THE 1970 LABOR DAY STORM

BY

DAVID B. THORUD

AND

PETER F. FFOLLIOTT

FLOOD CONTROL DISTRICT
OF
MARICOPA COUNTY

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LIBRARY

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DAVID B. THORUD

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PETER F. FFOLLIOTT

Professor and Assistant Professor
Department of Watershed Management
University of Arizona

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INTRODUCTION

The 1970 Labor Day Storm caused more loss of human life than any other storm in Arizona's recent history. In addition, many dwellings, roads, bridges, and other structures were damaged by record flooding. Consequently, the meteorological and hydrological features of this event, and the resulting damage to human, cultural, and natural resources should be documented and analyzed. Such analyses may contribute to improved estimates of the magnitude and frequency of future storm and flood events, and could assist engineers and planners in the design and location of new communities, drainage systems, bridges, dams, and other cultural features.

Based on a suggestion from the Arizona Water Resources Committee, Governor Jack Williams requested the Water Resources Research Center at the University of Arizona to arrange a study of the 1970 Labor Day Storm. The study is designed to be an over-all evaluation based on the collation of reports and other data summaries prepared by federal, state, and local agencies concerned with the Storm and its consequences in Arizona. With the help of Governor Williams, appropriate offices were contacted and available reports and data summaries requested.

A preliminary report of the 1970 Labor Day Storm has been prepared for the 1971 Arizona Watershed Symposium. A final evaluation of the Storm, which is scheduled for completion later this year, will include additional analyses not available at this time. Comments and suggestions that may increase the usefulness of the final report will be appreciated.

ANALYSES

Meteorological Event

The complex meteorological events involved in the 1970 Labor Day Storm began on September 2nd, when moist air, associated with tropical storm *Norma,* flowed into Arizona from the Pacific Ocean and the Gulf of California (National Oceanic and Atmospheric Administration 1970). This air mass extended over the State during the next two days, and reached sufficient depth to allow the formation of thunderstorms over southeastern Arizona on the 3rd. Thunderstorms spread northwestward into the Phoenix area by evening, and continued to spread northwestward over the State at night.

A convergent flow of air in the lower atmosphere over southern Arizona on the 4th caused heavy rainfall to occur on the east side of the Baboquivari Mountains and northward to Tucson and the Avra Valley. This rainfall ended late on the 4th.

On the morning of the 5th, a cold front had extended from southwestern Utah into southern Nevada, and an associated deep upper trough was located over Nevada and southern California. Simultaneously, in advance of the cold front, a surface trough was oriented from Las Vegas, Nevada to Palm Springs, California. Strong, southerly winds developed in the lowest 10,000 feet of the atmosphere early on the 5th. Orographically induced rainfall increased sharply over the mountains of central Arizona as the troughs approached from the west. In addition, a combination of the eastward advancing trough and normal daytime heating generated lines of thunderstorms in the desert valleys of western Arizona by midafternoon. These thunderstorms progressed eastward and intensified, resulting in heavy rainfall by late afternoon and evening in the Salt River Valley. Most of the activity associated with the lines of thunderstorms had weakened by late evening, and precipitation ended over the central mountains and the northeastern plateau. However, the eastward movement of the surface trough had slowed during the day, causing renewed storm activity throughout the evening in the desert valleys eastward of the Buckeye area.

The original cold front dissipated by the evening of the 5th, and the surface trough, which was now located east of Phoenix, acquired the characteristics of a cold front. This newer and weaker cold front progressed southward to a position between Tucson and Douglas on the morning of the 6th. Strong, southerly winds continued south of the front, and there was more orographic rainfall over the mountains of southeastern Arizona. Late on the 6th, all atmospheric disturbances had weakened and most of the precipitation ceased, bringing the Storm to an end.

An isohyetal map of total storm precipitation shows that orographic effects were prominent (Figure 1). The higher rainfall totals (six inches or more) were mainly associated with the Sierra Ancha, Mazatzal, Bradshaw, Black Hills, Santa Catalina, and Baboquivari mountain ranges. Heavy rainfall also occurred along the Mogollon Rim northeast of Payson and on the high country south of Flagstaff.

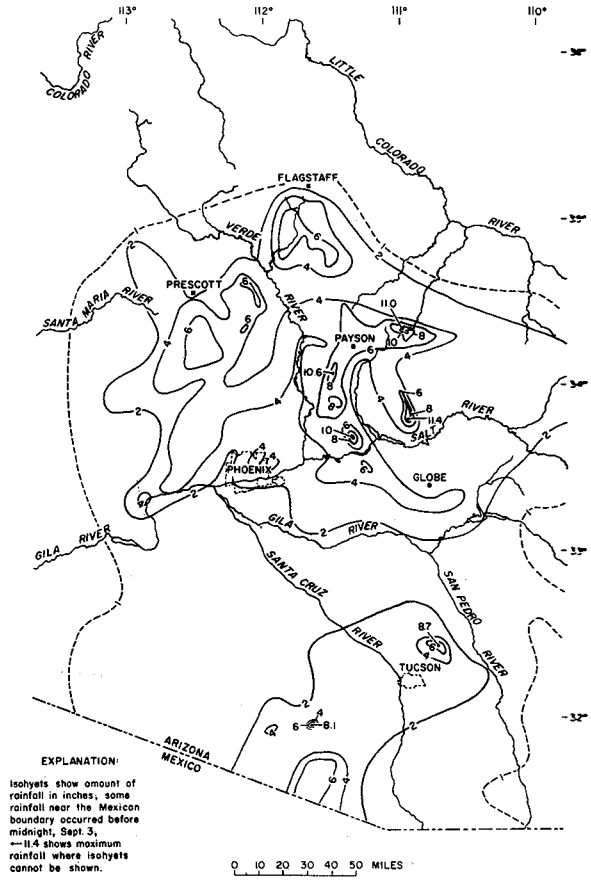

FIGURE 1

Rainfall, September 4-6, 1970 in southern and central Arizona (adapted from Roeske 1971).

New precipitation records for a 24-hour observational day were established at many National Weather Service stations in Arizona (Table 1). The most spectacular record was established at Workman Creek, located in the Sierra Ancha Mountains. Here, a rain gage recorded 11.4 inches of precipitation during one 24-hour period, establishing a new record

for Arizona. The previous official National Weather Service 24-hour record was only six inches, recorded at Crown King on December 19, 1967. The Payson Ranger Station record is also of interest, as the 6.2 inches measured here during a 24-hour period was the greatest amount since establishment in 1892.

Rainfall intensities greater than three inches in four hours were reported for several stations during the Storm (Roeske 1971). Maximum rainfall intensities computed from a sampling of recording rain gage records for selected time intervals are presented in Table 2. These data were obtained in or near mountain ranges receiving large total rainfall amounts (Figure 1), but the intensities are not necessarily representative of entire mountain ranges.

TABLE 1

New 24-hour Observational Records of Total Rainfall Resulting From the 1970 Labor Day Storm, and Previous Records for Several Stations (National Oceanic and Atmospheric Administration 1970).

Station	New Record	Old Record	Records Began	Date of Old Record
	– – – inches – – –			
Bar T Bar Ranch	5.30	3.96	1952	6-14-55
Bartlett Dam	4.50	4.00	1939	8-28-51
Groom Creek	4.25	3.85	1942	12-26-66
Junipine	5.28	4.71	1935	2-7-37
Mummy Mountain	3.94	2.29	1955	9-13-66
Jayson 12 NNE	4.29	3.53	1950	7-31-67
Payson R.S.	6.20	4.37	1892	10-29-59
Payson	5.36	3.74	1948	10-29-59
Sasabe	4.36	2.75	1959	6-16-69
Sedona R.S.	5.50	2.69	1943	9-12-58
Sierra Ancha	4.77	4.58	1935	8-28-51
Tonto Creek F.H.	5.63	4.30	1944	1-26-57

TABLE 2

Maximum Rainfall Intensities for Selected Time Intervals During the 1970 Labor Day Storm at Several Locations.[1]

Station	Elevation	Total Storm Amount	TIME INTERVAL 15 min.	30 min.	2 hours	6 hours
	(ft.)	(in.)	– – – – – – (in. per hr.) – – – – – –			
Sierra Ancha Mts. (Upper Pocket Ck.)	4600	7.17	3.17	2.98	0.99	0.44
(S. Fork Workman Ck.)	6800	11.75	2.09	1.98	1.18	0.72
Mazatzal Mts. (Three Bar)	3700	8.04	2.52	1.65	1.15	0.61
Bradshaw Mts. area (Whitespar)	5700	2.64	1.12	0.95	0.49	0.26
Black Hills area (Mingus Mt.)	6300	2.18	0.80	0.56	0.31	0.12
Plateau SE of Flagstaff (Beaver Ck.)	7400	6.74	3.08	2.90	1.19	0.64

[1] Courtesy of the U. S. Forest Service.

Stations in the Sierra Ancha and Mazatzal Mountains and on the plateau southeast of Flagstaff had maximum 15-minute intensities exceeding two inches per hour. Intensities of this magnitude could easily exceed infiltration rates on some watersheds, particularly those with shallow storage over bedrock, and thereby lead to surface runoff and high peak streamflows. Infiltration rates are even more likely to be exceeded by high rainfall intensities when total storm precipitation is high, as observed at many locations during this storm.

Analysis of the Workman Creek rainfall record further supports the conclusion that the 1970 Labor Day Storm was an unusual event in Arizona. Preliminary indications suggest that the total rainfall of 11.4 inches recorded during 24 hours at this station may occur only once in 500 years, on the average.[2] This does not necessarily mean that such a storm occurs at 500-year intervals. Actually, the same event could occur two years in a row at the same location, but such a sequence is unlikely.

The Workman Creek frequency analysis represents only a small area. More general analyses suggest that the Storm may have been a 100-year event in other areas. According to a frequency map prepared by the U. S. Weather Bureau (1967), a 24-hour rainfall total of five-to-six inches is a 100-year event at many locations in central Arizona. This amount was equalled or exceeded at several of these locations during the 1970 Labor Day Storm.

Hydrological Event

Arizona experienced high peak streamflows and subsequent flooding as a result of the 1970 Labor Day Storm. The peak discharge of several streams possibly exceeded that of the 50-year flood, and some stations may have exceeded the 100-year flood (Roeske 1971). As expected, much of the flooding was associated with areas receiving high rainfall amounts and high rainfall intensities. The spatial relationship between areas receiving at least five inches of rainfall and several streams with high peak flows is shown in Figure 2.

The most serious flooding was in central Arizona, where large, sudden flows occurred on Tonto, Sycamore, Dry Beaver, Wet Beaver, and Oak Creeks, and in the East Verde and Hassayampa Rivers (Roeske 1971). New River and the Agua Fria River also had high peak streamflows. Flooding occurred in Altar and Brawley Washes in southern Arizona, primarily due to heavy rainfall near the border town of Sasabe; also, Sabino Creek near Tucson experienced a record peak streamflow. Flood flows occurred in the Little Colorado River, partly as the result of inflows from the Puerco River and Chevelon and East Clear Creeks.

[2] Personal communication, U. S. National Weather Service, June 25, 1971.

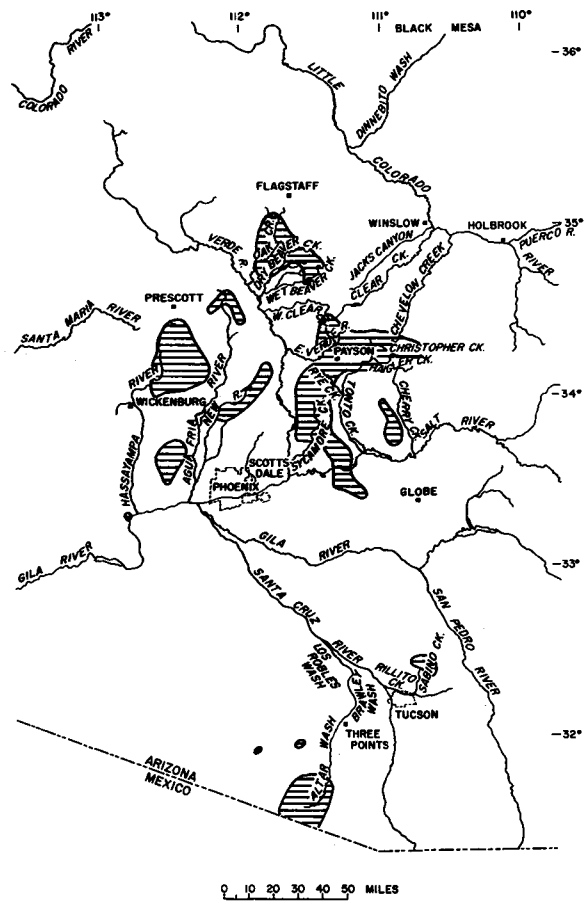

FIGURE 2

River system and areas that received a total rainfall of five inches or more during the Labor Day Storm of 1970 in Arizona. The rainfall zones are crosshatched (adapted from Roeske 1971).

Flood stages and peak discharges recorded at selected stations during the 1970 Labor Day Storm (Table 3) indicate new records for many locations (Roeske 1971). In the Gila River Basin, at least 30 of the 50 U. S. Geological Survey streamflow gaging stations had record peak flows. Estimates of recurrence intervals for peak streamflows (Table 4) further substantiate the significance of this hydrologic event.

In central Arizona, the recreation areas near Kohl's Ranch on Tonto Creek were severely damaged by flooding (U. S. Forest Service 1971), and it was here where more lives were lost than in any other area. At Kohl's Ranch, an estimated peak streamflow of 18,400 cfs occurred on the 5th. This flow, combined with high flows from two tributary streams, Christopher and Haigler Creeks, caused a peak flow of 46,300 cfs at Tonto Creek near Gisela on the 5th. The peak streamflow of Tonto Creek near Gisela may have exceeded the 50-year flood by a ratio of 1.2, based on preliminary studies of recurrence intervals (Roeske 1971).

TABLE 3

Flood Stages and Discharges During the 1970 Labor Day Storm (Roeske 1971).

Location	Drainage Area	Beginning of Record	GAGE HEIGHT Previously Known Maximum	GAGE HEIGHT September 1970	DISCHARGE Previously Known Maximum	DISCHARGE September 1970
	(mi.²)		---- (ft.) ----		---- (cfs) ----	
Tonto Creek below Kohl's Ranch	24	—	—	—	—	18,400
Tonto Creek near Gisela	430	1964	19.0	29.2	30,000	46,300
Christopher Creek near Kohl's Ranch	24	—	—	—	—	11,900
Rye Creek near Gisela	122	1965	9.0	29.0	8,130	44,400
Tonto Creek above Gun Creek near Roosevelt	675	1940	16.7	18.2	—	53,000
Sycamore Creek near Fort McDowell	165	1959	15.0	20.2	15,800	24,200
East Verde River near Childs	328	1961	—	19.2	17,000	23,500
Dry Beaver Creek near Rimrock	142	1960	10.0	14.2	10,600	26,600
Oak Creek near Cornville	357	1885	23.0	16.5	—	24,700
Verde River below Tangle Creek, above Horseshoe Dam	5,872	1925	19.0	18.8	100,000	67,500
Hassayampa River at Box damsite near Wickenburg	417	1921	18.3	34.6	27,000	58,000
New River near Rock Springs	67	1962	10.7	13.0	10,600	18,600
Agua Fria River near Mayer	588	1940	—	14.9	13,000	19,800
Altar Wash near Three Points	460	1966	10.4	13.8	10,700	22,000
Brawley Wash near Three Points	776	1962	13.0	15.8	—	13,200
Sabino Creek near Tucson	36	1932	9.6	10.2	6,400	7,550
Little Colorado River at Holbrook	11,300	1870	—	14.0	60,000	20,000
Chevelon Creek near Winslow	994	1916-19	19.8	17.5	25,300	8,010
Clear Creek near Winslow, below Willow Creek	321	1947	21.5	20.9	16,400	15,300
Dinnebito Wash near Oraibi	261	1968	4.6	10.0	5,890	28,900

The estimated peak streamflow in Christopher Creek near Kohl's Ranch was 11,900 cfs. Rye Creek, another tributary of Tonto Creek, had a peak flow of 44,400 cfs, but, fortunately, the peak flows on these two streams occurred about two hours apart. The peak streamflow on Rye Creek was estimated to be twice as large as the 50-year flood. The highest discharge in Tonto Creek above Gun Creek was 53,000 cfs, which may be a 30-year flood.

Flows on Tonto Creek and some of its tributaries were particularly destructive as a result of debris produced during the flood. The debris, which consisted of rock materials, whole trees and parts of trees, formed dams in the channels (U. S. Forest Service 1971). In some cases, the dams caused channel diversion as a head of water built up; in other cases, they breached, sending a surge of destructive water, rock materials and timber downstream to the next restriction point where the process might be repeated. This process may have produced higher peak flows than would be expected in the absence of debris dams.

Sycamore, Dry Beaver and Oak Creeks and the East Verde River had peak streamflows ranging from 23,5050 to 26,600 cfs. These flows exceeded the 50-year flood on all but the East Verde. West Clear Creek did not experience serious flooding, and the peak streamflow in Wet Beaver Creek only slightly exceeded the previous record. The flows from tributary streams contributed to the highest peak flow in the Verde River above Horseshoe Dam (67,500 cfs) since a flooding event in August 1951, which was also associated with a tropical storm. However, the 1970 Labor Day flood on the Verde River was about a once-in-15-years event and, in this sense, would not necessarily be considered a rare occurrence.

TABLE 4

Provisional Estimates of Recurrence Intervals for Peak Streamflows during the 1970 Labor Day Storm (modified from Water Resources Review for September 1970, and Roeske 1971).

Location	Date	Peak Discharge	Estimated Recurrence Interval	Ratio of September 1970 Peak Flow to 50-year Peak Flow
		(cfs)	(years)	
Tonto Creek near Gisela	5	46,300	–	1.2
Rye Creek near Gisela	5	44,400	–	2.3
Tonto Creek above Gun Creek near Roosevelt	5	53,000	30+	–
Sycamore Creek near Fort McDowell	5	24,200	–	1.6
East Verde River near Childs	5	23,500	25+	–
Dry Beaver Creek near Rimrock	5	26,600	–	2.0
Oak Creek near Cornville	5	24,700	–	1.2
Verde River below Tangle Creek, above Horseshoe Dam	6	67,500	15+	–
Hassayampa River at Box damsite, near Wickenburg	5	58,000	–	2.5
New River near Rock Springs	5	18,600	50	–
Agua Fria River near Mayer	5	19,800	20	–
Altar Wash near Three Points	4	22,000	6	–
Sabino Creek near Tucson	6	7,550	100+	–
Little Colorado River at Holbrook	6	20,000	20	–

The Hassayampa River at the Box damsite experienced a peak streamflow of 58,000 cfs, which is estimated to be at least twice the 50-year flood. New River near Rock Springs and the Agua Fria River near Mayer had peak streamflows estimated to be 50- and 20-year floods, respectively.

Flood flows of 22,000 and 13,200 cfs were observed in Altar and Brawley Washes, respectively, near Three Points. A record peak streamflow of 7,550 cfs occurred in Sabino Creek, which drains from the Santa Catalina Mountains. This flow occurred two days after the flooding in Altar and Brawley Washes, and was at least a 100-year event (Table 4).

The Little Colorado River at Holbrook had a peak streamflow of 20,000 cfs, which was estimated to be a 20-year flood (Table 4). Downstream from Holbrook, Chevelon and East Clear Creeks added to the volume of the Little Colorado River, which then caused flooding in Winslow on the 6th. Peak streamflows in Chevelon and East Clear Creeks near Winslow were 8,010 and 15,300 cfs, respectively.

Rainfall in northeastern Arizona was believed to be only one-to-two inches during the Storm, but reliable data are scarce (Roeske 1971). Some runoff values were large enough to suggest greater rainfall than this at higher elevations. For example, Dinnebito Wash, which drains from Black Mesa, had a peak streamflow of 28,900 cfs on the 5th. The previous known maximum flow was 5,890 cfs, although the period of record is short.

Losses and Damages

The heavy rainfall associated with the 1970 Labor Day Storm brought subsequent flooding throughout central and northeastern Arizona, southeastern Utah and southwestern Colorado. This flooding caused widespread and unprecedented losses and damages to human, cultural, and natural resources.

Tragically, 23 lives were reported lost in central Arizona. The greatest loss of life occurred in Gila County, where 14 lives were lost in the Kohl's Ranch area on Tonto Creek, and one life in the Christopher Creek area. In Maricopa County, one life was lost in Camp Creek Wash north of Carefree, three in Mesquite Wash east of Canyon Lake, three in Sycamore Creek near Sunflower, and one in the New River drainage inside of the Phoenix Metropolitan area.

The total number of people injured or hospitalized as a direct result of the Storm is unknown, but presumed many.

Emergency assistance was provided to approximately 400 families by the Maricopa County Chapter of the American National Red Cross. These families received $64,000 in assistance, including food, cloth-

ing, maintenance, etc. On the night of the Storm (in the Phoenix area), the Red Cross opened two shelters in Scottsdale – one on Granite Reef Road near a break in the Arizona Canal and one near the Indian village of Vista del Camino. Emergency aid was given to many families at both shelters.

Damage to sewage collection and treatment facilities occurred in the immediate aftermath of the Storm in Phoenix, Scottsdale, Holbrook, and Wickenburg. To the knowledge of the Arizona State Department of Health,[3] this damage had no detrimental effects on public health. Prompt action by local officials undoubtedly minimized health hazards.

Flood waters caused damage to public water supply systems in Buckeye, Tempe, and Phoenix, and to ten small water systems in the outlying area around but not including Payson. Fortunately, all systems were quickly restored to an adequate operating condition.

A complete accounting, in physical units, of the losses and damages to private and public developments, to transportation and communication systems, and to croplands, rangelands, and forests as a result of the Storm is not possible. It is known, however, that losses and damages were many and extensive.

Temporary and permanent residences, farming and ranching operations, business establishments, and recreational facilities were damaged or destroyed in many areas that experienced record flood stages and peak discharges. Areas that suffered extensive destruction include, but are not exclusive of, the following – Upper Tonto Creek drainage, with considerable damage in the vicinity of the Kohl's Ranch area; portions of the Sycamore, Dry Beaver, and Oak Creeks' and East Verde River watersheds; along the Hassayampa River above and including Wickenburg; many urban, suburban, and agricultural sites in central Arizona, particularly in Maricopa County; and, at Holbrook on the Little Colorado River.

Damage to highways, including interstate, primary, secondary, and private systems, was widespread throughout central and northeastern Arizona. Landslides blocked access to right-of-ways, culverts plugged with debris caused many washouts, and road surfaces were eroded by flood waters.

The use of power transmission lines and telephone systems was interrupted in some areas, although, in most instances, service was quickly restored.

Flood waters rolled over fields planted to sugar beets, grains, and other crops in central Arizona, and extensive inundation of cotton crops occurred. Structural failures to irrigation and erosion control systems, diversion dams, dikes, and ponds compounded the losses and damages to croplands in this area.

While the rainfall received as a result of the Storm furnished some short-term additional livestock water, the accumulation of sediments and other debris reduced the capacities of many permanent livestock water impoundments. Extensive damages to allotment fences and livestock driveways also occurred across many rangelands, although the extent of these damages is difficult to ascertain. The lateness of the Storm in the growing season prevented significant increases in usable forage for livestock consumption.

Sediments and debris were deposited in several reservoir systems, particularly along the Mogollon Rim. Three recreation reservoirs in the Chevelon drainage, Bear Canyon, Black Canyon, and Chevelon Canyon, and the Blue Ridge Reservoir on East Clear Creek, received accumulations of debris that endangered spillway operations. Since urban developments are situated in the flood plains below some of these reservoirs, an even greater disaster was possible if additional rainfall and flooding had occurred.

High flood stages and peak discharges drastically altered the character of many stream channels throughout the Storm-affected area. Often, trees growing along channels were uprooted and piled downstream, preventing free movement of water in the channel. The scouring action of flood waters also caused many stream improvements and diversion channels to be lost or severly damaged. Again, with these conditions, there existed the possibility for additional serious destruction if subsequent storms had occurred before repairs were completed.

On September 22nd, at the request of Governor Williams, President Nixon declared the flood-damaged areas of Arizona a major disaster. This action paved the way for political jurisdictions and, in a restricted sense, for private parties to be reimbursed by the Federal Government for eligible expenditures made as a result of the Storm.

The (Arizona) Department of Civil Defense and Emergency Planning advised leaders of political jurisdictions affected by the Storm of the financial assistance available, as specified in Public Laws 81-875 and 91-79, and assisted them in the preparation of applications for funds. Categories of eligible work, under the Public Laws, include – debris removal from private and public properties; protective, health, and sanitation measures; and emergency repairs and temporary replacement of (a) streets, roads, and bridges, (b) dikes, levees, and drainage facilities, (c) public buildings and related equipment, and (d) public utilities.

As of March 10, 1971, the Department of Civil Defense and Emergency Planning had reviewed and processed to the (Federal) Office of Emergency Preparedness 19 applications from 14 political jurisdictions and one State agency for financial assistance to restore public property (Table 5). Additionally, four jurisdictions submitted applications to obtain assistance for residents or private businesses.[4]

[3] Correspondence from the Arizona State Department of Health, Phoenix, dated December 22, 1970.

[4] Correspondence from the Department of Civil Defense and Emergency Planning, Phoenix, dated March 10, 1971.

TABLE 5

Requests for Financial Assistance[1], as Specified by Public Laws 81-875 and 91-79.

Applicant	Categories of Eligible Work in Application[2]							Total Funds Approved[1]
	Ap	A	B	C	D	E	F	(dollars)
Coconino County		*		*				7,100
Gila County	*			*				42,390
Maricopa County	*	*		*	*			83,322
Navajo County		*	*	*	*			40,986
Yavapai County	*	*	*	*				20,534
City of Flagstaff		*		*				4,835
City of Phoenix		*	*	*	*			73,038
City of Scottsdale		*	*	*		*	*	27,119
City of Tempe	*		*	*			*	8,903
Town of Buckeye							*	40,205
Town of Holbrook		*	*	*	*		*	58,799
Town of Wickenburg			*	*			*	67,536
Arizona Game & Fish Dept.		*	*	*	*		*	64,898
Buckeye Water Conservation and Drainage Dist.					*			6,000
Roosevelt Irrigation Dist.		*			*			75,856

[1] Records available to Department of Civil Defense and Emergency Planning, as of March 10, 1971.

[2] Categories of Eligible Work:

Alphabetical Identification	Public Law	Eligible Work
Ap	91-79	Debris removal from private sectors
A	81-875	Debris removal from public sectors
B	81-875	Protective, health, and sanitation measures
C	81-875	Emergency repairs and temporary replacement of streets, roads, and bridges
D	81-875	Emergency repairs and temporary replacement of dikes, levees, and drainage facilities
E	81-875	Emergency repairs and temporary replacement of public buildings and related equipment
F	81-875	Emergency repairs and temporary replacement of public utilities

The amount of financial assistance approved by the Office of Emergency Preparedness, as of March 10, 1971, was $621,521. This figure, being preliminary, is subject to refinement due to supplemental applications, or by decisions made in the final audit of completed-work claims. Also an applicant may appeal the disapproval of financial assistance by the Office of Emergency Preparedness. An updated assessment will be made in our final report.

It is necessary to add financial assistance and expenditures provided through media other than the above-mentioned to obtain a monetary estimate representing the total loss and damage picture for the 1970 Labor Day Storm.

For example, a state and its political jurisdictions must expend, within a 12-month period immediately preceding a request for a Presidential declaration of

a major disaster, a certain amount before a request to the President will be honored. Arizona's obligation of $750,000 was satisfied, and this figure should be included in the total loss and damage summary.

Also, a record of expenditures by federal agencies operating within Arizona must be considered. A preliminary indication of expenditures by federal agencies was obtained from records available to the Department of Civil Defense and Emergency Planning, as of March 5, 1971 (Table 6). Adjustments in these assessments may be made prior to completion of the final evaluation report on the Storm.

It is difficult to ascertain the total cost of the 1970 Labor Day Storm in dollars. However, based on preliminary analyses of existing reports and data summaries, the figure exceeds $5,000,000. Furthermore, with possible increases in financial assistance provided by Public Laws 81-875 and 91-79, and additional expenditures contemplated by some federal agencies, the final figure may approach $7,000,000. In either case, the widespread and unprecedented losses and damages caused by the Storm must be considered unparalleled in Arizona.

DISCUSSION

In terms of safety hazards to human well-being, the most important flooding during an event such as the 1970 Labor Day Storm may be on small, remote streams that are utilized for recreation. The unwary camper or cabin dweller may not appreciate the vulnerability of his location should a rapid rise in water level occur. These streams can respond quickly to a precipitation event with little advance warning, especially if breached debris dams release surges of water downstream. Furthermore, structures for safely containing flood waters are uncommon. In recognition of the increasing use of riparian environments for recreation, the hydrologist along with other professionals should have a significant role in the design and location of streamside facilities. Also, perhaps additional warning systems should be perfected.

A potential problem of replication in reporting was encountered in collating losses and damages. Some information provided by one agency could have been included in loss and damage appraisals of other agencies. Undoubtedly, duplication did not occur in formal appeals for relief; however, it was not always possible to completely sort-out, identify, and categorize losses and damages as reported.

Another problem involved reports and data summaries that expressed losses and damages attributed to the Storm only in terms of monetary units in some categories. Without knowledge of losses and damages in physical units, or of the appraisal procedures used in the development of monetary estimates, it is difficult to assess, interpret and combine on a common basis the information provided by different agencies. In addition, data presented in monetary units have the disadvantage of being time-dated by current costs for labor, equipment, materials, etc.

Although no amount of benefit can compensate for the loss of life, the 1970 Labor Day Storm did cause increased storage in surface water reservoirs. Preliminary evaluation suggests that the total combined gain to reservoirs on the Salt and Verde River basins was in excess of 160,000 acre-feet. This water gain may have been particularly significant since below normal precipitation and runoff characterized the following months. The winter-spring runoff of 1971 was the lowest in 12 years on the Salt River basin and the lowest in eight years on the Verde River basin (Enz 1971).

The Labor Day Storm probably increased groundwater supplies, but estimates of recharge are not yet available.

This storm was not the first tropical storm to be associated with flooding and damage in Arizona. Other examples include tropical storms *Tillie* (September, 1964) and *Claudia* (September, 1962). Another storm of tropical origin produced heavy flooding in August, 1951. Conditions seem to be right for such storms to produce floods perhaps once every four or five years in Arizona (Sellers 1960). Possibly a generalized and integrating analysis of their meteorological and associated hydrological characteristics should be undertaken for Arizona. To our knowledge, no such analysis exists, although some reports describing individual storms are available. A comprehensive study involving meteorology, hydrology, and engineering skills may yield useful design and safety information. This information could be particularly important for central and southern Arizona, where settlement and construction continue at a rapid pace, and where storms of tropical origin seem to have great impact.

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TABLE 6

Record[1] of Expenditures by Federal Agencies on Matters Relating to the 1970 Labor Day Storm.

Agency	Expenditure (dollars)
Small Business Administration (Approval of 140 loan applications)	855,800
Corp of Engineers (Channel restoration, etc.)	850,000
Geological Survey (Replace streamflow gages, etc.)	33,500
Federal Highway Administration (Repair roads, streets, etc.)	925,000
Forest Service (USDA) (Channel restoration, etc.)	400,000
Farmers Home Administration (USDA) (Approval of 4 loan applications)	40,000
Soil Conservation Service (USDA) (Engineering services)	12,000
Agricultural Stabilization & Conservation Service (USDA) (Soil rehabilitation, etc.)	463,300
Department of Labor (Approval of unemployment compensation)	150

[1] Available to Department of Civil Defense and Emergency Planning, as of March 5, 1971.

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