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Arizona Canal  
Diversion Channel

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ARIZONA BILTMORE ESTATES  
AND THE  
ARIZONA CANAL DIVERSION CHANNEL  
Cudia City Wash to 16th St.

CONCEPTUAL STUDY  
AN ALTERNATIVE TO ACDC



DEPARTMENT OF THE ARMY  
LOS ANGELES DISTRICT, CORPS OF ENGINEERS  
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## ARIZONA CANAL DIVERSION CHANNEL

### Part of the Authorized Flood Control Project of the U.S. Army Corps of Engineers for Phoenix and Vicinity

This paper presents planning and technical information on the design of the Arizona Canal Diversion Channel (ACDC) as part of the comprehensive Phoenix and Vicinity Flood Control Project supported by local Phoenix area governments and authorized by Congress.

This paper is in two parts. Part One sets the context for the ACDC, presenting information on the entire Phoenix and Vicinity Flood Control Project. Part Two presents detailed information on the ACDC.

### Phoenix and Vicinity Flood Control Project

#### The Phoenix Flooding Problem

Phoenix is the last large flood prone area in the United States not protected by any type of flood control system. Severe local storms and floods in 1905, 1921, 1935, 1936, 1939, 1943, 1951, 1955, 1956, 1957, 1963, 1964, 1967, 1969, 1970, 1972, 1978, and 1980 have caused financial damage to the people of Phoenix. Large floods occurred along Cave Creek in 1905 and 1921. Because of the 1921 flood (when the State Capitol was flooded), the City of Phoenix, Maricopa County, and the State of Arizona, in cooperation with private interests, built Cave Creek Dam in 1923. Even with the dam, since 1923 there have been two large floods (1943 and 1967) and several small to medium floods on Cave Creek. Major floods have also occurred in surrounding areas.

In August 1963, a cloudburst occurred over the City of Glendale. The high-intensity rainfall caused considerable damage in Glendale and the Maryville section of Phoenix. There also was flooding above the Arizona Canal near 19th Street.

A major flood in September 1970 caused the death of 23 people (more loss of life due to a flood than any other in Arizona's recent history) and caused millions of dollars in property damage. Heavy rainfall on the

mountainous areas of Central Arizona resulted in sudden large flood flows in Tonto, Sycamore, Oak, and Beaver creeks, and in the East Verde and Hassayampa rivers. While this storm was not centered over the Phoenix area, it is meteorologically possible that a storm of equal or greater magnitude could affect Phoenix.

The storm of June 21-22, 1972, did cause extensive damages to the Phoenix Metropolitan area. President Nixon declared Maricopa County a major disaster area because of the damages. People incurred over \$4 million in flood damages from runoff between 40th Street and Dreamy Draw Dam.

More recently, Phoenix and surrounding areas were placed in danger from three storms: in February and March 1978, December 1978, and February 1980. In the March 1978 storm, the old Cave Creek Dam held 7,000 acre-feet of water and filled to within six inches of its brim. Flood water releases from Cave Creek Dam flowed down Cave Creek into the Arizona Canal, then spilled out into the urban areas of Phoenix. The Canal also spilled over at 43rd Avenue and 59th Avenue.

Phoenix citizens and local governments became extremely concerned about the flooding threat in the late 1950's (after the four floods in the previous ten years). Faced with the prospect that the threat would become greater and greater as development increased, the Corps of Engineers was requested to develop a comprehensive flood control plan for Phoenix and surrounding areas. To begin its work, the Corps held a public meeting in late 1959 to give all local interests the opportunity to describe the flooding problem and comment on the extent of the improvements needed. At that time, the Flood Control Advisory Committee (the predecessor of the Flood Control District of Maricopa County) presented its first proposal for improvements in the area.

From 1959 to 1963, the Corps worked closely with the Flood Control District and its consultants to refine the proposal. As a result of the studies, the Corps--in cooperation with the Flood Control District of Maricopa County--developed a comprehensive five-phase flood control plan for the Phoenix metropolitan area. In 1963, the Corps presented the plan to the people of Phoenix. The plan cited the need for phased improvements in five areas:

- Phase A--Indian Bend Wash from the Arizona Canal to the Salt River.
- Phase B--Phoenix and Vicinity (including New River).
- Phase C--Glendale-Maryville and South Phoenix.
- Phase D--Salt River downstream to the Gila River.

- Phase E--Indian Bend Wash upstream from the Arizona Canal.

There was general agreement with the proposed plan, and it was formally approved by Maricopa County. In 1965, Congress authorized final planning of projects for the first two phases: Indian Bend Wash (currently in the final construction stages and scheduled for completion in November 1983) and Phoenix and Vicinity (the subject of this paper). Phases C through E were subsequently incorporated into the Corps' Phoenix Urban Study and the Central Arizona Water Control Study.

### **The Phoenix and Vicinity Authorized Project**

The purpose of the flood control project authorized by Congress for Phoenix and vicinity is to protect people from flood flows originating in a 2,695-square-mile mountain and desert area which drains toward the metropolitan area. Many streams including Cudia City Wash, Dreamy Draw, Cave Creek, Skunk Creek, New River, and Agua Fria River drain flows from this mountain and desert area to the Phoenix area. Currently, a major factor in Phoenix area flooding is the interaction between the Arizona Canal (an irrigation water delivery system flowing to the west) and the many streams which intersect the canal. Urban development has obliterated the historic courses of these streams below the canal. During flooding, flows from these streams have broken through and over the canal. The problem is worsened by overland drainage from the north. The canal traps the flood waters until they overtop the canal barrier. This problem is becoming more severe as urban development north of the canal increases and runoff becomes greater.

As history has shown, floods have different intensities. The Standard Project Flood (SPF) is the flood that would result from the most severe combination of meteorologic and hydrologic conditions considered reasonably characteristic of the region. Present development within the SPF area subject to flooding consists of 50,500 acres: 17,680 acres of residences, 4,060 acres of commercial and industrial businesses, 12,530 acres of farmland, 2,800 acres of public and semipublic lands, 260 acres of parks, and 13,170 acres of undeveloped land.

A 100-year flood is the label for a flood which has a one-percent chance of occurring in any year, or a 22-percent chance of occurring in any 25-year period. A 100-year flood would inundate 31,540 acres.

The authorized Phoenix and Vicinity Flood Control Project, depending on the area, provides either SPF or 100-year flood protection. It is a comprehensive and fully integrated system of four dams in the mountains to the north, 20 miles of channelization, and 19 miles of flowage easements on open space with some floodproofing, levees, and channelization. The project also calls for recreational development, environmental and cultural resources preservation, and esthetic enhancement.

The four dams of the project are:

- Dreamy Draw Dam, on Dreamy Draw, completed in 1973.
- Cave Buttes Dam, on Cave Creek, completed in 1979.
- Adobe Dam, on Skunk Creek, completed in 1982.
- New River Dam, still to be built on the New River.

The 17-mile-long Arizona Canal Diversion Channel (ACDC), to be built north of the Arizona Canal from 40th Street on the east to Skunk Creek on the west, will intercept and convey discharges from Dreamy Draw and Cave Buttes dams as well as all other tributary flows west to Skunk Creek.

On the western end of the project, the flood waters would flow south along Skunk Creek, New River, and the Agua Fria River to its confluence with the Gila River. Channelization of these streams was not as strongly justified. Instead, flowage easements will be obtained for the 100-year flood plain.

The project will provide SPF protection from flood waters originating above the four dams and 100-year protection from flood waters originating between the dams and the ACDC.

Construction of the Phoenix and Vicinity Flood Control Project began in 1972 with the construction of Dreamy Draw Dam. Completion is scheduled for 1991.

The project will protect development worth approximately \$10.1 billion (in 1981 dollars). The total project cost estimate is \$612.3 million (including \$32.3 million for recreational development). The estimate includes:

- Actual costs for the completed portions of the project (Dreamy Draw, Cave Buttes, and Adobe dams), current studies, and construction underway.
- An allowance of approximately \$245.4 million for estimated inflation during the nine remaining years of construction.

Of the total estimate of \$580 million for the project's flood control features, \$329 million is a Federal cost, and \$251 million is a non-Federal cost. For the \$32.3 million for recreational development, \$15.3 million is a Federal cost, and \$17 million is a non-Federal cost. Inflation has been accounted for in project costs.

## Project Alternatives Considered

In every flood control project the Corps of Engineers must study and consider a full range of alternative solutions along a spectrum from no action to nonstructural measures to complete structural improvements. Structural improvements are those built by man to contain the flow of flood waters. Nonstructural measures are actions taken by man to constrain future development in the flood plain (e.g., restrictive zoning), compensate people for economic loss due to flooding (e.g., acquiring flowage easements, providing flood insurance), or protect property against damage from inundation (e.g., flood proofing).

The Corps studied many alternatives. Six were considered in detail: one plan for no further action (after the construction of Dreamy Draw Dam), three plans for complete structural improvements (dams only, channels only, and a combination of dams and channels), and two plans combining structural and nonstructural improvements. The main criteria for evaluating alternative plans encompass:

- Plan acceptability. Is the plan acceptable to the concerned governments and publics?
- Plan completeness. Does the plan incorporate all necessary actions to ensure full attainment of the defined project purpose?
- Plan effectiveness. Will the plan, when implemented, achieve its objectives?
- Plan efficiency. Which plan will achieve national economic development, environmental quality, and other objectives in the least costly way?

Based on its evaluation, the Corps selected a modification of the originally authorized project: one of two plans combining structural and nonstructural improvements. Specifically, this plan was selected because:

- Of the four alternatives providing the largest degree of flood protection, the costs for flood control improvements are the least.
- It provides the second highest maximum flood control benefits (only 0.5-percent less than the alternative with the highest), but at 18-percent less cost for flood control improvements.
- Its benefit-to-cost ratio for flood control is the highest of the four alternatives providing the greatest degree of flood protection. The benefit-to-cost ratio expresses the extent to which economic benefits from a project to the nation (measured mainly in terms of flood damages prevented) are compared to project costs.

- It has the least impact on the environment compared to the three other plans which provide comparable flood control benefits.
- It is the plan most supported by local governments and acceptable to the general public.
- It has the greatest recreational benefits among all the alternatives.

### **Project Support**

As indicated before, the Corps planned and designed the Phoenix and Vicinity Flood Control Project in close coordination with the Flood Control District of Maricopa County and the City of Phoenix. In studying the array of alternatives, the Corps sought public input in a series of public meetings and in informal sessions with citizen environmental and planning groups. The Corps closely coordinated its planning with other Federal, state, and local government agencies. The result of this effort of coordination and cooperation, over a 20-year period of extensive planning, is a project which has been broadly supported throughout the Phoenix area.

### **The Arizona Canal Diversion Channel**

This part of the paper discusses the purpose of the ACDC, its features, alternatives considered for the eastern portion of the channel, the level of flood protection provided, channel design, environmental and cultural considerations, and water quality issues.

#### **ACDC: Purposes**

The ACDC is intended to protect people in Phoenix, Glendale, and Peoria against 100-year floods and to convey flood waters draining from the dams in the mountains. If the ACDC were not built, flood flows from the dams and from severe storms between the dams and the Arizona Canal would build up behind the Canal until they overtopped it, then breaking out in various places all along the Canal. The residents of Phoenix, Glendale, and Peoria would continue to face the residual flood threat from runoff downstream of the four dams.

#### **ACDC: Features**

The ACDC will be 17 miles long, from Cudia City Wash near 40th Street on the east to Skunk Creek on the west. It will intercept flood waters from the Phoenix Mountains and from Cudia City Wash, Dreamy Draw, Cave Creek, and several minor tributaries, as well as from uncontrolled overland flow. Currently, these flood waters frequently exceed the capacity of the

Arizona Canal, causing breakouts and flooding to the south. The ACDC has three types of channel configuration:

- From 40th Street to 47th Ave. A mostly reinforced concrete channel with vertical walls to minimize the amount of land and associated development to be purchased. Another configuration (for example, a concrete trapezoidal or an unlined channel) would have required the purchase of much more property at much greater cost and the relocation of many more people. The Corps selected the channel with vertical walls because it significantly reduces the cost of property acquisition and minimizes social disruption due to relocations.
- From 47th Avenue to Cactus Road. A concrete trapezoidal channel. While more land must be acquired than for a concrete vertical wall channel, it is the least costly configuration because of less urban development in this portion of the project area.
- From Cactus Road to Skunk Creek. An unlined channel. This will permit recreational uses in the channel bottom during no-flood situations: bicycling, jogging, and equestrian trails; picnic areas; and playing fields and courts. This type of construction is possible for this stretch of the channel because there is even less urban development than from 47th Avenue to Cactus Road. This type of construction is feasible for this stretch of channel. It is preferred by the communities of Peoria and Glendale.

The visual impact of the channel will be minimal. Since it will be entrenched along its entire length, people will see it only from bridge crossings (and where it is covered, not at all). Experience with other Corps projects similar in design has been that rectangular concrete channels, when viewed from relatively low altitudes or acute angles at a distance, do not dominate the esthetics of an urban area. In addition, the ACDC design calls for esthetic features. In the concrete-lined portions of the channel (from 40th Street to Cactus Road), the Corps will add esthetic features such as landscaping and channel-wall designs to further soften the impact of the ACDC on the Arizona terrain. The Corps has begun to meet with affected residents to present and discuss optional esthetic features most desired.

#### **Alternatives: the Eastern Portion of the ACDC**

Originally, the Corps planned for an ACDC only 12.4 miles long: from Dreamy Draw on the east to Skunk Creek on the west. In June 1972, residents affected by Cudia City Wash in the eastern part of the area sustained over \$4 million in flood damages. This flood awakened Phoenix area governments to the prospect that more severe floods might cause much

more severe damage. In 1974, the Phoenix City Council requested that the Corps consider, as part of the authorized project, providing flood control improvements from Dreamy Draw to Cudia City Wash in order to protect people threatened by flooding from this drainage area. Cudia City and many minor washes flow to the Arizona Canal between 36th and 40th Streets. The Corps agreed, given the severity of the 1972 problem and the potential threat. After a thorough technical and economic evaluation consistent with Federal law, the Corps found that incorporating this extra area into the project would be economically justified and that it therefore should be a part of the Congressionally authorized project.

The Corps examined in detail three alternatives: (1) extending the ACDC 4.6 miles east to 40th Street; (2) building a number of small detention basins in the Cudia City Wash drainage area within the town of Paradise Valley; and (3) building a collector channel along the Arizona Canal to intercept and convey flows from 36th Street to 40th Street and then into a box culvert that would convey the collected flood waters and flows from Cudia City Wash south under the Arizona Canal and along 40th Street to the Salt River.

The 4.6-mile extension to the ACDC will ensure the conveyance of 100-year flood flows in the ACDC. The detention basins would reduce the peak flow in Cudia City Wash at the Arizona Canal and therefore reduce the size of the ACDC between Cudia City Wash and Dreamy Draw. The collector channel along the Arizona Canal from 36th Street to 40th Street and the 40th Street culvert would avoid introduction of increased flood waters into the ACDC altogether.

The Corps rejected the detention basins in Cudia City Wash drainage area. The Town of Paradise Valley strongly opposed the detention basins. Construction of the basins would undo residential development already underway or prevent development approved by Paradise Valley's Town Council. In 1974, the Town Council adopted a motion opposing both the ACDC through Paradise Valley and the detention basins.

The alternative of a collector channel along the Arizona Canal from 36th Street to 40th Street and a box culvert under 40th Street from the Arizona Canal to the Salt River was estimated to cost over \$45 million, as reported in the Main Report of the Phase I General Design Memorandum (March 1976). The cost estimate for extending the ACDC 4.6 miles east to Cudia City Wash was \$39 million. Because of the differences in costs and the fact that the ACDC extension would control floods originating in the Phoenix Mountains between the Cudia City Wash and Dreamy Draw drainage areas (while the collector channel would not), the Phoenix City Council opposed the collector channel. Given Phoenix's strong opposition, the Flood Control District of Maricopa County (the local project sponsor) gave its support to the alternative of extending the ACDC 4.6 miles to 40th Street. The Corps accepted the Flood Control District's position. The ACDC

extension was clearly the best alternative based on flood control benefit, cost, and local acceptability criteria.

In early 1982, the Corps consolidated its project files, discarding project data no longer considered to be necessary to continue with the design of the authorized project which was strongly supported by the City of Phoenix and the Flood Control District of Maricopa County. This consolidation was undertaken in response to a Corps record-reduction directive. In late 1981, the data on alternatives to the 4.6-mile ACDC extension which were developed in 1972-74 were no longer needed, since by then the ACDC extension was a fully integrated and accepted part of the project (and since the total costs of the alternatives, excluding utility relocations, were included in the 1976 project report). Moreover, the costs of the alternatives to the extension were no longer current. Corps policy is to update and continue only those data which are important to authorized project design.

### **The Level of Flood Protection**

In trying to provide flood protection south of the Arizona Canal, the Corps analyzed three levels of flood protection: from the Standard Project Flood, the 100-year flood, and the 50-year flood. Strictly from an economic standpoint, the Corps found that improvements to prevent each size flood would be economically justified. However, the Corps also found that improvements to protect against the 100-year flood were in the best overall public interest. There were two main reasons.

First, the Corps found that improvements to protect people south of the Arizona Canal against the 100-year flood would result in better net economic benefits than improvements to protect people from a lesser (50-year) or greater (SPF) level of protection.

Second, the Corps concluded that improvements to protect people from a Standard Project Flood would be too economically and socially disruptive to the Phoenix metropolitan area. Constructing the ACDC to provide SPF protection for residents south of the Arizona Canal would require the Flood Control District to acquire substantially more land than for the authorized project: 62 percent more land, which would be permanently removed from the tax rolls; a 47-percent increase in home relocations; a 55-percent increase in apartment building relocations; a 63-percent increase in business relocations; and 630 additional acres of flowage easements along Skunk Creek and the New and Agua Fria rivers. The Flood Control District has said that since it could not afford the increased costs, it could not continue to support the project if SPF design criteria were adopted for the ACDC. And, without this diversion channel, the flood flows from two of the completed mountain dams would have no place to go but into the Arizona Canal or--inevitably--into the Phoenix area to the south.

There is a legitimate concern about whether the ACDC, designed to protect people from the 100-year flood, might cause more severe damage to them during a Standard Project Flood. It will not. In fact, the ACDC would carry away over 50 percent of the SPF, resulting in far less damage than under existing conditions. Several aspects of the ACDC support this conclusion:

- East of Cave Creek. Runoff from the Phoenix Mountains will generally be concentrated, following the same course, with or without the ACDC. Diverted flows already in the ACDC will not overtop the channel banks unless additional flood waters downstream enter the channel at the same time. But if this happens, those flood flows would cause flooding downstream without the ACDC. With the ACDC, however, the flooding threat is much less frequent. Only flows exceeding 100-year protection will spill over the Arizona Canal--much greater protection than is provided at present.
- West of Cave Creek. Flood flows move overland, not following well-defined channels. Without the ACDC or due to channel overtopping from floods greater than the 100-year flood, downstream flooding can occur at any point because of breaks in the Arizona Canal. With the ACDC, there will be no canal breaks for any flood up to 100-year protection. The flood flows will be totally confined within the ACDC.
- Flood waters from Cudia City Wash. If the flood flow from the area served by Cudia City Wash exceeds the 100-year flow, the excess will be allowed to spill out at its source. If necessary, structures will be built on the ACDC for this purpose. Flows exceeding the 100-year flood in the drainage areas between Cudia City Wash and Dreamy Draw will not continue in the ACDC.
- Biltmore Estates retention basins. The Corps has considered these basins in the design of the ACDC. The watershed containing the basins contributes little to design peak discharges on the ACDC, with or without the basins. The final ACDC design will ensure that the ACDC does not adversely affect the capacity of these retention basins.

In summary, no one will be worse off all along the channel from any flood greater than the 100-year flood. But the ACDC will ensure that thousands of residents in Phoenix will have much greater flood protection than they now have.

## **Channel Design**

The Corps of Engineers designed the ACDC using standard hydraulic design criteria. Some of the elements that go into the design include the flood water discharge, channel geometry, channel slope, channel roughness, the amount of sediment in flood flows, flood flow velocities, design freeboard, and the availability of land right-of-way in which to build the channel. Using these parameters, the Corps develops a water surface profile to design a channel. The Los Angeles District has designed and built over 300 miles of concrete-lined channels based on its hydraulic design criteria.

In recent months, some critics--mainly concerned with the 4.6-mile ACDC extension from 40th Street to Dreamy Draw--have raised questions about certain aspects of the channel's design criteria: channel roughness, the design discharge, sediment in the flood flow, freeboard, and flood velocities. The Corps uses this section of the report to provide necessary data on its design criteria.

### **Channel Roughness**

An important factor in the hydraulic analysis is the energy lost from friction between the water and the channel surface. The loss depends on the roughness of the channel. The rougher the channel, the slower the velocity of water and, therefore, the larger the channel needed for a specified flow rate. The quality of concrete and surface finish which the Corps requires ensures that the channel surface will be relatively smooth. To allow for surface roughness, the engineer must use a coefficient factor. A commonly used coefficient to account for surface roughness is the Manning coefficient factor. A factor of 0 implies no friction between the walls and the water and therefore is unattainable. A factor of 0.012 would indicate the smoothest surface attainable under ideal conditions, while a factor of 0.016 would suggest a relatively rough concrete surface. The selection of higher roughness coefficients may be necessary under certain conditions because weather conditions might cause the surface to deteriorate with age.

The Los Angeles District has designed almost all of its concrete-lined channels using Manning's roughness coefficient factor of 0.014. This is a conservative factor consistent with the quality of the finished surface. It allows for the effects of weatherization and concrete erosion. Those effects are very small on concrete channels in Southern California and Southwestern Arizona, mainly because of the lack of freezing and thawing which cause rapid deterioration of the concrete finish.

Data collected during actual flood events on existing channels in Southern California support the Corps' use of 0.014 as the conservative coefficient factor. Tujunga Wash, the Los Angeles River Channel, and Alhambra Wash each had coefficient factors of less than 0.013. The channels ranged in age from 14 to 45 years at the time of the coefficient factor test.

The Los Angeles District consulted a Corps of Engineers Committee on channel stabilization for expert advice on the appropriateness of 0.014 as the roughness coefficient factor for the ACDC. This committee, consisting of 10 members from Corps offices and research laboratories throughout the country, confirmed the Los Angeles District's conclusion. It is also supported by expert engineers outside the Corps. L.C. Urquhart (Civil Engineering Handbook) recommends a factor of 0.014 for concrete-lined channels with good surfaces. Ven Te Chow (Open Channel Hydraulics) recommends a factor of 0.013 for concrete-lined channels with troweled surfaces.

### Design Discharge

The 100-year design discharge for the ACDC at Cudia City Wash is 6,800 cubic feet per second (cfs). The Part 1 Hydrology Report (1974) presented the methodology used by the Corps to generate the design discharge and other design flood values. The methodology has been published for seven years and has been coordinated with and reviewed by many local organizations including the Arizona Department of Water Resources, the Flood Control District of Maricopa County, and the City of Phoenix. The Part 2 ACDC Hydrology Report (1982) provides a comprehensive description of all data sources, assumptions, and results to produce the design discharge of 6,800 cfs.

The basic procedure was to utilize all available runoff information in order to establish discharge frequency relationships for watersheds under study in the Phoenix region. Discharge frequency relationships were established for urban watersheds in Phoenix, based on the observed runoff experience of urban watersheds in Southwestern Arizona.

Regionalization of discharge frequency relationships is a commonly used technique when streamflow information is insufficient or unavailable for the watershed being studied. While the ideal procedure for computing 100-year flood flows would be to use site-specific data, they are not available on the project drainage area.

There are, of course, other methods to establish a discharge frequency value. When different procedures are used, it is the general rule that the results will be different. Using the method of the U.S. Soil Conservation Service (SCS), one engineer established a discharge frequency value for the ACDC of 7,200 cfs. The difference between the Corps established value of 6,800 cfs and 7,200 cfs is less than six percent—so close as to suggest that good judgment was used in both methods to estimate the magnitudes of variables involved. Given the normally short periods of time that stream gages have been installed on small watersheds in Southwestern Arizona, the statistical confidence limits on 100-year flood determinations are more than plus or minus six percent for natural, undeveloped watersheds. For watersheds undergoing urbanization, such as metropolitan Phoenix, the confidence limits would be even greater. Hence, the six-percent difference

in 100-year design discharge estimates constitutes virtually complete agreement in terms of design flood magnitudes.

The SCS method (as well as the HEC-1 computer program developed by the Corps) assumes that runoff frequency is equivalent to the rainfall frequency which causes it. But this is not necessarily the case, since water will percolate into the ground. The SCS and HEC-1 methods are most valuable if they include calibrating rainfall-runoff variables to site-specific data in Cudia City Wash or calibrating the procedure to actual observed discharge frequency relationships for urban watersheds in the region. The Corps suspects that if this were done using the SCS method, the result would be a frequency discharge closer to 6,800 cfs.

### **Freeboard**

Another important part of channel design is to add "freeboard"--increasing the channel's depth beyond what is absolutely required to handle the size of flood to be controlled. Freeboard is added to ensure that the desired degree of protection will not be reduced by unaccountable factors. The freeboard for the ACDC is a minimum of two feet. This is the standard used by the Corps of Engineers for rectangular concrete channels. The Los Angeles County Flood Control District uses the same figure for channel velocities less than 35 feet per second. (The velocity in the ACDC will be 11 to 12 feet per second.) The SCS uses the larger of 10 percent of the flow depth or one foot, which for the ACDC would result in about two feet of freeboard. One engineer has argued that using criteria of the Bureau of Reclamation, the ACDC freeboard should be 5.3 feet. The Corps, in reviewing the Bureau's criteria, found that 5.3 feet of freeboard would only be required for a leveed channel (which does not apply to the ACDC). According to the Bureau's criteria, the ACDC freeboard would be 2.6 feet. However, the Bureau's criteria are for irrigation canals and not flood control channels. The ACDC, a flood control channel only, will contain no flood flow most of the time. Irrigation canals flow at or near capacity most of the time. Therefore, more freeboard for irrigation canals may be desirable to accommodate flood flows that may enter the canal.

The Corps continues to find that two feet of freeboard for the ACDC is sufficient. In any event, the Corps does not use additional freeboard to account for any insufficiency in design. That is not good engineering practice. If the Corps believed that its design parameters for the ACDC were inappropriate, the Corps would redesign the channel.

### **Flow Velocities**

Concern about velocity has been expressed because of the risk of channel failure or overtopping which might cause great damage. The ACDC has no risk of failure; and in rare instances of overtopping, no one will sustain greater damage than under current conditions. As stated above, the

ACDC will have flood velocities of 11 to 12 feet per second. The ACDC channel will be lined with 10- to 33-inch-thick reinforced concrete with double rows of rebar. It is rare to design a concrete-lined channel for such slow velocities. Normally these velocities would call for side slopes lined with rock and unlined inverts. On the ACDC, the concrete lining on a portion of the channel is only to minimize the requirements of right-of-way purchase and not to handle the flow velocities. Therefore, there is no risk of failure.

Observations of rare instances of overtopping Corps-built channels indicate that the channels sustain no damage. For example, in 1980 one channel in Los Angeles overtopped with a velocity of 30 feet per second. There was no channel damage.

In the covered portion of the ACDC, the Corps will make certain that the channel never flows full because of the increased friction created by the cover. To ensure that the box never flows full, flows in excess of the design discharge will be allowed to overflow upstream of the covered section and enter the Arizona Canal. Breakouts from the canal are what happens currently.

#### **Environmental and Cultural Considerations**

The project's impact on environmental and cultural resources is discussed fully in "Design Memorandum No. 3, General Design Memorandum, Phase I, Plan Formulation," and the "Final Environmental Impact Statement" (both published March 1976). The Corps selected the authorized plan in recognition of the documented impacts, concluding that, given the severity of the flooding problem and the effects of other alternatives providing a high degree of flood protection, the selected plan's environmental impacts are justified. These reports were widely circulated and coordinated with the public.

The Corps is sensitive to preserving cultural and archaeological sites of value. For example, the existing dam at Cave Creek (built in 1923) has been nominated to and listed on the National Register of Historic Places and preserved for its historical values. The Corps has an active archaeological program at Adobe Dam, New River Dam, and Cave Creek to preserve and understand the petroglyph sites and cultural artifacts discovered there.

The Corps acknowledges the cultural significance to Arizona of the Arizona Biltmore Hotel and the Wrigley Mansion (although they are not included in the National Register of Historic Places, nor are they designated Arizona State Landmarks). However, the ACDC, after construction, will not adversely affect these properties.

## **Water Quality**

One-hundred-eighty days prior to discharge into Skunk Creek, a permit (under the National Pollutant Discharge Elimination System) must be filed with the U.S. Environmental Protection Agency and the Arizona Department of Health. The Corps fully intends to incorporate the requirements of these agencies as they relate to water quality and construction of the project.

## **Conclusion**

The Phoenix and Vicinity Flood Control Project is a comprehensive, integrated system of structural and nonstructural measures to provide a high degree of flood protection to the people of Metropolitan Phoenix. It is under construction. Failure to complete construction of all the elements would mean that the people of Metropolitan Phoenix would continue to be subjected to extensive flood damages.

The ACDC is an essential part of the total system. It completes the project. It provides a level of protection (100-year) which optimizes flood control benefits, is the best economically and financially, and has the greatest support. The ACDC protects thousands of people not now protected—people who are increasingly vulnerable to flood damages as urban development continues. It makes conditions worse for no one. SPF protection, requiring a complete redesign of the channel, would delay completion, require relocation of significantly more people along the channel, and overtax the Flood Control District's ability to pay for it.

The ACDC design is conservative, based on the standard Corps design criteria and the agency's long history as the main flood control builder in the country. Those criteria have been reviewed and endorsed by the Corps technical review offices and the main Arizona agencies concerned with the project: the Arizona Department of Water Resources, the Flood Control District of Maricopa County, and the City of Phoenix.