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Floodwaters in southern Arizona, sometimes of high velocity and with a high concentration of runoff, scour stream channels that then could shift and change. Severe property damage may result. *Photo*: Fred Wehrman

Flood Hazards, a Concern in Desert Areas of Arizona

Semiarid, with a scarcity of water resources, Arizona might seem an unlikely state to be threatened by flooding. Flooding in Arizona, however, does indeed pose serious threats to life and property in the state. In fact, because of erosion and scouring in unstable stream channels, certain flood hazards exist in the arid Southwest that are not generally present in humid regions of the United States.

As an Arizona water issue, flooding has attracted some recent attention. Many officials and citizens of the state remember the destructive floods of 1983 in southern Arizona. Some may also recall the four other significant floods that occurred in the area between 1965 and 1983, an unusual cluster of events in recent Arizona flood history. These floods helped alert the state to the occurrence of floods and a susceptibility to their effects. Flooding is also of interest because of climate change, a topic of recent discussion and some controversy.

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Climate, Geology, and Flooding in Arizona

Climate and geology, two basic factors that determine flooding, vary greatly in Arizona, especially north to south. As a result, the occurrence and effects of floods vary greatly within the state. The plateaus of northern Arizona concentrate drainage into incised channels or canyons. Communities are usually built on upland surfaces and therefore are generally unaffected by floods as water drains down entrenched river systems. Other northern communities are built on very permeable surfaces that quickly drain water underground. For example, the surface of Flagstaff is mostly volcanic rock.

Flooding is more of a problem in southern Arizona where water runs off normally dry desert lands. This region is dominated by basin and range topography, with most communities located along stream channels in the center of basins or on piedmonts at the base of mountains. Along with being areas subject to various kinds of flood hazards, the lowlands of the basin and range province of the state are where more than 90 percent of Arizona's population resides.

Southern Arizona experiences precipitation mainly during two seasons: summer and winter. The precipitation is the result of three distinct climatic patterns. Summer thunderstorms usually begin in late June or early July and initiate the monsoon season. The thunderstorms may occur in a limited area, possibly affecting only part of a watershed. They are generally of short duration, and the resulting runoff may quickly fill and overtop streams and washes causing local flooding.

Flash floods can result from summer thunderstorms. Described as too much rain falling in too small an area in too short a time, flash floods are a critical natural hazard in Arizona. Since 1970, 68 Arizona residents have lost their lives in flash floods, often when attempting to drive through swollen streams at dip crossings.

Another form of precipitation that affects Arizona comes from West Coast tropical storms. They usually move into the area during September and October. With intense precipitation and covering an entire region, tropical storms cause the most destructive flood events in southern Arizona. Climatic conditions interacting with such a storm were responsible for the rainfall of September 27 to October 3, 1983, and subsequently referred to as the 1983 floods. Consequences included eight deaths and 975 reported injuries and an estimated $226.5 million damages.

Occurring usually between November and March, winter rainfall tends to be of lesser intensity than storms in other seasons. Winter storms, however, tend to be of longer duration, frequently lasting several days, and cover more geographical area. Runoff from winter storms can combine with snowmelt to cause significant erosion.

Are Floods Becoming More Frequent, More Intense?

Observations seem to indicate that more frequent and intense flooding has been occurring recently in southern Arizona. For example, the flow of the Santa Cruz River, which has been gauged since 1913, set a record in 1914 that was not exceeded until 1965 when flows established a new record. The 1965 flow record was in turn exceeded twice, in 1977 and 1983. Two other flows exceeded the 1914 record during the 1960s.

That the occurrence and intensity of floods are increasing in Arizona would seem evident. Not as clearly defined are the causes of this development, whether human-made or natural, and, if a combination, to what extent is each a factor. The matter is complex. For example, regional climatic changes may be the cause of increased flooding in southern Arizona. If these changes are, in fact, occurring, are they a phase of a natural climatic cycle that operates in the Southwest, or are they the result of an extraordinary event, possibly related to the greenhouse effect, a suspected human-caused phenomenon?

The question is central to the work of University of Arizona geoscientist, Victor R. Baker, and the UA Arizona Laboratory for Paleohydrological and Hydroclimatological Analysis (ALPHA). Concentrating on the Salt and Verde Rivers during the last 2,000 years, ALPHA researchers found that floods equal to, or exceeding the magnitude of recent flood events in southern Arizona have occurred before in the region. Interestingly, though, the past floods have not been as large as some theories have predicted and only modestly larger than what has been occurring recently.

Research also suggests that flood events are possibly occurring more frequently now than in previous periods. How unique then is the recent flooding that has been taking place in southern Arizona? Baker is reluctant to draw general conclusions until additional, in-progress research yields information about conditions in other Arizona and Southwest rivers.

Urbanization is also an important factor to consider when assessing the intensity of floods in Arizona. Through urbanization, the natural land surface is often leveled and covered with impervious surfaces—buildings, roads, sidewalks, parking lots, etc. Increased drainage results. In an urbanized area, runoff is estimated to be four times that of a comparable undeveloped desert area. The drainage from the increased runoff that concentrates in rivers and washes accelerates the quantity and velocity of the flow on downstream reaches. Channels enlarge becoming deeper and wider, and damage from erosion becomes a greater threat.

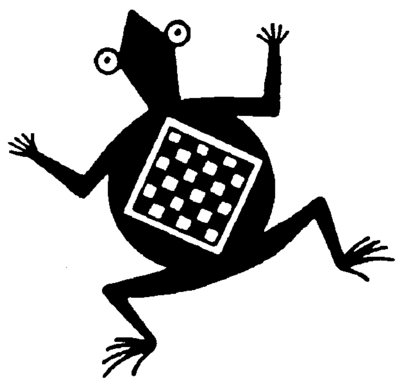
The above discussion identifies factors that may contribute to the increased occurrence and intensity of floods in Arizona. Also important to examine are the effects of various geologic and climatic variables that influence the type of floods experienced in the area. Because of such variables, flooding in Arizona differs from flooding in more humid regions of the United States. Sometimes overlooked, this is a theme with relevance to many areas of flood concern in Arizona.

Generally, erosion and inundation create the hazards associated with flooding, in whatever region flooding occurs. With its usually dry riverbeds and arroyos and minimal vegetation, however, Arizona is especially prone to the effects of erosion. Floodwaters, usually of high velocity and with a high concentration of runoff, scour stream channels that then shift and change. Lateral bank erosion may move a river channel as far as 800 feet. Land collapses, with resulting serious property damages and loss of land. Much of the estimated $226.5 million in damages caused by the October 1983 floods in southeastern Arizona resulted from bank erosion, as farmlands were lost and in urban areas buildings toppled with collapsing stream channels.

A different situation prevails in humid areas. River channels are likely to already be carrying flow that gradually increases as flood conditions develop. With riverbeds anchored by vegetation, channels are more stable, and less erosion occurs. As a result, overbanking is likely, as water inundates land areas in proximity to the river, creating the classic scene of buildings and property riding the crest of a flood.

Flood Control: Structural and Nonstructural

Flood control refers to various strategies meant to reduce and, if possible, eliminate the hazards of floods. Before discussing the topic, however, a note of caution is appropriate.



Mimbres pottery design of frog.

UA geoscientist Vic Baker, who studies the nature, causes and effects of floods, questions whether the term "flood control" is truly appropriate. He explains that flood control is based on anticipated flood events. These events will eventually be exceeded by larger floods that are difficult to anticipate and impossible to control with a reasonable expenditure of funds. As a result, Baker stresses that flood control in reality is a degree of flood protection and that people should not be led to believe that floods are controllable.

Different philosophies guide flood control strategies. Once thought to be a nuisance, stormwater was considered best managed and controlled if made to flow from an area expeditiously. To widen, straighten, and channelize were the prefered strategies to rid an area of floodwaters. Such methods are considered structural since they basically consist of physical modifications to adjust and change the flow of floodwaters. Structural methods include such measures as levees, floodwalls, channel improvements, and storage reservoirs.

The reliance on structural measures, which formed the guiding strategy of flood control for many years, has been widely criticized. Critics have questioned the effectiveness of structural methods to mitigate the adverse impacts of flood losses on the individual and community. For example, by directing and facilitating the flow of runoff, structural measures tend to increase the volume and velocity of a flood. As a result, more runoff flows with greater force, resulting in increased erosion of downstream banks and, therefore, greater flood damage.

Also, with an increased concern about the environment, a wariness has developed about the physical changes or modifications that result from structural methods. Jeff Zauderer, a researcher with the UA Office of Arid Lands Studies, has studied the beneficial effects of flooding and cautions that such benefits can be lost through structural flood-control measures. For example, floodplain riparian vegetation acts to disperse flood velocity and, as a result, water retention and infiltration is increased. These benefits are lost if vegetation is removed and channels are straightened and lined.

Zauderer also explains that floods of differing magnitudes structure the riparian habitat canopy. Such structuring occurs when floods with various velocities scour surfaces at different levels. The exposed surfaces provide new growth opportunities at differential growth rates. The varied canopy that results supports a greater diversity of fauna in the area.

Also, along with such ecological concerns, an aesthetic consideration contributes to a skeptism about structural methods. It is likely that most people would consider a natural riverbed as considerably more attractive than a concrete-lined channel.

As a result of the above concerns – many of which are now the focus of political debate – flood-control strategies have been developed to rely on nonstructural methods. Such methods avoid a physical modification of the environment and work to maintain the natural conditions of river channels. Nonstructural measures generally encourage society to adapt to natural flood conditions when occupying or modifying a floodplain. Various nonstructural measures are described below.

Zoning and other land-use requirements. Zoning for floodplains is used to set special standards for land uses in flood hazard areas. Zoning regulations include specifications about the use of structures and land, the height and bulk of structures, and the size of lots and density of use. Other land-use requirements might include such stipulations as locating fences to avoid a backup of debris during flooding and specific placement of septic tanks and sanitary sewer systems.

Acquisition programs. Acquisition programs can set aside flood-prone lands in two ways. Land is purchased outright or control is purchased through easements or development rights to preclude future uses incompatible with floodplain management programs. Acquisition is the most widely used nonstructural alternative.

Flood forecasting. Authorized by Congress to issue flood forecast and warnings, the National Weather Service collects data in Arizona to send to the Colorado Basin River Forecast Center in Salt Lake City. The center generates a forecast that is then adapted by the National Weather Service for local use. The Arizona Department of Water Resources collaborates with the weather service in this effort.

A technological flood-warning system called ALERT also provides flood forecasting. Rain gauges and streamflow gauges are positioned in flash-flood-prone watersheds. When it rains or streams rise, data are automatically radioed to local officials. Pima and Maricopa Counties have extensive ALERT systems, and other Arizona counties have plans to implement it.

To base a flood forecast on ALERT information, however, the complex relationship between rainfall and streamflow must be understood. Although mathematical rainfall-runoff models are available to calculate this relationship, there is concern that most models are not suited for the arid conditions of southern Arizona.

Soroosh Sorooshian, professor and head of the UA Hydrology and Water Resources Department, and Jene Hendrickson, graduate student of hydrology, are addressing this concern. They are studying a model, KINEROS, which was developed by the Agricultural Research Service for arid conditions, to determine how accurately flash floods can be forecasted and how forecast accuracy can be improved.

A concern is that thunderstorms that cause flash floods are so localized or spotty that even relatively dense rain-gauge networks can miss the high intensity center of the storm. Sorooshian and Hendrickson will use KINEROS with information from the Walnut Gulch Experimental Watershed near Tombstone to determine the extent of forecast error attributable to point sampling of spatially variable rainfall.

Information and education. To properly manage flooding, it is critical that policymakers, the public, and other concerned groups and individuals have access to various kinds of flood hazard information. Federal, state, and local agencies and private consultants are sources of information on topics that range from the hydraulics of various size floods on areas subject to inundation to advice on how to get flood insurance.

Other strategies that are considered nonstructural include disaster preparedness and assistance, warning systems, evacuation, flood insurance, and floodproofing.

The above discussion is not meant to imply that a dividing line necessarily separates those who favor nonstructural measures from those who are for structural methods. Rather than a structural versus nonstructural dichotomy, some believe a more basic controversy exists between those who would modify stream channels, usually with such structural methods as concreting and soil cementing to stabilize banks, and those who advocate leaving river channels natural. The latter group might support structural measures if, through their use, they enable the natural conditions of river channels to be retained. For example, retention and detention basins, which rely on both structural and nonstructural strategies, control runoff and enable river channels to flow naturally.

A detention basin collects and stores stormwater runoff for release at a controlled rate. A retention basin retains collected stormwater, usually for evaporation or infiltration into the subsurface. By temporarily storing water, detention measures extend the period of runoff, with the result of reducing the volume and flood peak. As a result, runoff can flow with less hazard to the natural streambed, if sufficient retention facilities are in use. At the same time, infiltration is increased by the storage of runoff, whether through retention or detention.

Retention/detention facilities are being incorporated into various new developments, with such facilities often required by city and county ordinances.

Rillito Creek Project

Although retention/detention basins have been primarily used to control floods, other uses for them have also been proposed. A multiple-use concept has been considered, with artificial recharge and recreation to be added to flood control as goals of retention/detention basins. To combine flood control with artificial recharge, however, requires technical and institutional coordination, a commitment that is often a challenge to the ways of traditional water management.

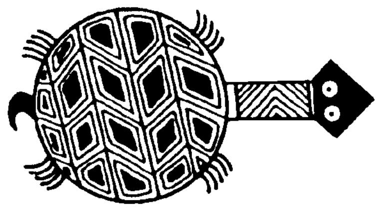
The Rillito Creek Project is a plan to test the multiple-use concept. A cooperative endeavor, the project is an effort to determine the economic, institutional, and technical feasibility of recharging floodwaters. The project involves coordination among the Arizona Department of Water Resources' Tucson Active Management Area, Tucson Water, and Pima County Flood Control District. Designed as a research and demonstration project, the operation will be Arizona's first large-scale recharge facility of stormwater runoff.

The rationale behind the project is direct and simple. Rainfall from storms becomes runoff that flows in streams and washes. If the runoff is diverted off-channel into sedimentation and recharge basins, water that would otherwise flow downstream could be infiltrated into the ground. Two beneficial results would be achieved: floodwaters would be controlled, and depleted groundwater resources would be replenished. The potential to recharge controlled source waters, such as effluent and CAP water, is also to be evaluated.

Additionally, various recreational and environmental benefits are expected to accrue. Recreational areas are to be created at the recharge site, and natural floodplain habitat maintained.

California has been recharging stormwater for over 30 years. The California projects, however, recharge drainages from flows regulated by upstream dams or detention structures. The Rillito project is unique since it is concerned with runoff unregulated by upstream detention structures and would recharge flow from a creek subject to flash flooding.

Not all water managers, however, are committed to the concept of artificial recharge of stormwater runoff. Some argue that it is the rare flood event – the 25-, 50-, or 100-year flood – that actually leaves a basin. They claim that such events do not justify the expenditures for a regional recharge facility, and the other more frequent types of runoff recharge naturally. Among such critics are some who feel that the only suitable location to justify an artificial recharge facility for storm water runoff would be at well locations where drawdown is to be augmented. Regional groundwater recharge projects are argued to be issues of more political than technical significance since the concept has grassroots appeal.



Mimbres pottery design of swimming turtle.

Floodplain Management

Floodplain management is a component of flood control and is concerned with land areas subject to flooding. Relying mainly on nonstructural measures, floodplain management generally has two goals: the protection and maintenance of natural floodplain values and the reduction of existing and future flood loss potential. The concept of floodplain management can be variously interpreted.

Some natural resource managers stress that floods, although now influenced by human activites, are natural and often beneficial occurrences, neither bad nor dangerous. It is when floods threaten human life and property that they are perceived to be an intimidating menance to be confronted with administrative and technical ingenuity. This view implies a shift in a popular perception of floodplain management. Floodplain management might now be seen as less of a defensive strategy against an impending hazard and more as a response to human carelessness and lack of foresight in building and residing on floodplains.

The federal government has a fundamental interest in how the nation's floodplains are used and managed. Concerned with the urbanization of floodplains, the federal government sought to formulate an effective floodplain management policy. Discouraged by early efforts to engineer flood-protection projects, Congress passed the National Flood Insurance Act of 1968. The act established a national flood-insurance fund to provide an alternative to expensive disaster relief from the federal government. Further, the act determined that a flood insurance program would be contingent upon a unified national floodplain management program. A floodplain was defined as an area subject to a one-percent chance of flood inundation in any given year or, as it came to be known, a 100-year flood.

Congress passed the 1973 Flood Disaster Protection Act to stem the continued urbanization of floodplains. Local communities were now required to participate in a flood insurance program. Further, such communities needed to adopt adequate floodplain management ordinances to be eligible for such federal support as federal flood insurance, federal loans for floodplain property, and federal disaster relief in the aftermath of a flood. Local communities were also required to develop hydraulic studies of major watercourses to delineate flood zones. The ordinances, which are submitted for approval to the Federal Emergency Management Agency, restrict development within these zones depending upon flood risks.

Thus encouraged, local communities worked to develop floodplain management plans. Their efforts were guided by the definition of a floodplain that was established by the 1973 act. To ensure national uniformity, the act retained the definition of a regulatory floodplain as an area inundated by a 100-year flood.

Federal legislation basically established a regulatory framework but left local communities the freedom to develop ordinances that best fit their specific conditions and needs. Various factors – social, political, technical and geological – determine what floodplain ordinances a community adopts. For example, communities may adopt different ordinances depending upon the extent to which they stress development and/or environmental values. Maximum development might benefit from massive channelization, bank protection and dams. A community that focuses more on environmental values might emphasize preservation, as well as a reliance on restrictive policies toward floodplain development.

Already a complex task, the development of floodplain ordinances further challenges policymakers when premises basic to federal floodplain management regulations are questioned. A common concern is whether certain premises are relevant to situations in the semiarid Southwest. For example, some researchers claim that the 100-year floodplain, a designation of central importance in federal regulations, is not as readily delineated in the Southwest as in more humid areas. This is because the analyses to determine the level of a 100-year flood generally assume a degree of stability in channel boundaries that is not characteristic of the Southwest. In this region it is possible for erosion to alter river channels significantly.

Also, concern is expressed that federal floodplain management regulations do not sufficiently acknowledge the hazards that result from frequent channel-bank erosion. In alluvial, ephemeral-stream systems throughout the Southwest extensive erosion can occur without the action of unusual floodwaters and in areas not designated as 100-year floodplains. Federal regulations do not ensure that residents of such areas are adequately cautioned or protected.

Along with the federal government and local communities, the state also has a role in floodplain management. The Arizona Department of Water Resources (ADWR) is the state coordinator for the National Flood Insurance Program (NFIP). As a result, ADWR is involved in such activities as assisting communities to adopt ordinances and to qualify for NFIP; establishing state floodplain management standards; implementing flood hazard mitigation measures; and notifying the Federal Emergency Management Agency of community failures in floodplain management.

Arizona Cities and County Flood Control Districts

Both county flood control districts and local communities are involved in flood control and the development of floodplain ordinances. Established by state statute in 1978, county flood control districts are to reduce the risk of flood loss, minimize the impact of floods on human safety, health, and welfare and restore and preserve the natural and beneficial values served by floodplains. Established as political taxing subdivisions of the state, districts have the power to tax to support flood-control projects. Their areas of jurisdiction may include incorporated and unincorporated areas.

Legislation allows an incorporated city or town within a county to assume responsibility for its floodplain management. For example, Tucson maintains its own floodplain management program in Pima County as do Phoenix, Scottsdale, and Tempe in Maricopa County, and Flagstaff in Coconino County. The districts however support flood-control projects throughout their areas of jurisdiction, including incorporated areas which have retained flood plain management responsibilities.

The arrangement has the potential for conflict. Incorporated areas with dense populations, such as Scottsdale, Phoenix, and Tucson, have expressed concern that, although they make a significant tax contribution to the districts, they do not necessarily receive a proportional return of flood-control services and projects. For example, some Tucson city officials believe the areas that benefit most from the tax are mainly along major rivers, often outside city limits, with local stormwater drainage projects within the city neglected by the district.

Districts respond by saying that they take a more regional view than does a city. If viewed in this broader context, the purchase of flood-prone land upstream of a city does in fact benefit the city. If such land is preserved in a natural state, channelization and encroachment will be reduced; thus reducing peak discharges and flow events in the city.

In an attempt to avoid or mitigate conflict between city and county, the Maricopa Flood Control District established a Citizen's Flood Control Advisory Board, with the Phoenix city engineer as a member. By law such a board can be established only in counties with a population of one million or more.

The Tucson Stormwater Management Study

The Tucson Stormwater Management Study is being developed partly in response to current arrangements that separate stormwater management along political boundaries, with responsibilities divided between the city of Tucson and Pima County Flood Control District. The study is to develop a comprehensive stormwater management plan. The plan is to have a regional, watershed focus. Along with seeking technical solutions to problems, the drainage plan intends to work out institutional arrangements to facilitate comprehensive stormwater management, possibly even consolidating city and county efforts in this area.

Encompassing the flow of runoff within an area, a watershed is a hydrologically appropriate unit to determine the management of stormwater. Under present arrangements, however, stormwater runoff within a watershed may flow through separate jurisdictions, managed by different criteria. As a result, land use policies upstream may not be coordinated with the principles for managing stormwater runoff downstream. A comprehensive program covering an entire watershed would provide a much more favorable basis to plan present and future runoff management needs.

Phase one of the Tucson study is complete. This phase included a division of the urbanized area into six major watersheds. Characteristics of each watershed were described, problems defined, and methods to solve problems identified. Also part of phase one was an institutional and financial assessment between the two governing bodies: the city of Tucson and Pima County Flood Control District. Phase two, which is expected to last about 18 months, includes developing a pilot drainage-basin master plan for one of the basins identified in phase one, as well as developing specific strategies for implementing an equitable financing plan and intergovernmental arrangements.

A regional approach to stormwater management is currently favored by many water managers. Pima and Maricopa County Flood Control Districts and the city of Scottdale have been involved with regional projects. Tucson's study, however, purports to be a more comprehensive effort, involving both institutional and technical considerations.

Conclusion

Flooding is a recurrent event in the natural history of Arizona. Scientists involved with paleoflood hydrology, which is the study of past or ancient flows, have determined that extraordinary large floods have occurred in Arizona during the past few millenia. Distant in time, such events are generally studied as natural occurrences.

Floods continue today, with increases in occurrence and intensity during the last 25 years in southern Arizona. Although still studied as natural events, floods are now also the concern of policymakers and others who must deal with the destruction and social dislocation caused by flooding. A major change has obviously occurred between the paleoflood events and modern floods. Humans have increased and established centers of population in areas affected by floods.

At issue, therefore, is developing public policy that will enable humans to cope with flooding. The options available to policymakers can be summarized in two questions. To what extent can and should floods be controlled? And, to what extent can humans be guided and prevented from actions that expose them to the hazards of flooding? Not mutually exclusive questions, some ground for interpretation exists, although policymakers have been giving more attention lately to the latter question.

That an effective flood strategy evolves is an issue of special importance, if, as some evidence seems to indicate, climatic changes are occurring. Floods might be an even more prominent concern in the future.

Arroyo is published quarterly by:

Arizona Department of Environmental Quality
2005 North Central
Phoenix, AZ 85004
(602) 257-2306

Arizona Department of Water Resources
15 South 15th Avenue
Phoenix, AZ 85007
(602) 255-1554

Arizona State Land Department
1616 West Adams
Phoenix, AZ 85007
(602) 542-3500

Office of Arid Land Studies
College of Agriculture
University of Arizona
845 North Park
Tucson, AZ 85719
(602) 621-1955

Water Resources Research Center
College of Engineering and Mines
University of Arizona
Tucson, AZ 85721
(602) 621-7607

Address comments to:
Joe Gelt, Editor/Writer
Water Resources Research Center
Geology Building, Room 314
University of Arizona
Tucson, AZ 85721

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