DESERT RUNOFF : Hazards in Arizona

by Susan M. DuBois and Brian R. Parks

Each year Arizonans experience extensive losses due to desert runoff. Since 1862 runoff processes have resulted in at least 194 deaths (recorded) and more than $475 million in property and agricultural losses. Fifty-eight percent of this estimated cumulative monetary loss has occurred during the past ten years, 43 percent since 1975.

The curves in Figure 1 show a clear trend toward increasing losses with succeeding high-flow events throughout the historical runoff record, especially in recent years. Moreoever, surges in losses appear to coincide with surges in urban population growth. Possible factors relating these two curves will be discussed later. Figure 2 illustrates that runoff-related damage has occurred frequently in all populated regions of the state.

Flooding is the most common term applied in discussions of hydrologic risk. Often, the word is used synonomously with *runoff* or *erosion*. However, technically defined, flooding describes a condition of overbank flow, a spreading of water onto a floodplain*, away from a runoff channel. In Arizona, as elsewhere, much so-called flood damage actually takes place during non-flood stage runoff periods, when flowing water is confined by well-defined but frequently shifting banks. Several examples follow:

1) Flash "flooding" occurs when water suddenly flows in a wash that was previously dry (Figure 3A). Potential victims include hikers, campers or motorists who either do not heed threatening weather signals or who choose to cross a rushing and powerful stream. Unfortunately, many people fail to view *dry washes* as active water conduits.

2) A continuous natural process of a flowing stream is bankcutting, or lateral erosion. This activity is concentrated along the outside bank of a meander, where water is moving most rapidly around the bend. Undercutting of soft bank material leads to cave-ins and channel migration (Figures 3B and 3C). During high

*Floodplain: "Relatively flat area or lowland adjoining the channel of a stream or watercourse and subject to overflow by floodwaters." Army Corps of Engineers Flood Plain Information Study for Maricopa County, Arizona, Vol. IV Wickenburg Report, app. 2, at 2 (1965).

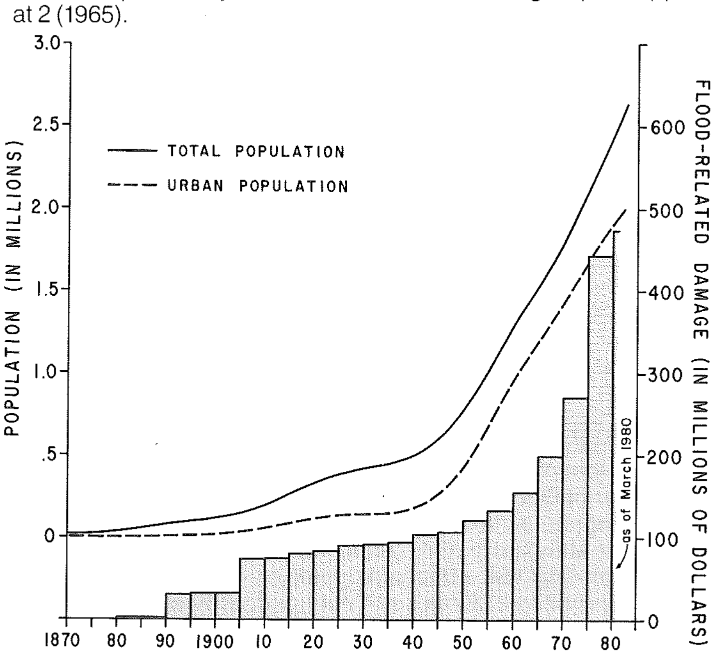


Figure 1A. Cumulative damage from high runoff over five-year intervals. Note that increased losses coincide with increased urban population.

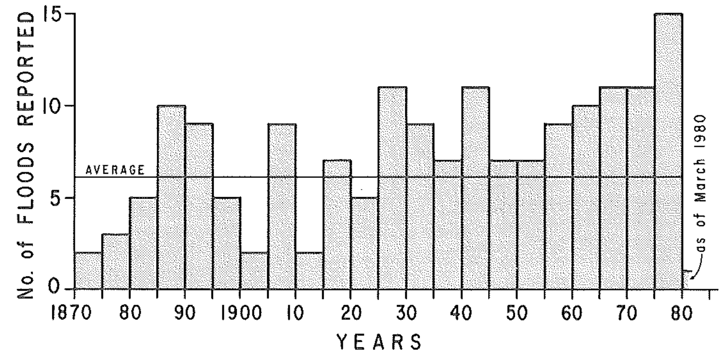
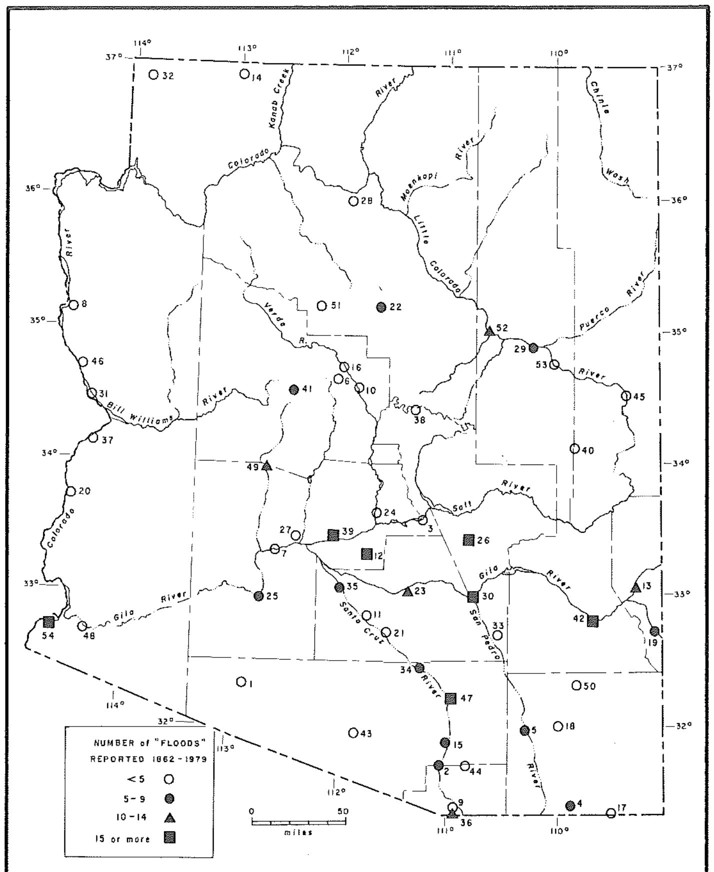


Figure 1B. Frequency of damaging runoff events. The average (7.26 per five-year interval) for the entire historical record has been consistently exceeded since 1925.



1. Ajo
2. Armado-Tubac
3. Apache
4. Bisbee
5. Benson
6. Bridgeport
7. Buckeye
8. Bullhead City
9. Camp Little
10. Camp Verde
11. Casa Grande
12. Chandler-Gilbert
13. Clifton
14. Colorado City
15. Continental
16. Cottonwood
17. Douglas
18. Dragoon
19. Duncan
20. Ehrenburg
21. Eloy
22. Flagstaff
23. Florence
24. Ft. McDowell
25. Gila Bend
26. Globe-Miami
27. Goodyear
28. Grand Canyon
29. Holbrook
30. Kevin & Vicinity
31. Lake Havasu City
32. Littlefield
33. Mammoth
34. Marana
35. Maricopa
36. Nogales
37. Parker
38. Payson
39. Phoenix & Vicinity
40. Pinetop
41. Prescott
42. Safford & Vicinity
43. Sells
44. Sierra Vista
45. St. Johns
46. Topock
47. Tucson
48. Welton
49. Wickenburg
50. Willcox
51. Williams
52. Winslow
53. Woodruff
54. Yuma

Figure 2. Damaging runoff events reported at population centers in Arizona, 1862–1980.

Figure 3A. Flash 'flooding' in canyon near Bisbee, 1897. Photo courtesy of Bisbee Council on the Arts and Humanities, Shatuck Memorial Archival Library, Douglas Collection, Bisbee.

stream flow, homes or other structures built near the eroding side of a meander are repeatedly threatened with the collapse and loss of foundation material and/or supporting ground. Many examples of poorly sited housing exist in Arizona where natural stream erosion processes were either not understood or, possibly, not acknowledged during planning and construction. Portions of some of these developments have already experienced damage and property loss. Results of one study (Slezak, 1980) along the Rillito River in Tucson indicate that channels can migrate locally as much as 818 meters (2,684 feet) horizontally during single high-flow events (e.g., winter storms of 1965 and December 1978). Losses due to lateral erosion may include houses, trailers, roads, water wells, sewer lines, and bridges. Slezak concluded that bank erosion historically has been a more serious problem along the Rillito than has overbank flooding.

3) Downcutting or channel scour has caused much damage to roads, bridge piers, pipelines and other structures located within channel beds. Any obstruction, whether man-made or the river's own debris deposits, impedes the free flow of water and initiates scour and fill processes (Figure 4). In addition, saturated portions of the channel sand itself may flow during peak runoff periods. The thickness of channel material which actually flows may be several times the depth of water in the channel. Thus, during peak flow, bridges with relatively shallow footings may lack support (Figure 3D). Damage to bridge foundations may not be apparent after a storm because channel materials are no longer in motion, and depth of recent scour throughout the channel is not exposed.

Risks associated with true *flooding* include damage from standing or slowly moving water outside of channels (Figure 3E). Rotting of crops, ruined furniture and floors and unwanted silt deposits are examples of flood effects. Sheetflow, i.e., non-channelized water or mud flowing rapidly across the land surface, can present great soil erosion problems and basic water damage to homes or other properties.

Relief efforts, control measures and other policies associated with hydrologic risk mitigation have been the responsibility of many levels of government, as well as the private sector (Table 1). However, complex economic, political and social issues have

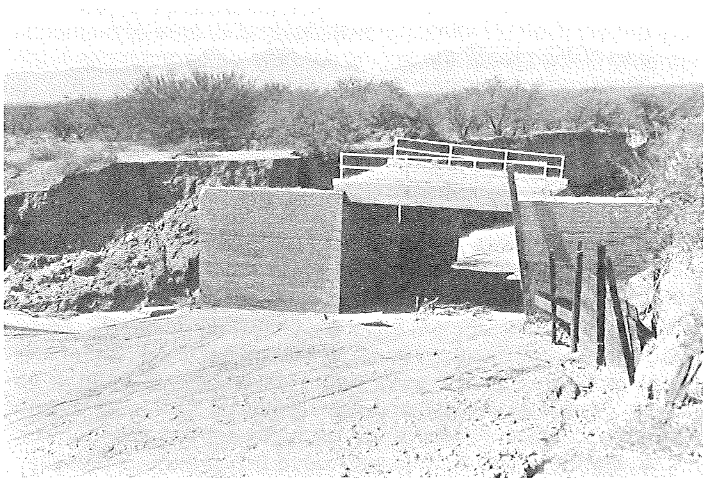


Figure 3B. Channel migration around newly constructed bridge over Palo Alto Road, southern Pima County, 1934. Photo courtesy of University of Arizona Library, Special Collections, Tucson.

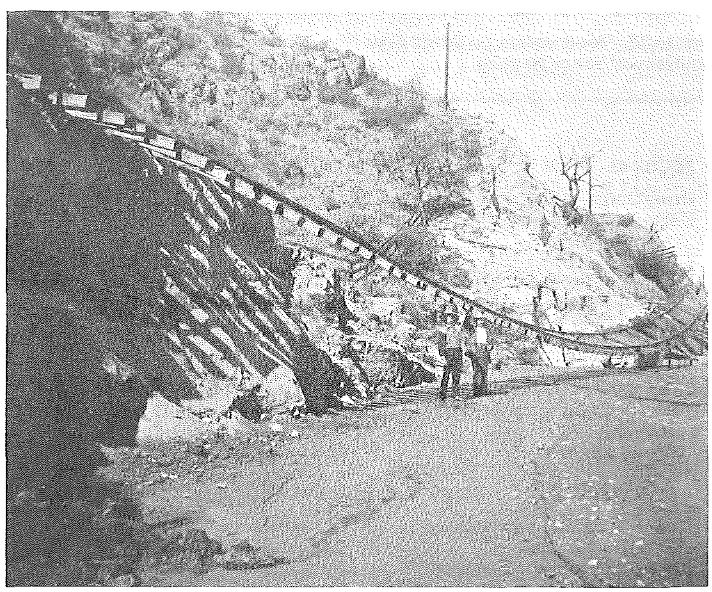


Figure 3C. Bank erosion left the Southern Pacific Railroad track dangling at Tucson, late 1800s. Photo courtesy of University of Arizona Library, Special Collections, Tucson.

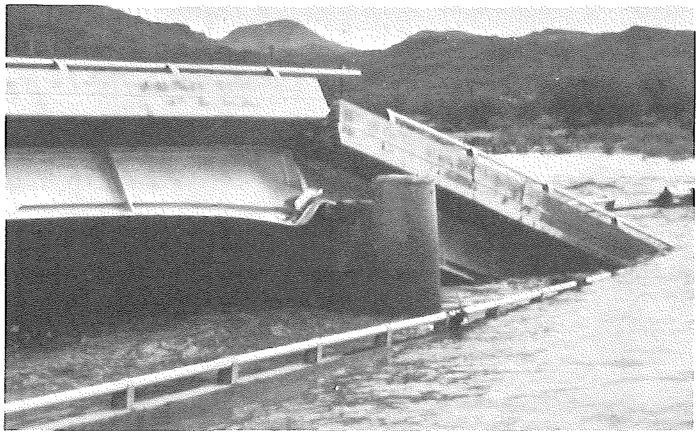


Figure 3D. I-17 bridge collapse on Agua Fria River, December 1978. Six deaths resulted from this event. Photo courtesy of Joe Gonzales, Soil Conservation Service, Prescott.

Figure 3E. Flood waters on Santa Cruz River floodplain, October 1977. Photo courtesy of Vance Haynes.

TABLE 1

FEDERAL	**Highway Patrol**
Army Corps of Engineers	**Legislature**
(Federal) Emergency Management Administration	**(Dept. of) Transportation**
Forest Service	**(Dept. of) Water Resources**
Geological Survey	**LOCAL**
Housing and Urban Development	**City and County Engineers**
National Guard	**Council of Governments**
Park Service	**Fire Departments**
President	**Hospitals**
Soil Conservation Service	**Planning and Zoning Commissions**
Water and Power Resources Service	**Police**
	Sheriffs
Weather Service	**Town Councils**
STATE	**PRIVATE OR VOLUNTEER**
(Office of) Economic Planning and Development	**Citizens**
	Consultants
(Div. of) Emergency Services	**Contractors**
Governor	**Developers**
(Dept. of) Health Services	**Red Cross**

Table 1. Agencies or Groups Involved in Water Management and Relief Efforts.

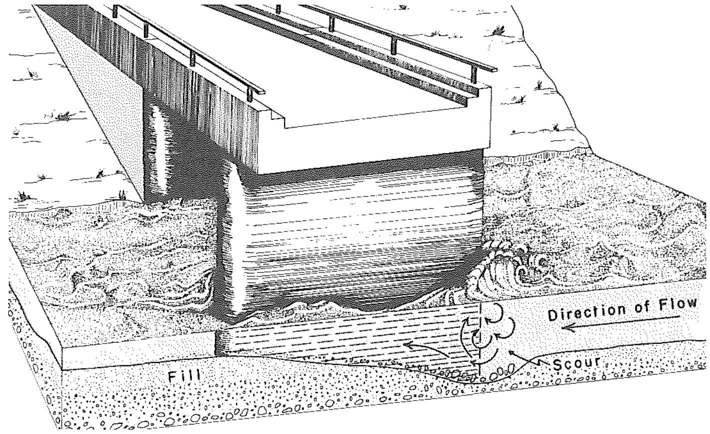


Figure 4. Diagram of scour and fill processes around an obstruction.

tended to inhibit any one agency or authority from either making a comprehensive judgement or providing a thorough solution to the problem. Elimination of hydrologic damage is possible, but the necessary measures might not be acceptable to all interested parties. For example, certain groups might seek to avoid governmental restrictions on the location of homes or other structures near drainage channels. In addition, taxpayers may not wish to bear the cost of a large dam built to protect property located in the predictable path of potential runoff. Conflicts of interest are often a real issue in geologic hazards mitigation.

Runoff control can generally be categorized as corrective (active) or preventive (passive). Corrective measures include dams, levees, channel straightening, storm sewers and concrete reinforcement of banks—all designed to contain and control potential flood waters and minimize damaging effects of erosion. Preventive measures, such as building codes and zoning ordinances, are planned to regulate development within floodplains and to assure maintenance of a channel sufficient in size to carry potential runoff. An excerpt from an article on Arizona "flood" control (Rooney, 1973) summarizes the need for preventive measures coordinated with corrective projects:

> *"Flood control projects are usually expensive, and the protection they afford is limited by the project's design characteristics. Very few, if any, works are constructed to withstand the maximum possible flood, and it is dangerous to assume that an area will ever be completely protected. Although a flood control project may reduce or eliminate the possibility of damage from minor floods, it may also encourage additional floodplain development. Thus, growing communities may unwittingly discover that they are continually expanding into unprotected areas. To some extent, then, the corrective project itself stimulates growth beyond its area of protection and helps create the setting for new damage unless additional corrective measures are undertaken.*
>
> *While corrective measures are extremely costly and almost always require federal financing, preventive measures require very little capital outlay. Because preventive regulations are matters solely of state and local concern, they may be implemented much more quickly and easily than projects requiring federal participation. Most importantly, preventive measures restrict rather than stimulate development in unprotected floodplain areas."*

Another potential problem involves conflicting multiple uses for corrective projects, such as dams. For instance, flood control and water supply objectives cannot both be met without great compromise. Simply illustrated, an empty reservoir can best accommodate flood waters; a full reservoir can best provide irrigation and other water needs. Ironically, these two purposes are often cited together in water plans to justify costs of large projects.

It appears that widespread and frequent damage from hydrologic events in Arizona is increasing, unabated (Figures 1 and 2). The corresponding surge of urban growth (six-fold) and increased property losses since 1940 (Figure 1A) can be attributed to the increase in building and occupancy of lands highly susceptible to runoff hazards. Further development of such areas appears inevitable as long as floodplains and, often, channel *beds* and *banks,* remain inexpensive, unrestricted areas in which to build.

• • •

The homeowner can use a few common sense measures for protection from risky property investments:

1. Visit the nearest USGS or local geological survey office and discuss the topography of your site. Where are the nearest drainage conduits? How susceptible is the site to flooding, bank erosion, etc.?
2. Obtain an air photo of the land surrounding your site from the city planning office or Soil Conservation Service. A sequence of photos taken over a 30–50 year period would be preferable. Check especially for stream migration patterns which may adversely affect your property.
3. Talk to neighbors about water damage history in your neighborhood. Have the streets and houses flooded? Do ponds collect in the yards for days after a rainstorm? Visit the site during or immediately after rainstorms to see if and where water collects or erodes the property.
4. Take a walking tour of surrounding land. Are drainageways that lead in and out of a new subdivision adequately connected through the property? Have natural drainage patterns been modified? Discover if your site included a former channel and was altered by terracing, bulldozing or landscaping.
5. Check insurance companies for the flood-prone status of your site.
6. If your investigations lead you to suspect the safety of your site, and you still wish to build, hire a professional consultant (geologist, hydrologist or engineer) to study your specific site needs and to offer technical advice.

• • •

REFERENCES

Slezak, M. H., 1980, Bank erosion as a socio-geologic hazard along the Rillito River, southeastern Arizona: Univ. of Ariz. Dept. of Geosciences 8th annual Geoscience Daze Abst., p. 31.

Rooney, M. R., 1973, Flood control and Arizona: Law and Soc. Order, *4,* p. 919–937.

NEW MAP

A depth-to-bedrock map of the basins in the Basin and Range Province of southern Arizona has recently been completed by Joan M. Oppenheimer and Dr. John S. Sumner through a grant from the USGS. The depth-to-bedrock values were modeled from residual gravity data based on 20,000 gravity stations using an iterative, 2-D model. The modeling program accounts for variations in the density of basin fill and the density of known salt bodies. Well data were used to refine the contours shallower than 2,000 feet.

Much of the study area is unexplored. This map provides a means for initial assessment of groundwater, mineral and other resources in southern Arizona. The 15 plotted quadrangles include: Kingman, Williams, Needles, Prescott, Salton Sea, Phoenix, El Centro, Ajo, Lukeville, Nogales, Tucson, Mesa, Clifton, Silver City and Douglas.

The map is available at the same scale as the Geologic Map of Arizona (1:500,000) at $25.00 each. Blacklines are available at 1:250,000 at $5.00 for each of the 15 quadrangles. The maps are published by and available from the Lab of Geophysics, Dept. of Geosciences, University of Arizona, Tucson, AZ 85721.

New Earth Science Exhibit

by Peter Kresan

The Arizona-Sonora Desert Museum, internationally known for its fine natural history exhibits, is finishing Phase II of the Earth Sciences Center with unique and exciting exhibits, summarizing the geology and life history of our region.

The uniqueness and dynamic history of the Sonoran Desert are the main themes for the new exhibits. Its Basin and Range landscape is blanketed with unusual and sometimes bizarre plants, inhabited by incredible desert creatures and endowed with rich mineral resources. The landscape is geologically new (within the last 15 million years) and very dynamic, but also contains evidence for very different and fascinating past environments (from shallow seas to violent vulcanism).

The dynamics of the earth's surface will be illustrated by the Orb, a spherical movie screen presentation, which will show the continents drifting across the earth through geological time. The orb will be surrounded by an oval exhibit wall, depicting the geologic evolution of our region, and representing a sweep through earth history. Specimens of rocks, minerals, fossils and living plants and animals will focus attention on the Sonoran geologic and life story. As a backdrop to the specimens, images will characterize the paleoenvironments in which the life existed and rocks and minerals formed.

Most exhibits will be open—without glass—and many specimens will be touchable. There will be no walls arbitrarily dividing geologic and life history. In this manner, the historical development of the Sonoran Desert region may be viewed as a continuum of interrelated geologic and life processes and events; it will also illustrate our unique position in the whole scheme of things. Such an open and integrated approach is in the tradition of the Museum's exciting and innovative exhibit technique.

The formation of Arizona's rich porphyry copper deposits within the heart of volcanoes is one of the important stories woven into the geologic history exhibits. A rich display fo Arizona-Sonora minerals will be exhibited in a jewel-like room, focusing on the themes of minerals and natural resources, and on the region's special significance as a commercial mining center, emphasizing copper. Visitors will become aware of the special geological circumstances that occurred through time, and which now allow us to mine these valuable mineral deposits.

You will be able to follow the progress of the Phase II exhibits in the Earth Science Center during your visits to the Desert Museum. Scheduled completion is for the fall of 1981. The Arizona-Sonora Desert Museum is looking forward to the day when the geologic story will set the stage for a better understanding of the natural history of our Sonoran Desert.

The capital campaign to fund Phase II is on schedule and on budget (in 1980 dollars) with 47% of total project cost received to date, or $315,000. An important component of this funding is the largest corporate grant ever received by the Desert Museum, a $75,000 challenge grant from the Anaconda Copper Company, Atlantic Richfield Foundation. Other major supporters are ASARCO, Inc., and Duval Corporation, Pennzoil Company.

Peter Kresan is a geologist who serves as a consultant to staff at the Desert Museum. He also teaches geology at the University of Arizona.