).

After the storm, a landscape of scoured and scarred channels remained, commonly eroded to bedrock. Devastated vegetation adjacent to channels

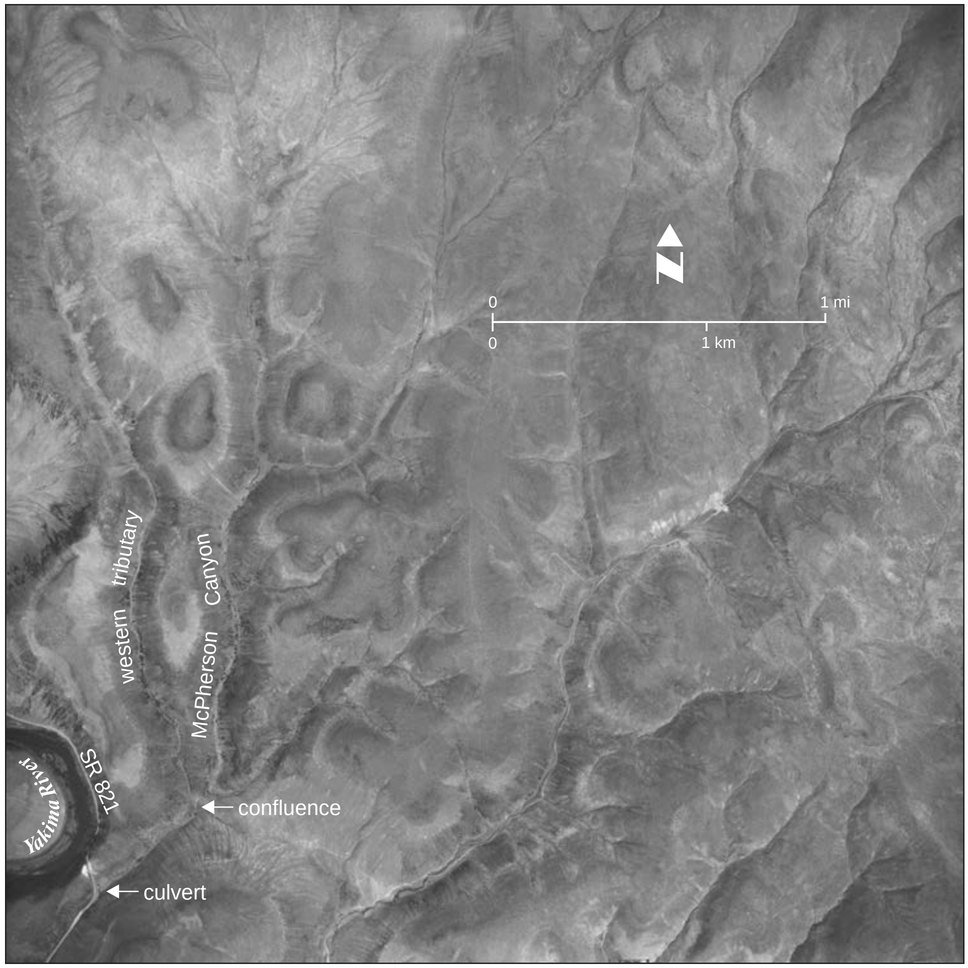
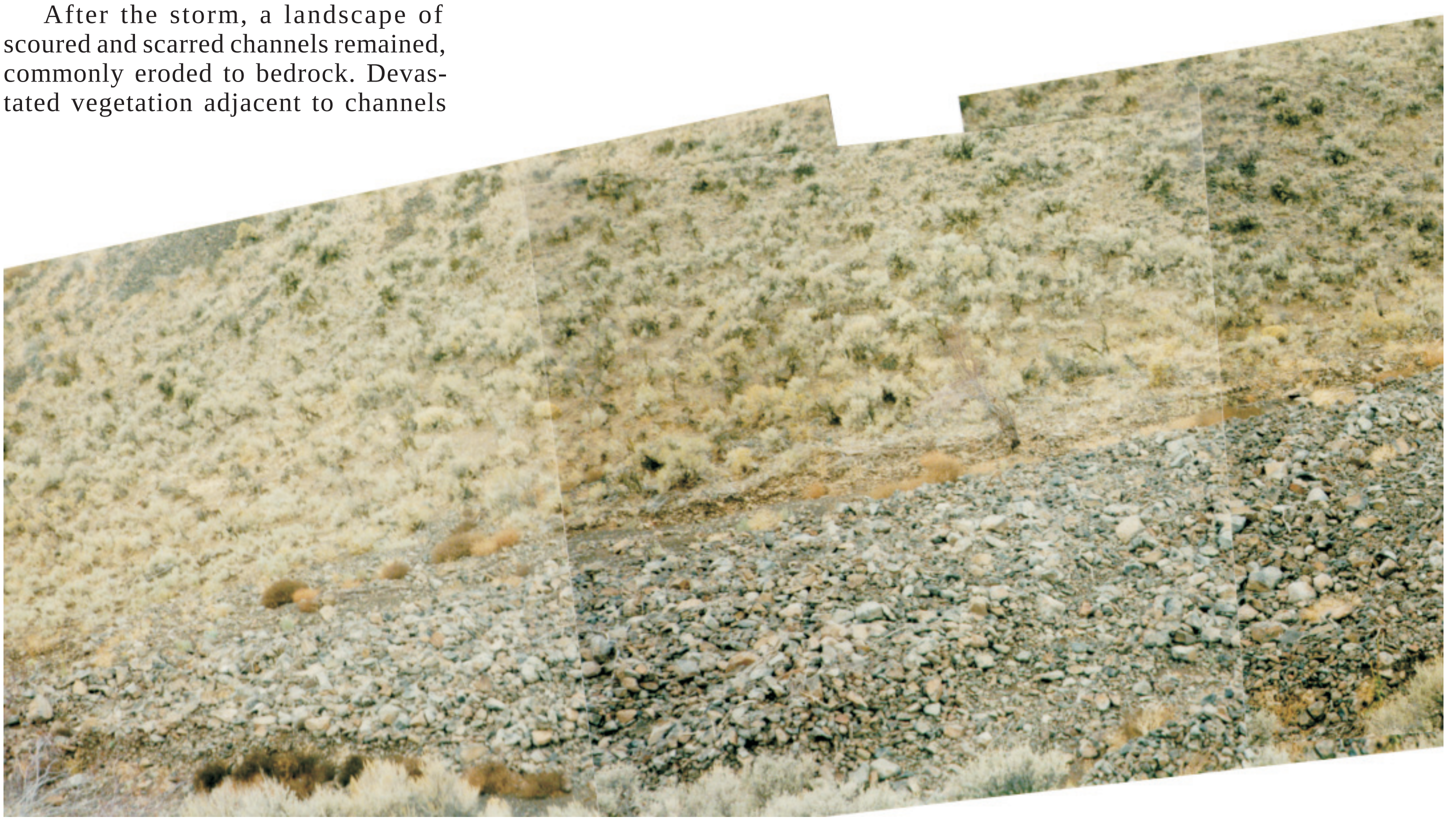


Figure 4. A 1942 air photo of the McPherson Canyon catchment area. Note the bare summits. The erosion illustrated in Fig. 5 occurred a very short distance above the top edge of the photo. The view in Fig. 7 runs approximately from the lower left to the upper right of Fig. 4. *Photo courtesy of the U.S. Department of Agriculture.*



and intermittent lobes of cobbles and boulders were typical. Fresh percussion marks on rocks testified to the force with which some of the entrained rocks struck one another. Debris suspended on bankside shrubs indicated that some flows had depths greater than 6 feet (1.8 m). Debris levees formed intermittently along channel flanks. Lobes of debris occurred wherever the velocity was so diminished that the slurry conveying the debris could no longer maintain its momentum. Deposition was especially favored where channel gradients and channel confinement or constriction lessened significantly. Some of the rock deposits show imbricate bedding, a few with basalt slabs a foot (30 cm) or more in diameter. Here and there, rocks remained perched precariously after their supporting slurry drained away (Fig. 2).

Ravines draining westward from the southwest flank of Manastash Ridge directly into the Yakima River canyon discharged rocky debris that quickly buried portions of State Route (SR) 821, depositing debris fans into the adjacent river channel. The deposits generally lie downstream of the principal precipitation catchment area. Every ravine abutting SR 821 between mileposts 19 and 23 (Fig. 1), a straight-line distance of about 2.6 miles (4.2 km), was affected to some degree by the torrents. Major debris deposits covered SR 821 in eight separate places between mileposts 19 and 21 opposite Beavertail Bend. Six reached well into the river. One of these buried the highway with debris more than 15 feet (4.6 m) deep and continued nearly 60 percent of the way across the river channel (Fig. 3). The ravines, all less than one mile (1.6 km) long,

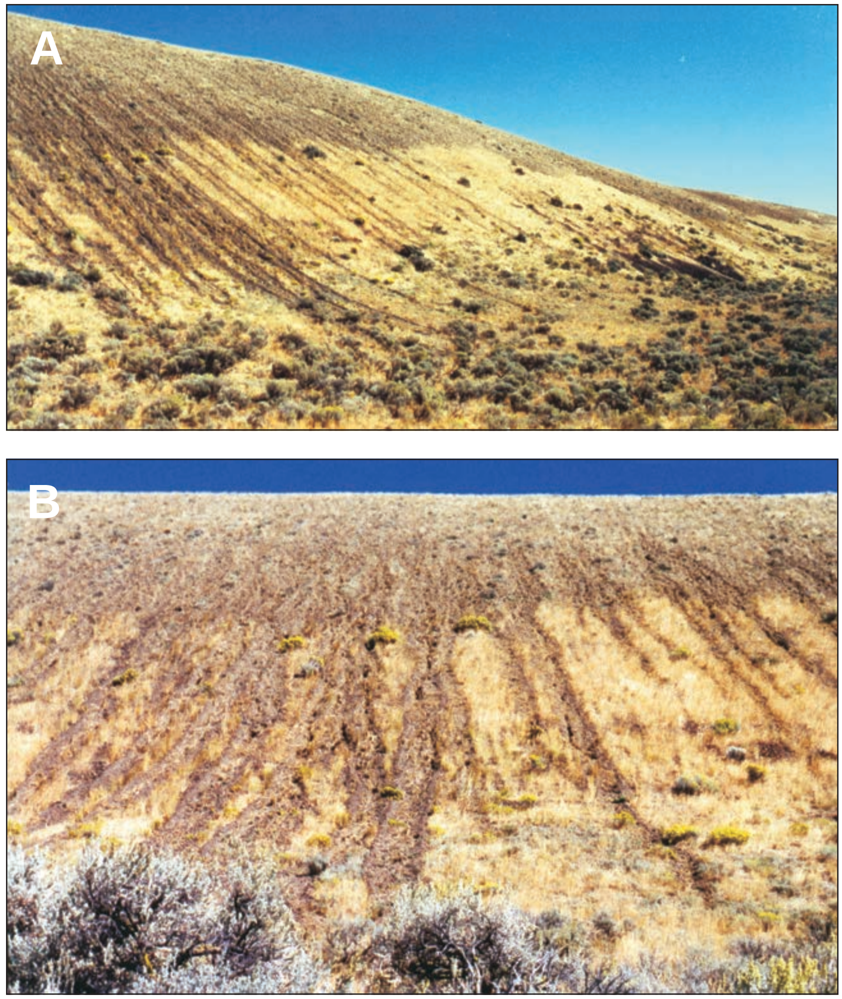


Figure 5A and B. *(top and middle, this page)* Streaked southwest flank of Manastash Ridge following the July 1998 storm. The streaks are furrows eroded through the loess (silt) mantle down to bedrock. *Photo courtesy of Will Johnson.*

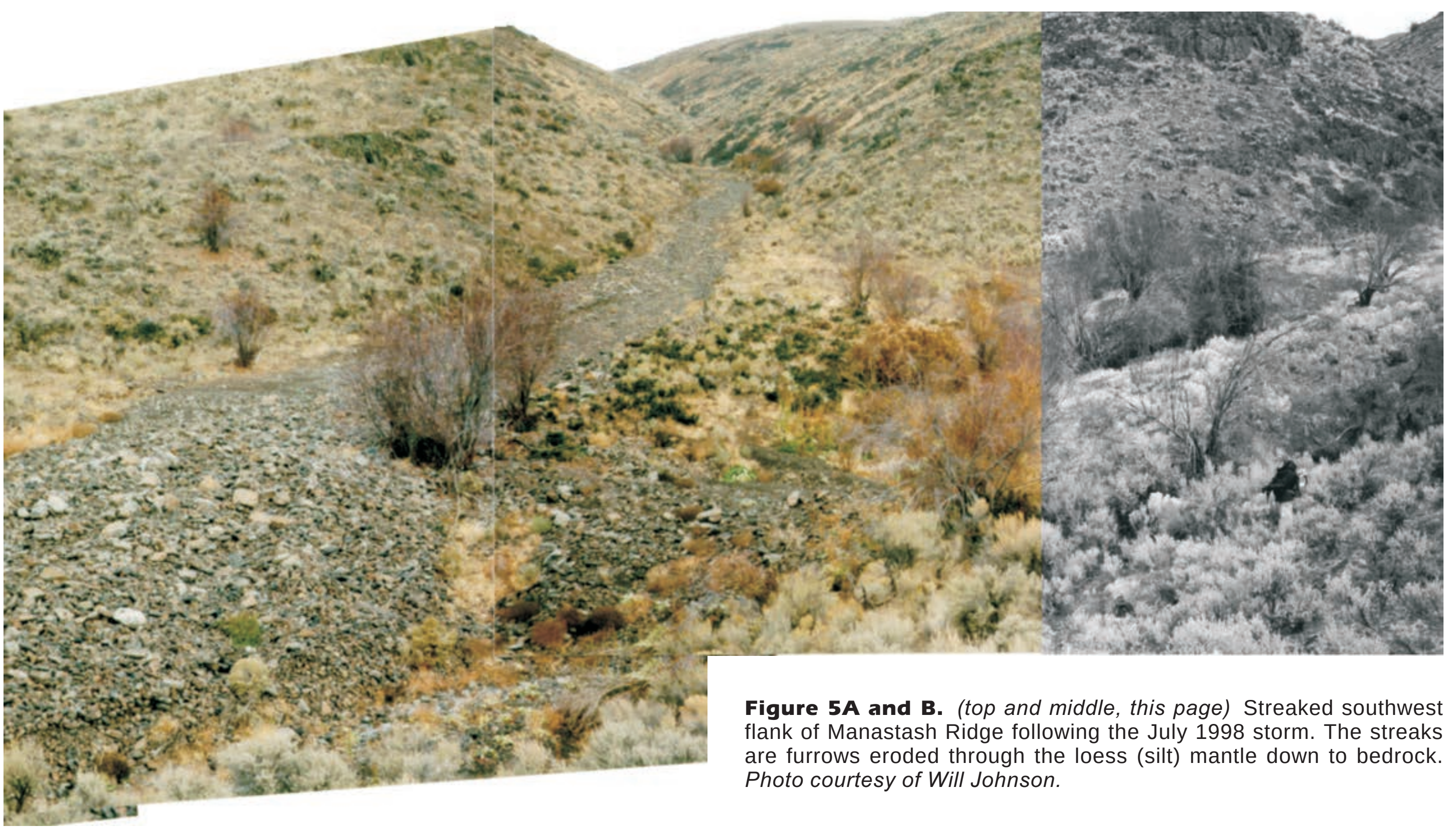


Figure 6. *(preceding page and bottom, this page)* Debris lobe at the confluence of the unnamed western tributary, upper right, and the main McPherson Canyon channel in the foreground.

Figure 7. Looking northeast from the mouth of McPherson Canyon to the summit of Manastash Ridge. Note the scoured channel between the highway crossing of McPherson Canyon and the confluence debris lobe. Erosion from the overflow of the culvert can be seen paralleling the highway downstream to the Yakima River. The catchment area for the debris flow in McPherson Canyon lies beyond the left side of the photo (Fig. 4). *Photo courtesy of the Washington State Department of Transportation.*

concentrated the flows and provided a very steep gradient. Channel incision was initiated at about 1,000 feet (300 m) above Yakima River level. Were there no maintained highway in place, there would have been steep alluvial aprons at the ravine mouths, accumulations testifying to past debris flows. Some would have coalesced, forming compound fans projecting into the river channel and deflecting it, at least temporarily.

What happened in lower McPherson Canyon and its upstream unnamed western tributary illustrates the nature and power of cloudburst-generated debris flows particularly well. Portions of the southbound lane of SR 821 at milepost 14 were washed out by inundation from an overwhelmed culvert that carries the ephemeral stream in McPherson Canyon beneath the roadbed. (The name ‘canyon’ is deceiving. Only a few hundred yards of McPherson Canyon’s stream channel are canyon-like.)

The damage here was about 3 straight-line miles (5.4 km) beyond the limit of the storm’s catchment area. Less than one third of McPherson’s 5.5-square-mile (14.3 km^2) watershed, which originates on the southwest slope of Manastash Ridge, collected the storm’s precipitation. The catchment area is covered, more or less, by sagebrush-steppe vegetation and a discontinuous, often thin, loess (silt) blanket (Fig. 4). From the ridge summit west of I-82, fresh, naked rows of loose rock interspersed with sparsely vegetated strips (stone stripes) extend downslope (Fig. 5). This loose rock and loess, augmented with debris gathered by sheetwash and rilling on the ridge's mid flanks, was the initial source of storm-delivered sediment to first-order channels of McPherson Canyon. The slurry that formed from the sediments had the velocity needed to entrain cobbles and boulders up to about 1.5 feet (0.5 m) in diameter (Fig. 3). Most of the discharge of water, entrainment of debris, and erosion occurred in the western tributary to McPherson Canyon. Only the upper portion, about one square mile (2.6 km^2), of the tributary's watershed was entirely within the catchment area.

A very large lobe of rocks (Fig. 6) was deposited by the debris flow where the western tributary joins the main channel of McPherson Canyon. Its volume and size approximates that of the largest of the deposits, estimated to be 50,000 cubic yards (38,227 m^3) in volume and more than 15 feet (4.5 m) deep, that flowed onto SR 821 near milepost 20 (Fig. 3). A widening of the valley floor, a decrease in channel gradient, and a change in channel direction combined to decrease flow velocity and deposit the debris lobe at the confluence.

The channel discharge that followed the loss of load at the confluence caused extensive downstream erosion and highway damage (Fig. 7). The now-more-liquid slurry was able to speed downstream, relatively unencumbered, to a culvert beneath SR 821. It overwhelmed the culvert and turned the highway embankment above the culvert into a 150-foot (46 m)-wide dam, temporarily ponding the surging water for a distance of 700 feet (220 m) upstream. When the impounded water overtopped the embankment barrier, it eroded a double cataract into the pavement where it plunged back into its channel adjacent to the highway's southbound lane. Other segments of the road were undermined as the flood continued down the channel to its confluence with the Yakima River. Subsequently, a narrower, deeper channel trenched this reach, a response to at least one last surge of essentially debris-free water.

The confluence debris lobe is the only major debris flow deposit that has remained undisturbed since the storm occurred. Those deposited on SR 821 were removed or bulldozed aside to maintain traffic through the Yakima River canyon. The configuration, composition, and other characteristics of the confluence debris plug suggest the sequence and some of the dynamics associated with the debris flows. The sequence appears to have been: (1) An initial, relatively sediment-poor flow came down the main channel of McPherson Canyon, and perhaps its western tributary as well. It was not associated with significant evidence of deposition. (2) A

Figure 8. **A**. Toe of the confluence debris lobe showing incision by flooding following initial deposition. **B**. Incision on debris lobe south flank. The western tributary, the source of virtually all of the debris, is on the upper left; the main McPherson Canyon channel is on the upper right.

Figure 9. *(right)* Stratigraphy of alternating cobbles and fines in incised channel of the western tributary indicates the occurrence of previous debris flow events.

subsequent flow down only the western tributary deposited the debris lobe. (3) A final(?) flow down the western tributary continued to the outlet of McPherson Canyon. The debris lobe is scarred by at least three gullies (Fig. 8) partially incised into its distal flank, suggesting that the lobe was overtopped after its initial deposition.

That this happened when less than 25 percent of the entire McPherson Canyon watershed lay in the catchment area illustrates the extraordinary amount of erosion that a cloudburst may generate even when it occurs over a very limited portion of a watershed.

PREVIOUSLY RECORDED DEBRIS FLOWS

Nothing in the preceding account is particularly unusual relative to the behavior of debris-flow-producing storms. There have been many previous debris-flow-producing storms in the general vicinity of the 1998 event. One on June 21, 1967, produced debris flows in two of the same ravines affected by the 1998 storm. Another, on Aug. 10, 1952, initiated debris flows in drainages west of the Yakima River near the 1998 site. A July 26, 1977, storm generated debris flows several miles to the east. Elsewhere in Kittitas County, intense summertime storms were recorded on Sept. 14, 1940, Aug. 20–21, 1990, and July 24, 1991. Some of the channels affected by the 1998 storm have very old debris flow levees that are much larger than the new ones. These are indicative of powerful storms in the past for which there are no written records (Fig. 9). The normal flow associated with these ephemeral streams is not capable of generating the significant channel erosion that is associated with debris flows.

CONCLUSION

Catastrophic events on a small, relatively localized scale may be significant to understanding the geomorphology in portions of upland semi-arid central Washington (Beatty, 1974). Cloudburst-generated debris flows are sudden, spasmodic events recurring at irregular intervals over limited surface areas. Their work is rarely observed, and their geomorphic importance in sculpting the landscape in central Washington is rarely appreciated.

Previously, periglacial activity during the late Pleistocene has been cited as the primary agent for loess segmentation and removal in much of central Washington (Kaatz, 1959). There is no reason to dispute that role. Periglacial processes were critical to the initiation of upland loess dissection. In post-glacial times, however, evidence indicates that summer cloudbursts may have supplanted frost action as a dominant landscape-shaping process.

During the Pleistocene, periglacial denudation proceeded in a rather steady incremental manner over extensive, largely contiguous areas that were either underlain by permafrost or exposed to deep seasonal frost (Clark, 1988). Holocene cloudbursts, on the other hand, occur over limited areas. For example, although at least seven cloudburst-like storms are known to have occurred in eastern Kittitas County in the last 50 years or so, only one has occurred in the area delineated in this paper.

It is unlikely that winter events, such as rain on snow, generate enough runoff on the ridges that separate Ellensburg from Yakima to produce debris flows. The south-facing slopes of the ridges are especially vulnerable to poor snow retention during frequent sunny winter days, hence there is usually insufficient snow to provide enough meltwater to combine with steady, prolonged, low-intensity rainfall (typical of local winter rain) to cause debris flows. Therefore summer cloudburst-generated debris flows should be considered a dominant agent of upland landscape change in the region between Ellensburg and Yakima during the Holocene.

ACKNOWLEDGMENTS

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REFERENCES CITED

Beatty, C. B., 1974, Debris flows, alluvial fans and a revitalized catastrophism: Zeitschrift Geomorphology Supplement, v. 21, p. 39-51.

Clark, M. J., editor, 1988, Advances in periglacial geomorphology: John Wiley & Sons, 481 p.

Costa, J. E., 1984, Physical geomorphology of debris flows. *In* Costa, J. E.; Fleisher, P. J., editors, Developments and applications of geomorphology: Springer-Verlag Berlin, p. 268-317.

Johnson, A. M.; Rodine, J. R, 1984, Debris flow. *In* Brunsden, Denys; Prior, D. B., editors, Slope instability: John Wiley & Sons, p. 257-362.

Kaatz, M. R., 1959, Patterned ground in central Washington; A preliminary report: Northwest Science, v. 33, no. 4, p. 145-156. ■

Debris Flows Websites

Debris-Flow Hazards in the United States [http://geohazards.cr.usgs.gov/factsheets/html_files/debrisflow/fs176-97.html]

Mudflows, Debris Flows, and Lahars [http://vulcan.wr.usgs.gov/Glossary/Lahars/framework.html]

History of Landslides and Debris Flows at Mount Rainier [http://wa.water.usgs.gov/fs_landslide.html]

New Liquefaction Website

The University of Washington has a new website about soil liquefaction with animation, photos, and discussions of liquefaction in major earthquakes—http://www.ce.washington.edu/%7Eliquefaction/html/main.html. The website was developed to provide general information for interested lay persons, and more detailed information for engineers. Visitors who are not familiar with soil liquefaction can find answer to typical questions below.

What is soil liquefaction?

When has soil liquefaction occurred in the past?

Where does soil liquefaction commonly occur?

Why does soil liquefaction occur?

How can soil liquefaction hazards be reduced?

More detailed information, presented at a level that does require an engineering background, can be obtained by following the links labeled “More” at the end of each section. There are also links to other sites on soil liquefaction research and earthquake and soil liquefaction information.