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Floods in the Southwest

By Rebecca Carter

A flood may be defined as any relatively high stream flow event that overflows the natural or artificial banks of a river or stream, according to Katie Hirschboeck of the Laboratory for Tree Ring Research at the University of Arizona. Hydrologists define stream flooding based on the volume of water flowing and use the term "peak-above-base" to identify large flows or floods that exceed a specified "base" discharge. These peaks-above-base are relatively rare (on average, one or two a year), but in wet years many peaks can occur, while in dry years the base discharge level might not even be met. The largest peak flows may negatively impact people through river channel erosion, riverbank collapses, road closures, and other related flood hazards. However, any significant flow of water can be important for aquifer recharge, especially in the Southwest, where many streams are dry a good part of the year.

No single weather pattern can account for all floods in the Southwest. Instead, winter frontal storms, late summer and fall tropical cyclones from the eastern North Pacific, and summer storms can cause floods. Floods can be divided into two types: localized flash floods, often caused by summer monsoon storms, and more extensive storms, such as the remnants of tropical storms or winter frontal systems. Whereas widespread storms can cause greater property damage, flash floods are far more dangerous to people. In fact, the National Weather Service office in Flagstaff, Arizona notes that flash floods are the number one weather-related killer in the United States, leading to about 150 deaths every year (1).

In the Southwest, monsoon-related thunderstorms typically occur from July through September. The damage that floods caused by monsoon storms inflict may be limited to the relatively small areas these storms affect. However, they are treacherous because storms miles away can cause them, sometimes leading to fatal surprises. This was the case in Lower Antelope Canyon in northern Arizona on August 12, 1997. Twelve hikers were caught in a 10- to 30-foot high wall of water as they hiked through a slot canyon; only one survived (2).

New Mexico offers examples of the damage that more widespread flooding can cause. On June 17, 1965, a hurricane in the Gulf of Mexico brought intense, widespread rainfall to the state, causing record discharges on some rivers and tens of millions of dollars in losses. Although this flood occurred during a major dry spell, it did not have an appreciable effect on the drought because of the short duration of the rainfall.

Arizona's largest flood in recorded history also was caused by widespread storms. During February 1891, heavy rainfall caused the Salt River at Phoenix to peak at 300,000 cubic feet per second. The river swelled to two to three miles wide and extended two miles north of the channel in central Phoenix.

Not all rainfall leads to flooding…
It takes more than just any old rainfall to produce a flood. Specific atmospheric and soil conditions are often the decisive factors that separate flood-causing rains from less remarkable precipitation. Flash floods, which have been described as "more water than you want in less time than you have," become more likely when a large storm gathers moisture from continuous, low-level flows and is held in place for several hours by the topography or weak upper-level winds. Flash floods can also result from dam failures, which may send huge quantities of water downstream and lead to great destruction. Rainfall on snow, which causes rapid melting, has also unleashed abrupt torrents of water in the Southwest (3).

Particular atmospheric conditions over the North Pacific are conducive to more extensive winter floods on rivers in the Southwest. A 1994 study (4) found that the largest winter floods in the Southwest occur when there is both an exceptionally strong low-pressure

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anomaly off the California coast and a high-pressure anomaly in the vicinity of either Alaska or the Aleutian Islands. The low-pressure system controls whether large floods will occur, whereas shifts in the high-pressure anomaly dictate which regions will experience floods. Topography and other air masses also play a role. The peak months for these occurrences, known as cutoff lows, are April and October, and they are unlikely in July and August (5).

The El Niño Effect

Recent results from streamflow studies by investigators at the U.S. Geological Survey, the Scripps Institute of Oceanography, and the Desert Research Institute show that 1) El Niño years bring, on average, increased mean flows and flood sizes to the Southwest and 2) the variability of annual stream flow and floods in the Southwest is two or more times greater during El Niño years than during either La Niña or non-Niño years. El Niños tend to bring either very wet or very dry winter stream flow conditions to the Southwest, with few years falling in the average range. Flow records were examined from the Salt River in central Arizona, which tends to react strongly to ENSO conditions. The mean annual flood on the Salt River is 585 cubic meters per second (cms) during El Niño years, 226 cms in La Niña years, and 630 cms during years that are neither, indicating that El Niño does not bring overall higher flow levels to the Salt River. However, the researchers found that El Niño does consistently bring a dramatic increase in the *range* of river flows, while both La Niña and neutral years tend to have relatively narrow ranges. Floods on the Salt River are four times more variable during El Niño years.

The researchers further examined the impact of the Pacific Decadal Oscillation (PDO) on stream flows during El Niño and La Niña years. They found that a positive PDO phase, such as the one that is believed to have ended recently, tends to strengthen El Niño's potential for bringing wetter conditions and higher stream flows to the Southwest. A negative PDO phase, which climatologists believe the Pacific has recently entered and is expected to bring generally drier conditions, tends to reinforce the ability of La Niña to bring drier than average conditions. The combination that currently exists, of El Niño and a negative PDO, also correlates with increased variability. However, it is not likely to lead to as high river flows as positive PDO conditions in the recent past would have.

In 1998 researchers (6) also found that in North America when the cool season coincides with an El Niño event and warm tropical Pacific conditions, there is an increase in the frequency of days with high precipitation and stream flow in the Southwest and a decrease in the number of such days in the Northwest. For several basins in the Southwest, extremely high flows are at least 10 times as likely to occur during El Niño years as during neutral or La Niña years.

Several other researchers agree that El Niño and La Niña conditions affect rainfall totals, particularly during the fall and spring. A study in 1992 (5) found that of 35 years with El Niño conditions, rainfall totals in 29% of the years were above normal, 54% were normal, and only 17% were below normal. The aforementioned 1994 study (4) also concluded that in the Southwest, there is an increased frequency of large winter floods during multiple-year El Niños and a virtual absence of large floods during the intervening periods.

An important factor in determining whether floods will occur is the condition of the soil when rainfall hits it. Rainfall is more easily and rapidly absorbed into dry soils, compared to soils that are already saturated by previous rainfall. Researchers in 1999 (6) also found that during El Niño years, not only were there more rainy days, but also more two-day- and three-day-in-succession precipitation events, which are more likely to lead to flooding. In fact, there were twice as many multi-day rains compared to neutral and La Niña years. They also found that there is a 30% greater likelihood of extreme events during El Niño and La Niña years than during neutral years.

Floods and Fire

The lack of vegetative cover caused by forest fires in areas of Arizona and New Mexico increases the likelihood of floods in these areas. When forest fires scar the land, there is often little vegetation left to catch runoff from heavy rains (3). Worse yet, the heat from such fires can leave the ground parched and unable to absorb water. Relatively modest rainfall amounts that would normally cause no problems can lead to dangerous flash floods in these areas. For example, this year monsoon thunderstorms over the Rodeo/Chediski fire burn area have produced large peak stream flows in response to relatively small amounts of rainfall. Such runoff can be toxic to fish and other organisms. The sediment-laden water running off the burn area contains organic debris, dissolved nutrients, and other chemical compounds released by the fire's combustion (7).

While New Mexico and Arizona have largely been spared the ravages of fire-induced flooding so far this year, the Durango, Colorado area has not been so fortunate. An inch and a half of rain fell in a little over an hour on September 7, 2002, on areas recently burned in the Missionary Ridge fire. The resulting mudslides

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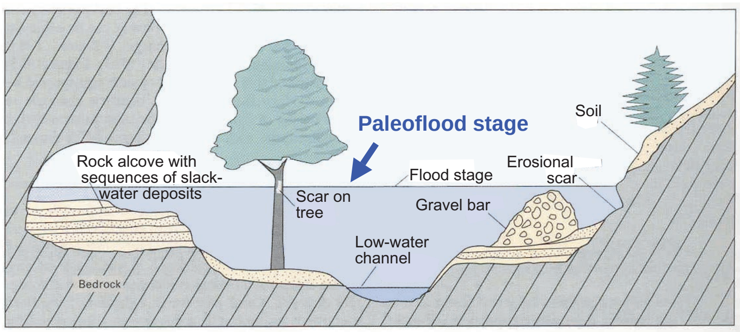
damaged homes and property. Flooding is anticipated to continue in the area for up to five years (8).

Past Floods

Current climatic conditions tell us something about the likelihood of flooding in the Southwest this winter; by the same token, evidence of previous flooding can tell us something about past climatic conditions. Researchers examining evidence of past flood events, such as erosion features, scars on trees, and slack-water deposits, have detected periods when flooding was a more frequent experience in the Southwest (see figure below). They also have learned that past floods were similar in volume in this region to more recent flood events, such as those that occurred in the Lower Colorado River Basin in 1993.



Paleoflood information: Where it comes from. Diagram showing a section across a stream channel with flood stage and paleoflood evidence (slack-water deposits, tree scars, gravel bars, and erosional scars). After Jarrett, R.D. 1991. Paleohydrology and its value in analyzing floods and droughts. Pages 105-116 in National Water Summary 1988-1989, Hydrologic Events and Floods and Droughts. U.S. Geological Survey Water Supply Paper 2375 and Baker, V.R. 1987. Paleoflood hydrology and extraordinary flood events. *Journal of Hydrology*, vol. 96, p. 79-99.

For More Information About Floods

(1) http://www.wrh.noaa.gov/Flagstaff/summer/flood.html

(2) http://geochange.er.usgs.gov/sw/impacts/hydrology/state_fd/

(3) http://www.wrh.noaa.gov/flagstaff/science/flashfld.htm

(4) L.L. Ely, Y. Enzel, and D.R. Cayan. 1994. Anomalous north Pacific atmospheric circulation and large winter floods in the southwestern United States. *Journal of the American Meteorological Society*, vol. 7, p. 977-87.

(5) Richard Hereford and R.H. Webb. 1992. Historic variation of warm-season rainfall, southern Colorado Plateau, Southwestern U.S.A. *Climate Change*, vol. 22, p. 239-56.

(6) D.R. Cayan, K.T. Redmond, and L. Riddle. 1999. Accentuation of ENSO effects on extreme hydrologic events over the western United States. *Journal of Climate*, vol. 12, p. 2881-93.

(7) http://www.usgs.gov/public/press/public_affairs/press_releases/pr1613m.html.

(8) Kostka, Jennifer. 2002. Between rocks and a hard place. *Durango Herald*, Sept. 10. http://www.durangoherald.com/