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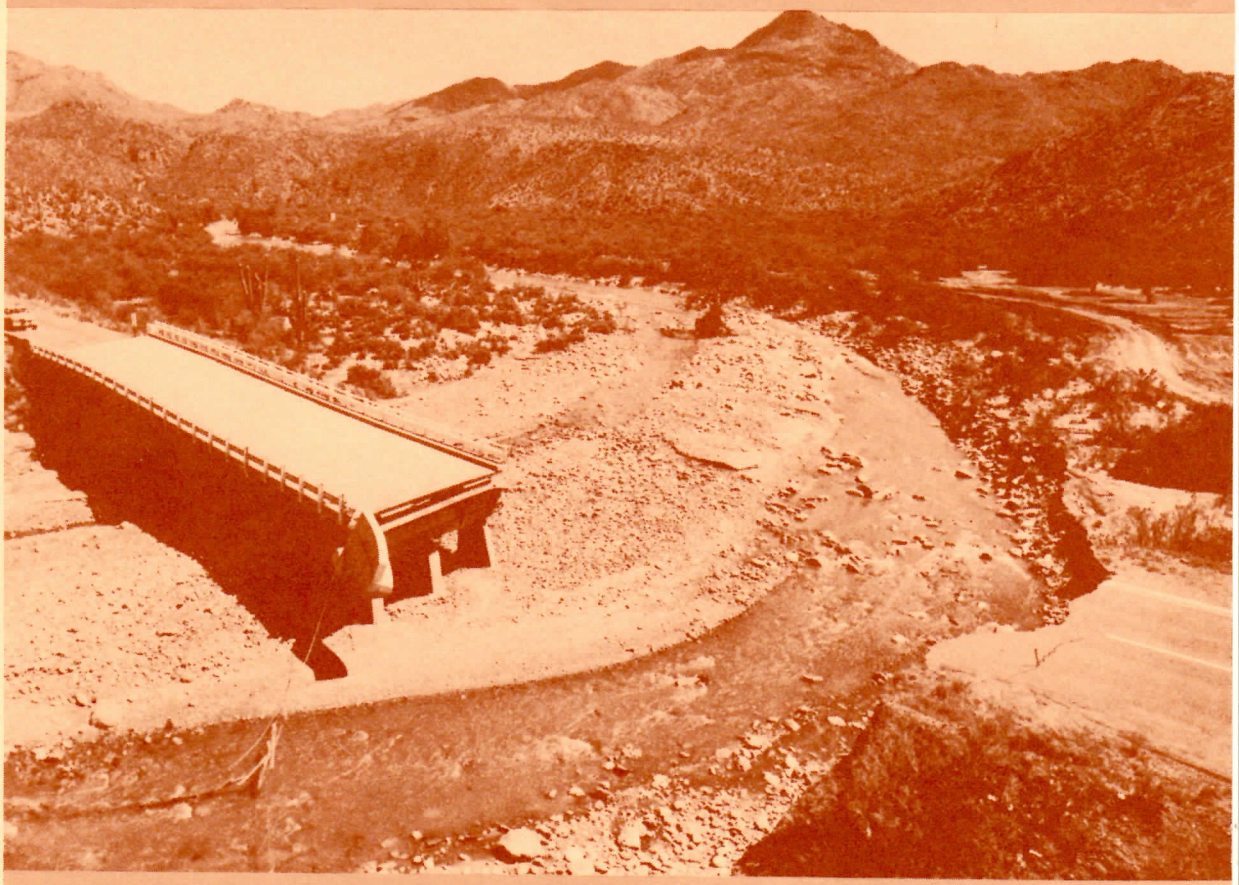
# Natural Disaster Survey Report 70-2

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

# ARIZONA FLOODS OF SEPTEMBER 5 AND 6, 1970

## A Report to the Administrator



ROCKVILLE, MD.
JULY 1971

U.S. DEPARTMENT OF COMMERCE
Maurice H. Stans, Secretary
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator

NATURAL DISASTER SURVEY REPORT 70–2

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A Report to the Administrator

ROCKVILLE, MD.
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Beautiful, but deathly dangerous. (Courtesy *The Arizona Republic*, Phoenix, Ariz.)

## FOREWORD

On September 9, 1970, A. L. Zimmerman, Hydrologist-in-Charge of the Salt Lake City River Forecast Center was appointed Chairman of a NOAA Natural Disaster Survey Team to determine the adequacy and effectiveness of the National Weather Service's data acquisition, forecast and warning, and communications systems preceding and during the devastating Arizona floods of September 5 and 6, 1970; and to determine the people's response to National Weather Service messages, statements, and warnings.

Death and destruction from rapidly rising flood waters can follow excessive rains closely in the steep mountain country of the West. Because the Arizona floods of the 1970 Labor Day weekend occurred in a relatively remote, but popular, outdoor recreational area where people are "on the move," dissemination of warnings to those in danger was difficult. This report establishes that Weather Service Offices in Arizona deserve special credit (1) for anticipating and advertising, through weather-news releases on Friday September 4, that mountain areas of Arizona were in for a wet weekend with a high potential for flash floods, and (2) for issuing prompt flood warnings when the general flooding became imminent.

H. H. Bedke

**H. H. Bedke**
Director, Western Region
National Weather Service

## PREFACE

The NOAA Natural Disaster Survey Team that investigated the Arizona floods of September 5 and 6, 1970, was made up of three members from the National Weather Service's Western Region Headquarters office at Salt Lake City, Utah—Lloyd H. Mager, User Services Representative; Harry L. Elser, Chief, Data Acquisition Branch; Woodrow W. Dickey, Scientific Services Division; and a fourth member, the Team Chairman, A. L. Zimmerman, Hydrologist-in-Charge, River Forecast Center, Salt Lake City, Utah.

The team, with the exception of W. W. Dickey, arrived in Phoenix, Ariz. on September 9, 1970, and traveled throughout the disaster area until September 12. Team members interviewed radio and television newscasters, members of the press and wire services, highway patrolmen of the Arizona Department of Public Safety, sheriffs and deputies, city police, State and county civil defense and local government officials, personnel of the U.S. Forest Service, and others who had personal knowledge of the disaster and of the National Weather Service's warning system. Chairman Zimmerman returned to Arizona on September 22 to survey sections of the disaster area that were inaccessible earlier because of washed-out roads, and to attend the Arizona State Civil Defense Meeting of September 24 and 25, 1970.

The survey team is grateful for all assistance rendered in accomplishing the survey mission, and particularly to: the Weather Services Offices at Phoenix, Flagstaff, and Winslow, Ariz., and the Weather Service Forecast Office at Albuquerque, N. Mex., for providing documentary information about weather and flood forecast services preceding and during the disaster; other Federal agencies and Arizona civil defense and law enforcement agencies for their cooperation; and the news services for making available news coverage and pictures. As Chairman, I express personal thanks to Byron Aldridge and Bert Thomsen of the U.S. Geological Survey for providing rainfall and stream gage data for use in the report, and to the Supervisors of the Prescott, Tonto, and Sitgreaves National Forests for providing campground-use estimates for the Labor Day weekend of the disaster.

**A. L. Zimmerman**
Chairman

## EXECUTIVE SUMMARY

The unprecedented flash floods in the central mountains of Arizona Saturday afternoon and evening, September 5, 1970, transformed a weekend camping holiday into a nightmarish tragedy for many persons. Never before in the State's recorded weather history had it rained so hard or so much in one day and never before had so many mountain streams and normally dry washes risen so rapidly or filled so fast with raging torrents. All-time previous record crests were exceeded. The 23 lives lost make this the greatest natural disaster in the history of the State. All who lost their lives were away from home and all but four were in automobiles. Fourteen died attempting to flee campgrounds in the headwaters area of Tonto Creek, just below the Mogollon Rim and about 30 miles northeast of Payson, Ariz.

This report—by the disaster survey team appointed by the Director of the Western Region headquarters office of the National Weather Service—describes the meteorological conditions that caused the natural disaster, the data collection and communication systems that made timely predictions and warnings possible, the dissemination of forecast statements and warnings, and the response of people to forecasts and warnings; and evaluates the adequacy and effectiveness of the National Weather Service relative to the disaster and improvements needed to better cope with future disasters of similar scope.

The survey team, in conducting the field investigation and evaluation, was impressed (1) by the alertness of the Weather Service Offices at Phoenix and Flagstaff, Ariz., in recognizing the imminence and danger of the flooding, and (2) by the positive steps taken by the two offices to disseminate warnings to officials and agencies having the responsibility for public safety and rescue operations. Significant findings from the survey appear in chapters 3, 4, 5, and 6. The most pertinent findings and recommendations follow.

**1. Finding:**

On Friday, September 4, the Weather Service Offices in Arizona, through weather-news releases, radio broadcasts, and forecasts, alerted the public to the likelihood of a wet weekend, with high flash-flood potential. Many people were discouraged from planning an outdoor weekend. These warnings were primarily based on subjective analyses of the synoptic weather pattern, the existence of a dying tropical storm that was feeding continuous streams of moisture over Arizona (as shown by satellite pictures), and indications of the first cold air outbreak of the season pushing south toward Arizona.

**Recommendation:**

a. The National Weather Service should continue every effort to provide early (Thursday or Friday) cautionary statements to the public about potentially dangerous weekend weather situations, especially for remote, outdoor recreation areas.

b. NOAA NWS should prepare and circulate literature about flash-flood hazards in the desert Southwest. This information should be made readily available at campground and tourist information centers.

**2. Finding:**

The NWS National Meteorological Center (NMC) rain forecast guidance in the 24-hour period preceding the excessively heavy rains did not adequately alert the weather forecast offices to the severity of the impending storm.

**Recommendation:**

a. NMC should make a careful reanalysis of of this situation, beginning at least as early as 0000Z, September 4, to try to discover why the numerical models did not handle the broadscale circulation features satisfactorily. It is recommended that the entire sequence be run on the fine-mesh PE model.

b. Case studies of excessive rains over the

southwestern United States, in which moisture from decaying tropical storms has been involved, should be made. These should be furnished to field forecasters to provide a better understanding of this type of meteorological event.

3. **Finding:**
Weather Service Offices (WSOs) in Arizona made maximum use of the data available to them and issued general flood warnings promptly, but the existing river and rainfall data-acquisition network in the disaster area was inadequate to accurately assess the magnitude and extent of the flooding as it was occurring.

**Recommendation:**
A limited, automated river and rainfall reporting network should be planned and implemented in this popular mountain recreation area.

4. **Finding:**
Telephone communications between Arizona WSOs and between WSOs and the Albuquerque Weather Service Forecast Office (WSFO) during the emergency conditions were subject to outages and were not generally adequate.

**Recommendation:**
a. NOAA should establish the planned WSFO at Phoenix as soon as possible, with attendant NOAA Weather Wire Service and adequate communications staff.
b. NWS should check the rain-fade failure in microwave communications with the telephone company providing longline service for northern and eastern Arizona, to ensure the best communications service possible to WSOs.

5. **Finding:**
The Albuquerque WSFO issues zone forecasts for Arizona, but all other statewide weather services—weather summaries, temperature and precipitation bulletins, flash-flood advisories—are issued by Phoenix WSO. Because the two offices each have "part of the action," it is difficult to place a total weather services product before Arizona users that reflects an optimum degree of continuity and a minimum degree of conflict. A great amount of Arizona weather information feedback reaches Phoenix; little reaches Albuquerque.

**Recommendation:**
NOAA should accelerate the establishment of the planned WSFO at Phoenix so that weather forecast and weather service statements and releases will emanate from the same office and assure better continuity.

6. **Finding:**
It is a difficult and challenging task to get weather warnings about dangerous conditions to outdoorsmen and recreationists in mountain areas during holidays and weekends. Each year the number in this group is increasing greatly.

**Recommendation:**
Better communications should be developed between WSOs and U.S. Forest Service recreation and ranger staffs in mountain and remote recreation areas so that severe weather and flood warnings are made available quickly to the staffs who have the responsibility for, and are experienced in, promoting the safety of outdoorsmen and tourists.

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CHAPTER 1

# Rainstorm and Floods of September 5 and 6, 1970

## THE STORM

The loss of 23 lives and the devastation wrought by the Arizona floods of September 5 and 6, 1970, make the Labor Day weekend calamity the greatest natural disaster in the history of the State. The rainfall Saturday September 5, from shortly after midnight until late evening, was unprecedented in America's weather history. During the 24-hour period from 10 p.m. September 4 to 10 p.m. September 5, 11.4 inches of rain were measured in the official recording rain gage at Workman Creek, about 60 miles east-northeast of Phoenix at an elevation of 7,000 feet. This rainfall amount exceeded the previous 24-hour record for Arizona by more than 5 inches.

Arizona is best known as a "fair weather" State, but like the neighboring States that share Southwest deserts, has its share of severe weather in summer and fall. This severe weather can be scorching heat, violent thunderstorms accompanied by strong winds and "cloudburst" rainfall, or more general excessive rains such as those which occurred on Labor Day weekend. An unusually large number of weather-caused deaths occurred in Arizona the summer before the September 1970 disaster. In August, five persons in a single party perished from heat and thirst after 3 days of exposure in a desert area less than 30 miles from Phoenix. Eight other persons lost their lives in three separate incidents because they were not able to escape flash floods that swept dry washes or creeks. The Reg Manning cartoon on the frontispiece tells a story that cannot be repeated too often—unfortunately the story is not always heeded.

In Arizona, most flash floods during summer and fall are very local in nature and are caused by cloudbursts of short duration (often less than one hour). The floods of the 1970 Labor Day weekend were caused by a different type of meteorological phenomenon, an eastern Pacific hurricane or tropical storm. About once every 10 years heavy rains in August or September, referred to by native Arizonans as "Mexican hurricanes," cause extensive flooding in Arizona. These heavy rains are spawned by influxes of moist air from dying Pacific tropical storms in the Baja California area. Pacific tropical storm NORMA, with its great amount of moisture-laden air, was the major meteorological event associated with the heavy rainfall of September 5 in Arizona—just as moisture-laden air from the dying Atlantic hurricane CAMILLE gave birth to the Virginia floods of August 19–22, 1969.

The area of heavy rainfall on September 5 and 6 extended northeastward from central and eastern Arizona into the Four Corners area of Utah, Colorado, Arizona, and New Mexico (fig. 1). In southern Utah, two persons lost their lives Saturday night, September 5, when their automobile dropped into flood waters as the road washed out beneath them in the remote Elmo Wash area of the San Juan River Basin. On September 5 and 6 flooding occurred along tributaries of the San Juan River in southwestern Colorado, and along the Little Colorado River

Christopher Creek Campground areas in the headwaters of the Tonto Creek drainage. Most of the deaths resulted when persons attempted to leave campground areas for home. The rapidly rising flood waters washed out roads and bridges and swept cars and their occupants along in the torrent. Reservoirs on the lower Agua Fria and Verde Rivers and Roosevelt Lake at the mouth of Tonto Creek controlled the flood flows and prevented catastrophic flooding on the mainstems of the Salt and Gila Rivers in the Phoenix area and farther downstream.

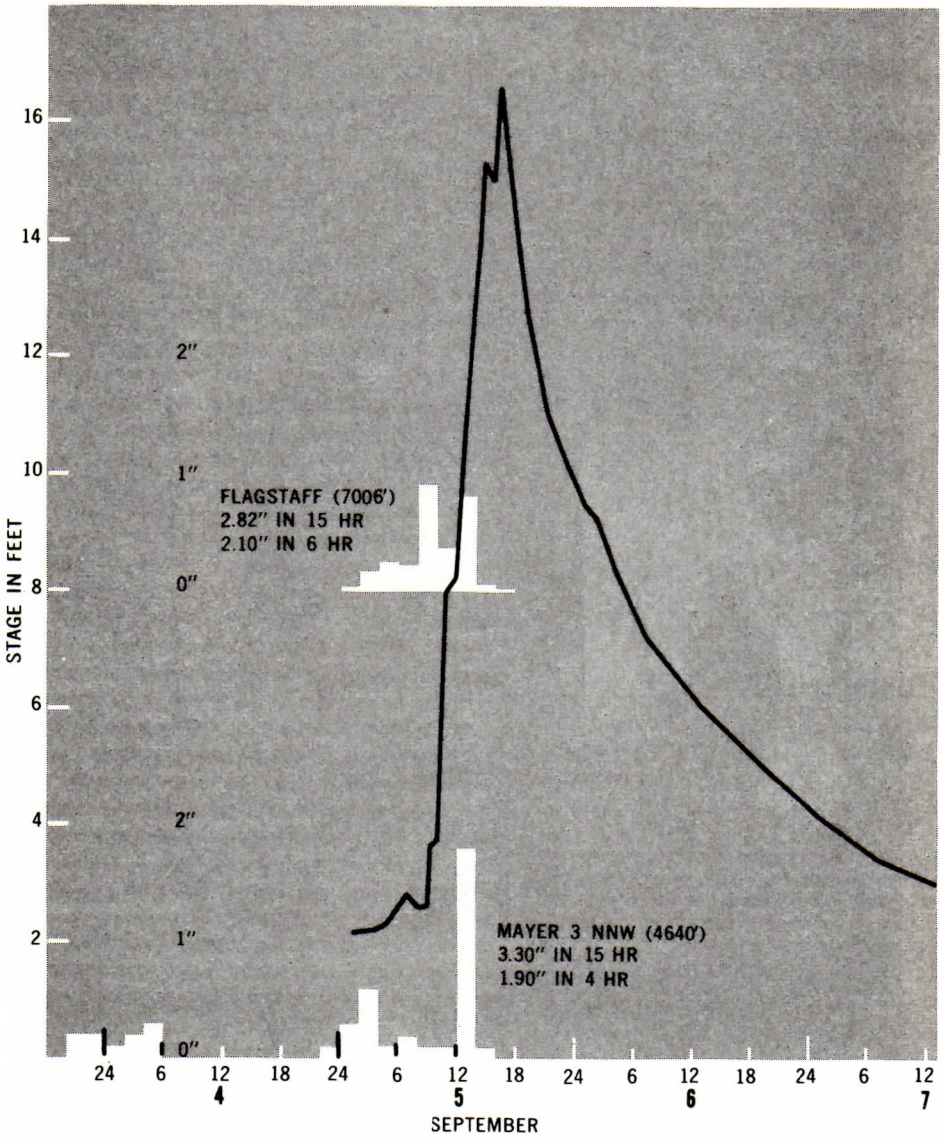
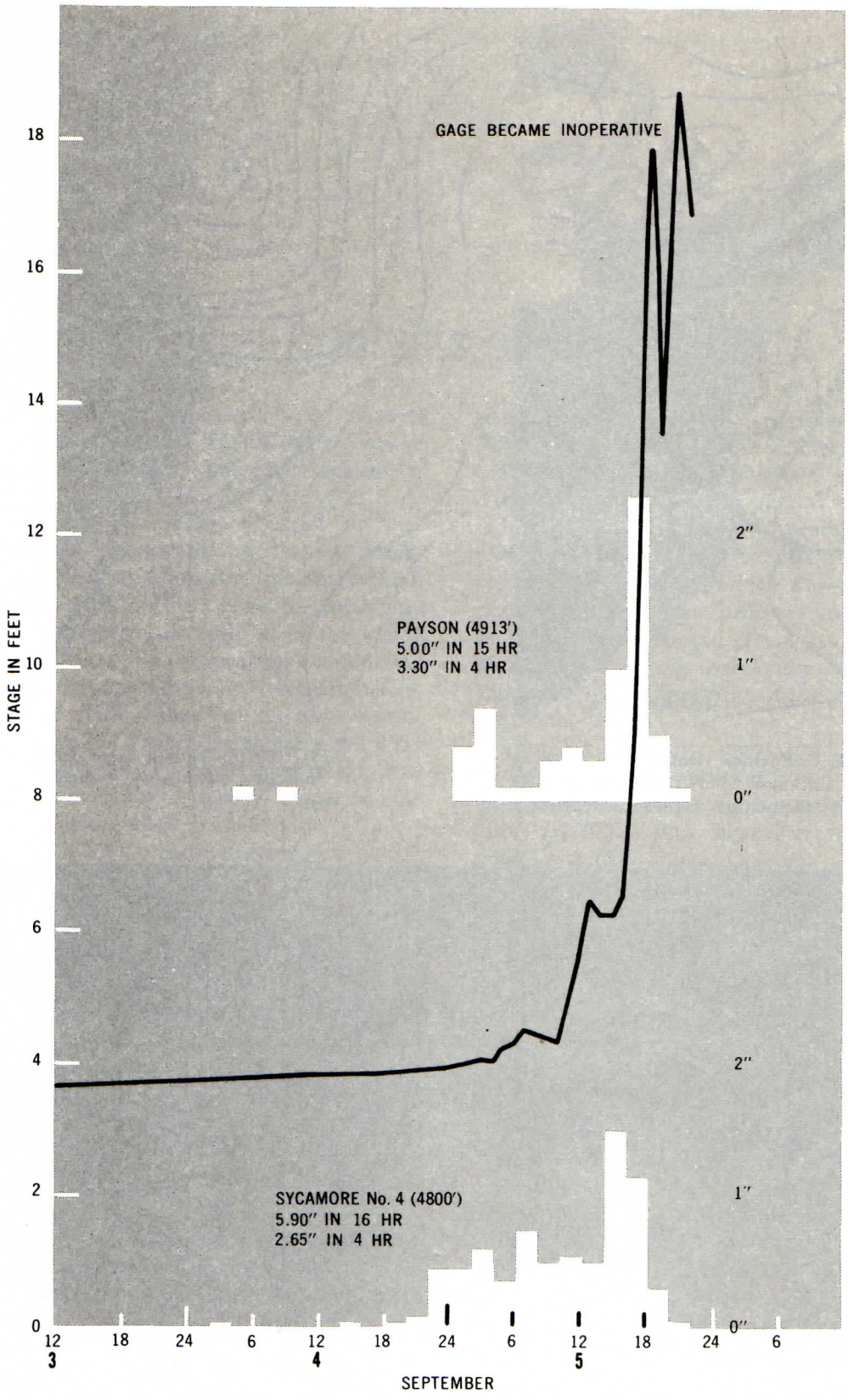



**FIGURE 5. Rainfall and stream stage comparison, Oak Creek near Cornville (location 2 in figure 3). Drainage area 357 sq. mi.; elevation 3,470 ft.**

**FIGURE 6. Rainfall and stream stage comparison. Tonto Creek north of Gun Creek (location 3 in figure 3). Drainage area 675 sq. mi.; elevation 2,523 ft.** ▶


GAGE BECAME INOPERATIVE
PAYSON (4913')
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3.30" IN 4 HR
SYCAMORE No. 4 (4800')
5.90" IN 16 HR
2.65" IN 4 HR
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SEPTEMBER

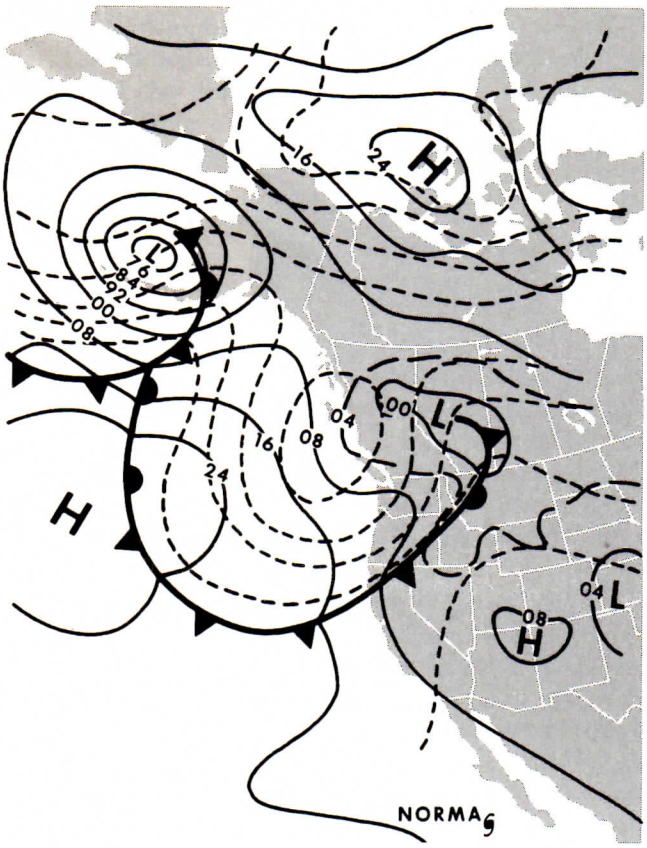
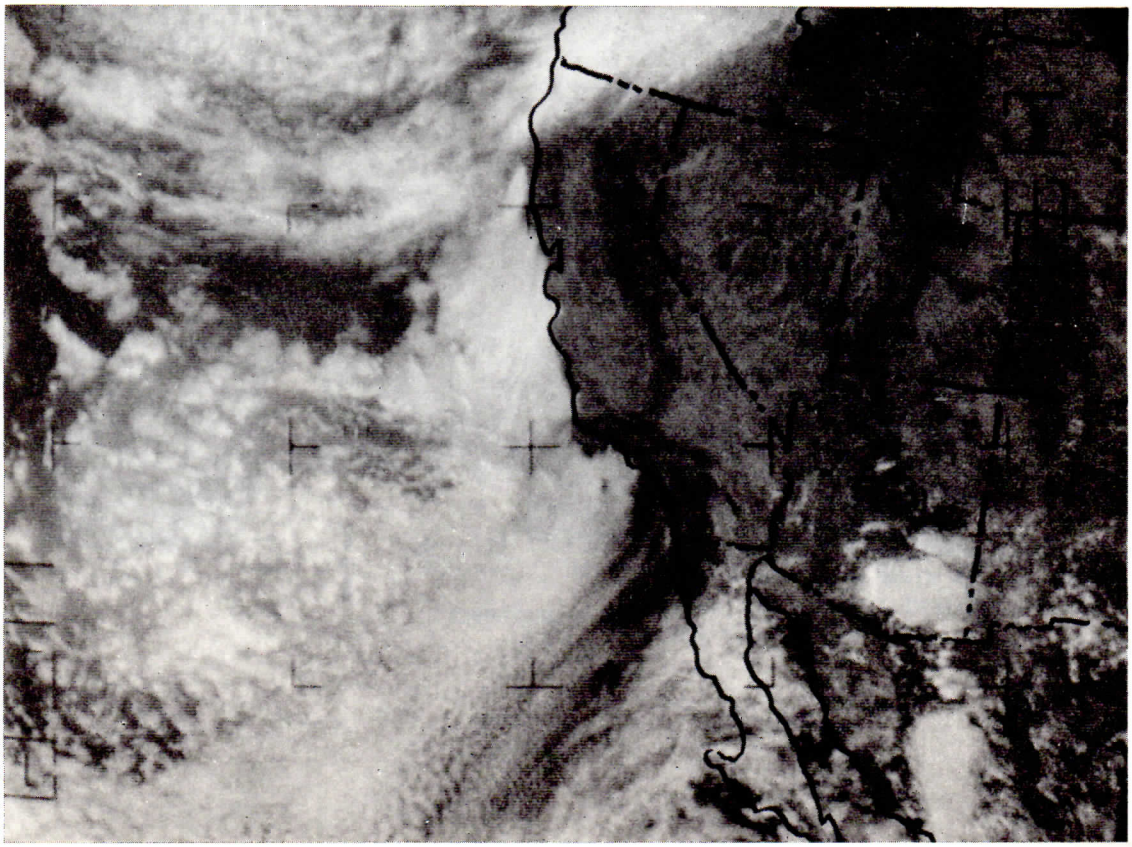



FIGURE 7. Surface weather and 1000- to 500-mb thickness chart for 5 p.m. MST Thursday, September 3 (0000Z, September 4).

FIGURE 8. 500-mb chart for 5 p.m. MST Thursday, September 3 (0000Z, September 4).



## CHAPTER 2

# Meteorological Analysis of the Storm

The stage for the excessively heavy rains in central Arizona and the Four Corners area of Arizona, Utah, Colorado, and New Mexico was being set as early as Thursday September 3. At this time, copious amounts of moist air were being carried northward by tropical storm NORMA while an unusually intense early-fall northern-latitude cold air mass pushed southward. These broad-scale features of the atmospheric circulation and the resulting combination of meteorological conditions all contributed to the intensity of the deluge over the disaster area. Between midnight Friday September 4 and noon Saturday September 5, 1 to 3 inches of rain had accumulated and by Saturday afternoon the flood-causing rains were at their peak.

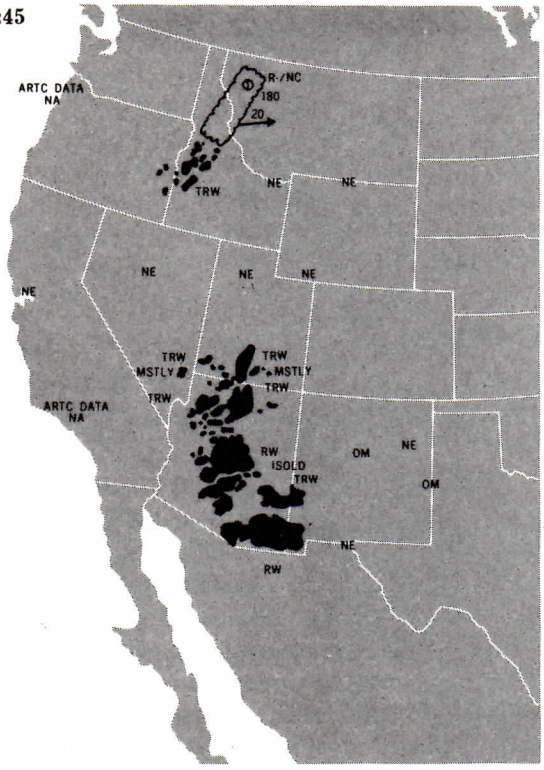
At 5 p.m. MST Thursday September 3 (0000Z Friday, September 4) tropical storm NORMA was centered at 22.7°N, 114.8°W, some 5 degrees of longitude west of the southern tip of Baja California (fig. 7). Tropical moist air from this storm was already channeled northward over the Gulf of California and across northwestern Mexico into southern Arizona. To the north a cold low aloft was centered just north of Vancouver Island (fig. 8). The surface positions of an intense cold front associated with this system extended from northwestern Montana southwestward across Idaho, eastern Oregon, and extreme northern California. A minor trough at 500 mb was located over the southern California coast between San Diego and Santa Maria, Calif. Thunderstorms and heavy rain were occurring in the tropical air mass over southeastern Arizona at this time. These features are illustrated pictorially in figure 9, which shows the spiral cloud bands over Baja California north of tropical storm NORMA, and clouds associated with thunderstorm activity over southeastern Arizona and along the leading edge of the cold front to the north.

◀ **FIGURE 9. Automatic picture transmission from ITOS 1 satellite, 3:52 p.m. MST Thursday, September 3, 1970 (22:52:13Z). Orbit number 2796; picture center at 29.8°N, 119.9°W.**

Thursday night the moist tropical air continued to spread northward and the minor upper-level trough moved eastward. By 5 a.m. MST (1200Z) Friday September 4, the minor trough was over southern Nevada and extreme western Arizona. Showers and thunderstorms preceded this minor trough in a north-south band from southern Utah through central Arizona as shown in figure 10 by the radar summary chart for 4:45 a.m. MST (1145Z). The automatic picture transmission (APT) from ESSA 8 satellite at 10:21 a.m. MST (1721Z) Friday shows clouds spreading over all Arizona and into eastern Utah and western Colorado (fig. 11). This picture also shows that the circulation around tropical storm NORMA was continuing to feed tropical moist air over Arizona. Clouds associated with the cold front approaching from the northwest are pictured over northern Nevada.

By late Friday afternoon, the minor trough had moved across northern Arizona and Utah and the band of shower activity preceding the trough extended from Colorado through New Mexico. Only a few showers remained over Ari-

FIGURE 10. Radar summary chart for 4:45 a.m. MST Friday, September 4 (1145Z).



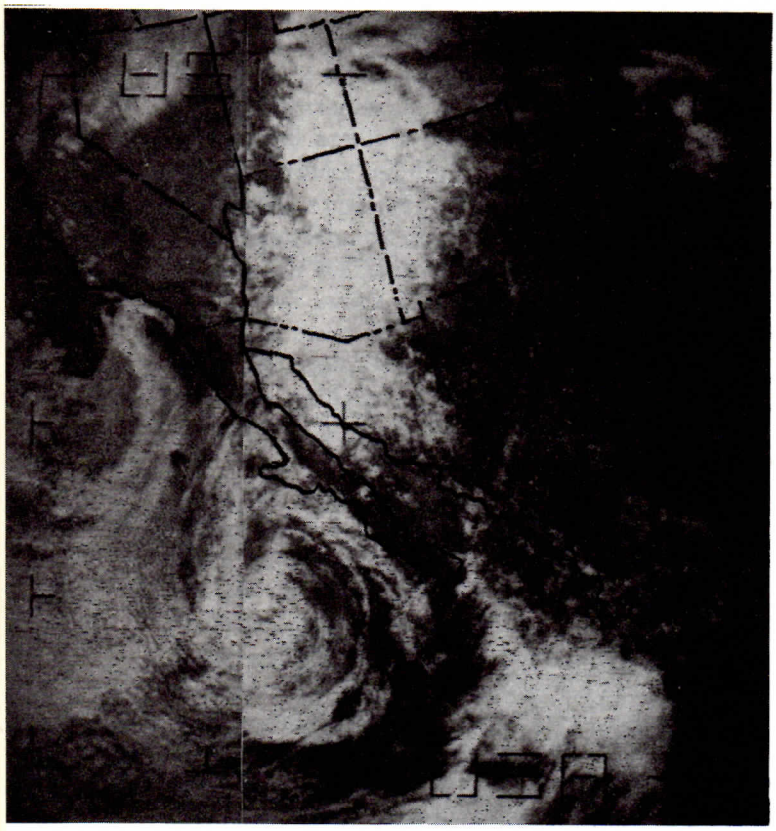



FIGURE 11. Automatic picture transmission from ESSA 8 satellite, 10:21 a.m. MST Friday, September 4, 1970 (17:21.32Z). Orbit number 7884; picture center at 28.9°N, 110.9°W.

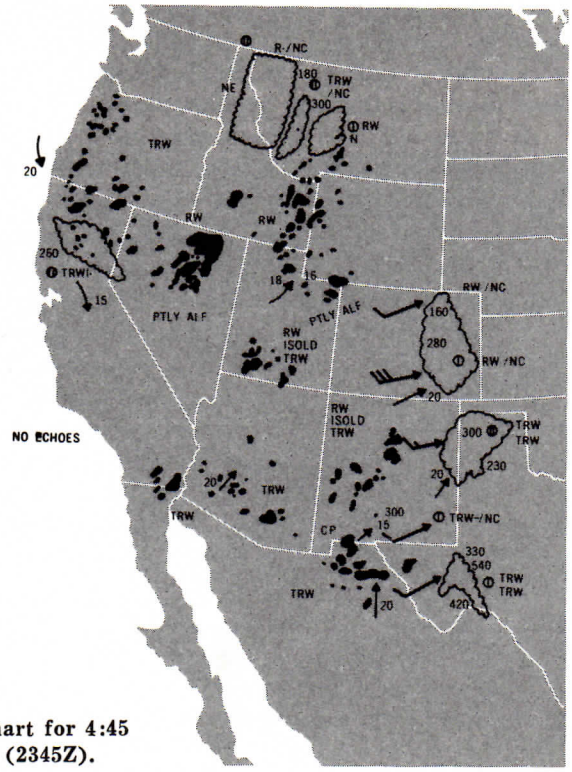



FIGURE 12. Radar summary chart for 4:45 p.m. MST Friday, September 4 (2345Z).

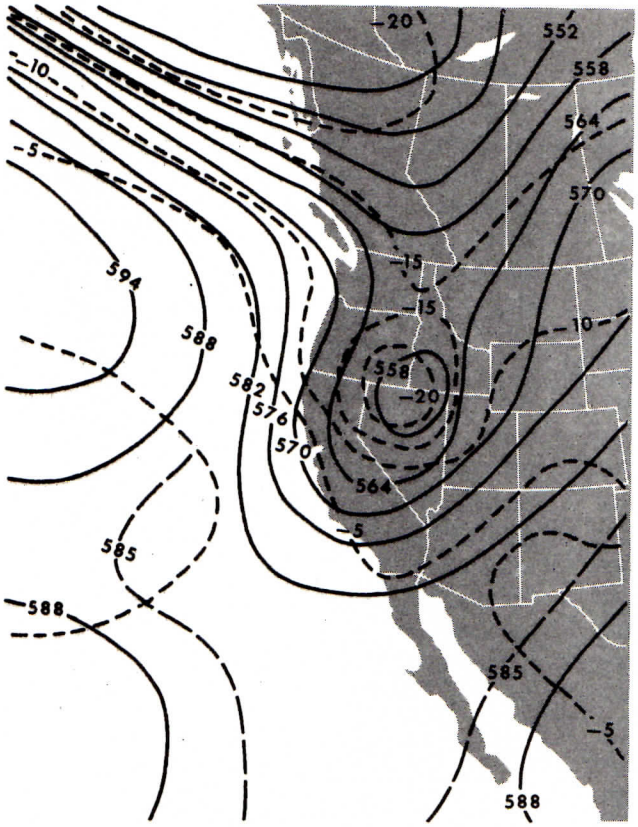



FIGURE 13. 500-mb chart for 5 a.m. MST Saturday, September 5, (1200Z).

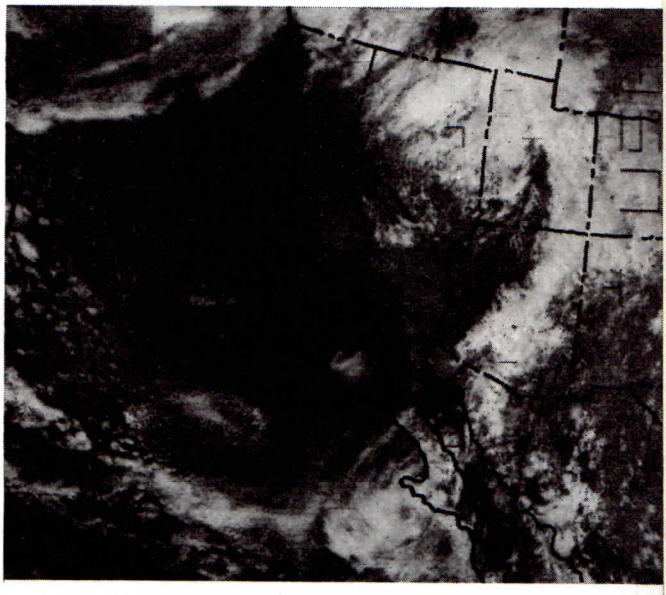


FIGURE 15. Automatic picture transmission from ITOS 1 satellite, 3:50 p.m. MST Saturday, September 5, 1970 (22:50:00Z). Orbit number 2821; picture center at 33.0°N, 120.6°W.

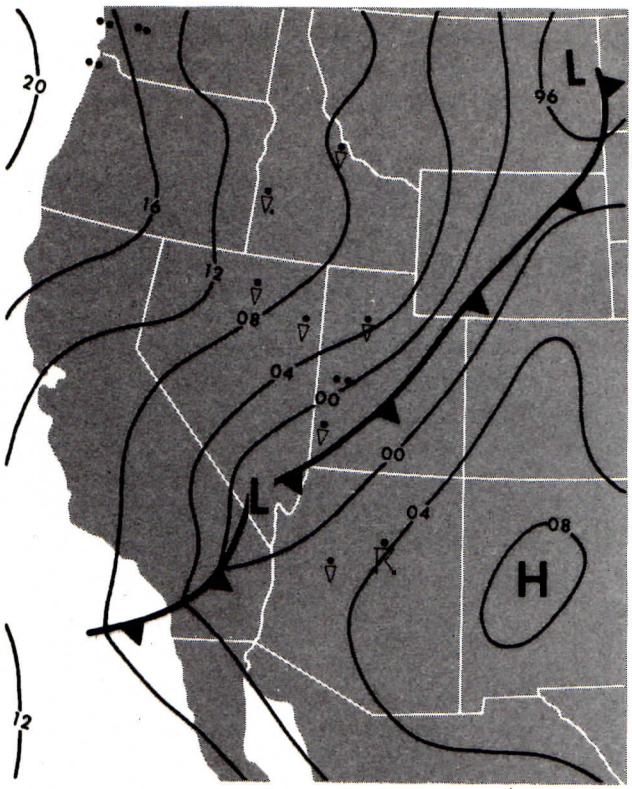



FIGURE 14. Surface weather chart for 5 a.m. MST Saturday, September 5 (1200Z).

zona, as shown in figure 12 by the radar summary chart for 4:45 p.m. MST (2345Z). However, tropical moist air still overlay Arizona—as indicated by surface dew point temperatures in the high 60's and 70's—awaiting the next triggering mechanism to release the moisture.

The next triggering mechanism rapidly approached from the northwest. During the 24-hour period from Thursday afternoon to Friday afternoon, the cold low aloft moved from over Vancouver Island southeastward to eastern Oregon, and the associated cold front extended across central Nevada and central California (maps not shown). Friday night these systems continued their southeastward advance so that by 5 a.m. MST (1200Z) Saturday September 5 the cold low was centered over northern Nevada (fig. 13) and the cold front extended across central Utah to the southern tip of Nevada where it formed a flat wave and continued southwest across southern California (fig. 14). As the cold trough approached from the northwest, and the surface low developed over southern Nevada and northwestern Arizona, strong (30- to 40-knot) southerly winds developed over Arizona in the lowest 10,000 feet.

The general upward flow of air over Arizona and southern Utah ahead of the cold trough and cold front, combined with strong orographic uplifting of moisture-laden, unstable, tropical air along the south side of mountains and the Mogollon Rim escarpment, caused extremely heavy rains throughout central Arizona and southern Utah. These rains began early Saturday morning, September 5, and continued most of the day as the front advanced slowly but steadily across Arizona and southern Utah. During this time, the circulation around tropical storm NORMA continued to feed tropical moist air northward over Arizona ahead of the frontal system. The ITOS–1 satellite picture at 3:50 p.m. MST (2250Z) on Saturday September 5 was taken about the time of peak shower activity over central Arizona and the Four Corners area (fig. 15).

Sunday morning September 6 the northern portion of the front was over New Mexico and Colorado. The southern portion had slowed and weakened. Tropical air still covered southern Arizona, but there were only light showers. The weather had calmed but the aftermath of the floods was a grim reminder of the death and destruction caused by the excessively heavy rains of the 1970 Labor Day weekend.

**Flooding at Van Buren and 48th Street, Phoenix. (Courtesy *The Arizona Republic*, Phoenix, Ariz.)**

## CHAPTER 3

# Rain and Flood Predictions and Warnings

### LEVELS OF FORECAST RESPONSIBILITY

The National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA) provides the general public with weather and flood forecast and warning services. These services continue those provided by the Weather Bureau (WB) of the Environmental Science Services Administration (ESSA) at the time of the Arizona floods of September 5 and 6, 1970. The organizational nomenclature in this disaster survey report is that of NOAA, but reflects the organizational restructuring of the forecast system begun by the Weather Bureau under ESSA.

Meteorological analyses and predictions are made available through a forecast system consisting of three levels—National, State or large portions of States, and zones.

1. The National Meteorological Center (NMC) at Suitland, Md., mainly through computerized operations, provides various broad-scale analyses and predictions in graphic form for the Northern Hemisphere. Similar products that show greater detail are made available for the conterminous States and adjacent marine areas. This basic (synoptic-scale) guidance material covers forecast periods to 72 hours and is distributed to Weather Service Offices over the National Facsimile System (NAFAX). Quantitative precipitation forecasts for 12-, 24-, and 48-hour periods also are provided for the conterminous States.
2. Weather Service Forecast Offices (WSFOs) are responsible for forecasts and warnings for States or large areas. WSFOs provide the main field forecast support and guidance to local Weather Service Offices.
3. Weather Service Offices (WSOs) are responsible for local weather forecasts based upon guidance from the two higher echelons and upon recent observations. WSOs are the most direct link to the public and are responsible for preparing and disseminating warnings of severe weather events to designated counties in their immediate vicinity.

Hydrologic analyses and predictions are provided through a forecast system consisting of two levels—River Forecast Centers and River District Offices.

1. River Forecast Centers (RFCs) analyze precipitation and stream data for established regions and prepare river and flood forecasts for use and dissemination by district offices in their region.
2. River District Offices (RDOs) maintain the rainfall and river reporting networks in established districts, transmit the data to the regional river forecast centers, and disseminate the RFC forecasts to the public and Federal and State agencies. Where RFCs are not yet established, RDOs have the sole forecast responsibility.

The Weather Service Office at Phoenix, Ariz., is also a River District Office and has the flood forecast responsibility for all of Arizona except a small area in the northwest corner of the State. The River Forecast Center for the area is at Salt Lake City, Utah. This newly established Center had a limited staff at the time of the Arizona floods, and was not yet assisting the Phoenix RDO with formal river forecast support. However, the Center did, occasionally, exchange and provide information pertaining to the overall hydrologic mission of the National

**Flood damage and debris near Kohl's Ranch; headwaters of Tonto Creek. (Courtesy Ed Wiggins, *The Mesa Tribune*, Mesa, Ariz.)**

"summaries" for the State every 3 hours. These "summaries" receive wide distribution and dissemination in Arizona. They are written to provide weather news to the press and wire services and other disseminators of weather information throughout the State and include such items as significant weather conditions, weather outlooks, and evaluations of flash-flood potential. On Friday morning, September 4, the potential for heavy rains and flash flooding was recognized by the Phoenix WSO, as indicated by the opening paragraph of the 8 a.m. Arizona weather "summary:"

> "Arizona appears to be headed for a good soaking over the next day or two. A tongue of moist, warm, tropical air is reacting with the first major Pacific cold front of the fall season. This is a combination that can produce very heavy rain in Arizona. Flash-flood potential is very high, and there may be some sustained heavy rains in the mountains resulting in prolonged periods of runoff into some streams and washes."

Subsequent summaries issued through Friday evening called attention to the very high flash-flood potential continuing into Saturday. However, Phoenix weather "summaries" issued Friday night and early Saturday morning did not stress the high flash-flood potential for Saturday, but reflected the "drier" NMC and WSFO guidance. The "summaries" issued Saturday, beginning with the 5:30 a.m. release, again stressed the very high flash-flood potential.

The Saturday morning Arizona weather summaries from Phoenix indicated that flooding was not expected on major rivers, but that an appreciable increase in streamflow was likely. This general statement turned out to be incorrect in that neither the record-breaking amount nor the intensity of rain were correctly anticipated.

The Phoenix WSO made special efforts to obtain and exchange information with NWS

offices beginning Friday September 4 and continuing throughout a 2-day period. These efforts reached their peak just prior to the issuance of the first flood warning at 2 p.m. MST Saturday September 5. The sequence of actions noted in the Phoenix log follows:

Palmdale Radar Unit called Phoenix (PHX) about 1:00 p.m. Saturday to report a line of intense echoes extending from 30 miles northwest of Prescott to 60 miles west of Gila Bend and moving southeast at 10–15 knots. About the same time, Crown King Ranger Station reported an accumulation of 5 inches of rain and still raining hard. The PHX WSO then called ABQ (Albuquerque) radar at 1:15 p.m., but there was little change from what was reported on NAFAX (National Facsimile Network). Phoenix WSO initiated a call to Junipine in Oak Creek Canyon to check precipitation; Junipine reported another 2+ inches and no major increase in stream flow. Junipine also reported that tourists had witnessed mud slides and flash flooding along tributaries in the Sedona and Indian Gardens area, but still reported no major flooding on the river. At 1:45 p.m. Phoenix WSO attempted to discuss the situation with Flagstaff WSO, but was unable to reach them because of a telephone failure in the Flagstaff area. Phoenix then used NAWAS (National Warning System of Civil Defense) to reach Flagstaff through the State Police. Flagstaff advised of more serious flooding on Oak Creek, and the decision to issue the flood warning was confirmed.

At 2 p.m. MST Saturday, September 5, Phoenix WSO issued flood warnings for Maricopa, Yavapai, Coconino, and Gila Counties, and a separate warning for the Verde Valley, Oak Creek, Beaver Creek, Cottonwood, Corn Valley, Camp Verde, and Sedona areas, affective immediately until 10 p.m. MST.

At 3:30 p.m., flood warnings were issued for the Agua Fria and the rapidly rising New River.

At 6:30 p.m., flood warnings were issued for the Hassayampa River from Wickenburg south to the Gila River.

At 8:00 a.m. MST Sunday, September 6, flash-flood warnings were continued for eastern sections of Maricopa and Pinal Counties and extended, effective immediately, for the rest of the day for all of Pima, Santa Cruz, Cochise, Graham, and Greenlee Counties and the extreme southern sections of Navajo and Apache Counties.

At 10:00 a.m., flood warnings were issued, effective immediately, for Little Colorado River above Holbrook to the mouth.

River forecast procedures at the Phoenix RDO do not provide specific river stage forecasts for the rivers and streams in the disaster area. The present data network for the area permits only general river forecast services, although, as illustrated in figures 4 through 6, heavy runoff follows heavy rain so closely in this area that there is little time to prepare and disseminate detailed forecasts.

#### FLAGSTAFF WSO FORECASTS AND WARNINGS

On Friday, September 4, local forecasts and direct radio broadcasts included statements about the likelihood of heavy rains on Saturday, September 5.

At about 4:30 a.m. MST Saturday, September 5, the Radar Unit at the Federal Aviation Administration Air Route Traffic Control Center (FAA-ARTCC) in Albuquerque called the Flagstaff WSO to advise that radar indicated steady, persistent rain 30 to 35 miles southeast of Flagstaff.

At 7:10 a.m., the Flagstaff WSO, by direct radio broadcast over two radio stations, stressed continued rain throughout the day—heavy at times.

At 9:00 a.m., the Flagstaff WSO telephoned Phoenix WSO concerning flood warnings. However, the meager information on the extent of heavy rains, and the most recent forecast guidance from Albuquerque WSFO, prompted the Phoenix WSO duty forecaster to be reluctant to issue specific flood warnings at that time.

At 12:10 p.m., after an exchange of information with the local office of the Arizona Highway Patrol and the Coconino County Sheriff's office, the following direct radio broadcast was made:

"For the past 24 to 36 hours moisture has been moving into Arizona from Old Mexico. The remnants of a tropical storm off lower California has supplied lots of moisture. Rain has been falling over the State all morning. Conditions are not getting any better. Holiday

travelers will do well to stay where you are or get to high ground. The heavy rain has not yet arrived. . . . Motorists, restrict your travel —get off the highways. Secondary roads will be impossible for travel."

At 12:40 p.m. all telephone lines were out for approximately 35 minutes.

At 1:15 p.m. an attempt was made to call the Phoenix WSO, but the call could not be completed. The Arizona Public Service Company and the Arizona Highway Patrol were contacted and requested to relay by radio a message to Phoenix that the Flagstaff WSO was issuing a flood warning for Coconino County, effective 2 p.m., as follows:

"Flooding expected all drainages in Coconino County. All streams rising rapidly. Two to five inches of rain received so far—at least one more expected this afternoon. Heavy runoff continuing for 12 to 18 hours."

#### WINSLOW WSO FORECASTS AND WARNINGS

The weather service area of Winslow was on the fringe of the heavy rain area. When flood warnings for the Little Colorado River were received from Phoenix early Sunday, September 6, the Winslow WSO relayed the warnings to appropriate city officials and to the radio station. There is neither a river- nor a rainfall-reporting network for the Little Colorado River. Its upper reaches drain an almost uninhabited area. Flood warnings were issued from Phoenix based upon reports that the Phoenix WSO received about upstream flooding in the Holbrook, Ariz., area.

The Winslow WSO, during the height of the flooding in the Central Mountain area, assisted those officials seeking information by relaying forecasts and discussing weather conditions. A discussion Saturday evening between Mrs. Walda Kennedy and an official of the U.S. Forest Service is referred to in chapter 6.

#### FINDINGS

1. Many weather statements released by the Phoenix and Flagstaff WSOs on Friday September 4 mentioned the high potential for heavy rain and flash flooding Friday night and Saturday.

2. Late Friday and early Saturday the NMC basic forecast guidance was "dry" for the next 24 to 36 hours. By 8 a.m. MST Saturday the QPF Unit at NMC was modifying that guidance toward "wetter."

3. Albuquerque WSFO forecasts and guidance followed the NMC guidance very closely on Friday and Saturday, September 4 and 5.

4. The fact that weather forecasts (zones) for Arizona emanate from a different source than weather summaries introduces a problem in maintaining desired continuity in the weather services provided for Arizona.

5. Flood warnings and statements for the disaster area were issued promptly by the Phoenix RDO upon receipt of observations of excessive amounts of rain, and were disseminated without delay.

6. The NMC products did not successfully forecast the southward plunging of the upper-air cold low and associated cold front over the western United States. This led to an underestimate of the rain potential of the storm.

7. The organization of the procedures to be followed in the distribution of severe weather and flood warnings from the Phoenix WSO is among the best and most efficient the survey team has witnessed. County maps which indicate the communications channels to key officials, the type of warnings to be distributed, and up-to-date telephone listings are kept in a loose-leaf form so that several persons can assist in disseminating information simultaneously.

#### RECOMMENDATIONS

1. NMC should make a careful reanalysis of this storm, beginning at least as early as 0000Z, September 4, to try to discover why the numerical models did not adequately handle the cold-low situation. It is recommended that the entire sequence be run on the fine-mesh PE model.

2. Case studies of past excessive rains over the southwestern United States in which moisture from decaying tropical storms has been involved should be made to provide a better understanding of this type of meteorological event.

3. The planned WSFO at Phoenix should be implemented as soon as possible to provide round-the-clock meteorologist coverage for Arizona and to improve the continuity of weather services available to the Arizona public.

## CHAPTER 4
# Data Collection and Communications

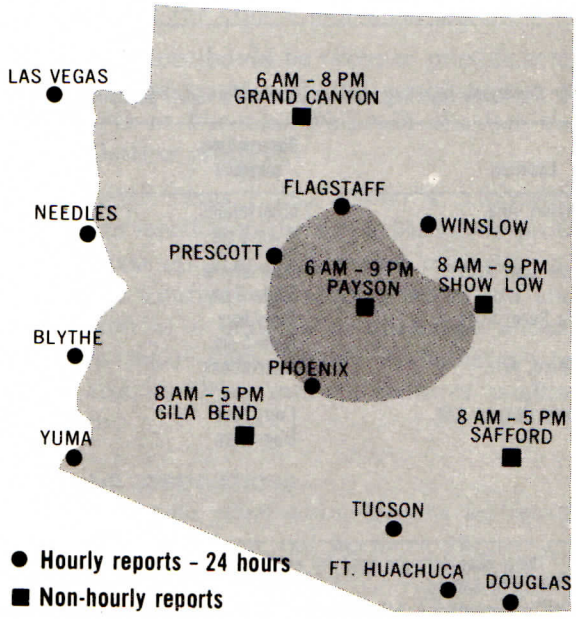
### SURFACE OBSERVATION NETWORKS

There are 11 regular reporting stations in the surface observation network that provide basic hourly data for operational monitoring of meteorological conditions over Arizona. These stations are listed in table 2, part A, and their locations are shown in figure 17. Hourly observations from these stations are collected on Service A teletypewriter system and 6-hour precipitation amounts are collected on either Service A or C. The areal density averages one station per 11,000 square miles. Spacing between stations ranges from 50 to 300 miles and averages 110 miles. Three of the stations are located on the periphery of the area of major flooding.

There are five additional stations in Arizona that report regularly but not hourly. These stations are listed in table 2, part B, and their locations are shown in figure 17. Arrangements for observations vary. In general, the observations are taken every two or three hours during daylight hours by local citizens who may serve gratuitously or receive a small fee for each observation taken. The reports are collected by telephone at Phoenix for entry on Service A (exception—Prescott FAA collects and transmits Grand Canyon reports). Precipitation is reported once or twice a day in the form of cumulative 24-hour amounts. If these stations are added to the regular monitoring network the areal density increases to one station per 7,000 square miles. Spacing between stations ranges from 50 to 200 miles and averages 80 miles. One of the stations, Payson, is located in the center of the area of major flooding.

There are nearly 300 cooperative substations in Arizona (fig. 18) that make observations, mostly daily temperature extremes and precipitation, for record purposes, that is, the data is not intended for realtime use. However, by special arrangement, observations from 23 of these cooperative observers are routinely collected by telephone at Phoenix once or twice a day for inclusion in the morning and evening weather tables released to the press. Some of the reports are collected by Flagstaff WSO for telephone relay to Phoenix. These reports include 24-hour precipitation amounts. Four of these reports—Globe, Nogales, Cottonwood, and Bisbee—along with a telemark river stage reading at Clifton, are incorporated in the River and Rainfall mes-

FIGURE 17. Regular-reporting surface station network for Arizona.



sage (SRUS) and transmitted by Phoenix on Service C at 8:40 a.m. MST daily. Four of the 23 stations are located in the area of flash flooding as indicated in figure 18.

During the storm many cooperative substation observers voluntarily telephoned reports of heavy precipitation to the WSOs at Flagstaff and Phoenix. Three of these—at Junipine, Crown King, and Baker Butte—proved to be key reports and are indicated in figure 18.

In addition to the routine dissemination of data via Service A and C as mentioned above, other significant reports are collected by WSOs and relayed to the WSFO via telephone during critical situations.

**Findings**

1. The density of the surface observation network is not adequate to define the areal extent, intensity, or time of heavy precipitation associated with flash flooding. Although the monitoring of the statewide regularly reporting network prompted issuance of the "high flash-flood potential" statement as early as Friday morning, specific action to issue warnings was keyed by reports of excessive rainfall from stations (such as Crown King, Junipine and Baker Butte) that are not in the regular reporting network. The probability is high that additional reports, from observers or automatic sensors in key locations throughout the area, would have prompted an

**Table 2. Regular reporting stations for Arizona**

A. Hourly reporting stations (precipitation every 6 hours)

| Location | Observations schedule | Collection and transmission | | Remarks |
|---|---|---|---|---|
| | | Every hour | 6-hr. precip. | |
| Phoenix, Ariz. | 24 hours | Service A | Service C | National Weather Service |
| Flagstaff, Ariz. | " | " | " | " " " |
| Winslow, Ariz. | " | " | " | " " " |
| Tucson, Ariz. | " | " | " | " " " |
| Yuma, Ariz. | " | " | " | 6-hour precipitation 06Z sent on Service A. Combined NWS/FAA |
| Las Vegas, Nev. | " | " | " | National Weather Service |
| Needles, Calif. | " | " | Service A | Federal Aviation Admin. |
| Blythe, Calif. | " | " | " | " " " |
| Prescott, Ariz. | " | " | " | " " " |
| Douglas, Ariz. | " | " | " | " " " |
| Ft. Huachuca, Ariz. | " | " | " | Military |

B. Non-hourly reporting stations (essentially report precipitation every 24 hours)

| Location | Observations schedule | Collection and Transmission | Remarks |
|---|---|---|---|
| Payson, Ariz. | 7 observations 6 am–9 pm | Telephone to Phoenix for entry on Service A | * Contract observer. 24-hour precipitation at 8 am and 5 pm. |
| Show Low, Ariz. | 6 observations 8 am– 9 pm | " | " |
| Gila Bend, Ariz. | Every hour 8 am–5 pm | " | " |
| Safford, Ariz. | 5 observations | " | ** Cooperative observer. 24-hour precipitation at 8 am and 5 pm. |
| Grand Canyon, Ariz. | Every hour 6 am–8 pm | Airline circuit to Prescott FAA for entry on Service A | † Reports by airline. |
| | | Also telephone 4 reports to Phoenix for entry on Service C at selected synoptic times | 12- and 24-hour precipitation included. |

* These observers are paid for each observation taken.
** City of Safford.
† Supplementary Aviation Weather Reporting Station (SAWRS).

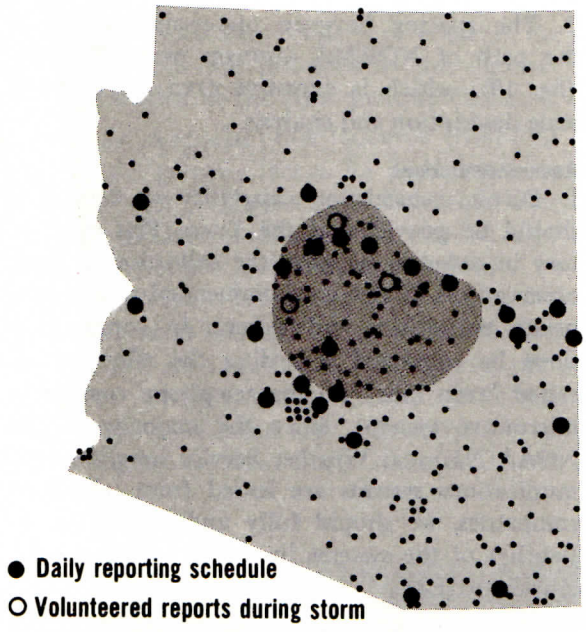



FIGURE 18. Cooperative substation network for Arizona.

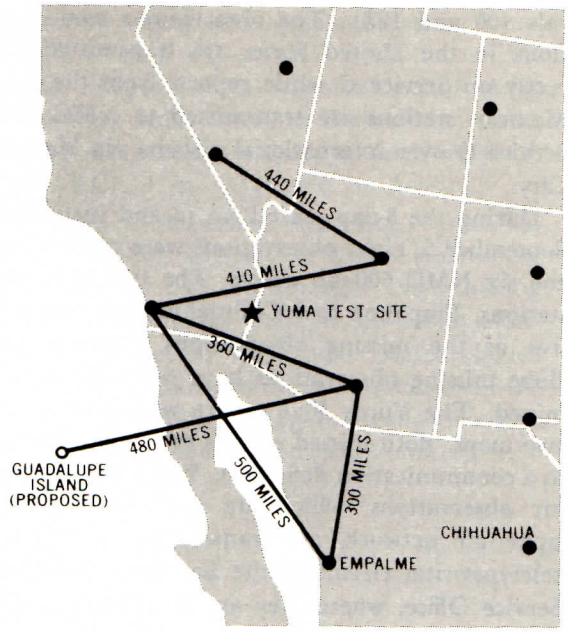



FIGURE 19. Upper-air observation stations for southwestern United States and northern Mexico.

earlier decision to elevate the potential for flooding to warning status. A surface network possessing the density and reliability to detect all flash floods in Arizona is impractical in terms of cost, availability of observers (particularly on weekends and holidays), and communications. However, widespread flash flooding of the scale associated with this storm could be detected by establishing a reasonable number of additional rainfall-reporting stations in key locations that would report whenever rainfall exceeded selected values, such as 0.5 or 1.0 inch.

2. The data collection and dissemination system is overly dependent on the use of manual telephone. For example, only one regular reporting part-time station (Payson) and six cooperative substations are located in the flash-flood area. These report to Flagstaff and Phoenix by telephone. Over two-thirds of the operational network reports for Arizona are collected manually by telephone. Both National Weather Service employees at Phoenix, and network observers, are pressed for time during critical weather situations. This time limitation is further aggravated by loss of reliability of rural telephone lines during heavy rain. A busy telephone line prevented the river-rainfall observer at Wickenburg from contacting Phoenix (and vice versa) on the day major flooding occurred.

**Recommendations**

1. Action should be initiated to establish additional reporting stations in key locations and to provide sufficient resources to keep the stations active during the critical flash-flood season.

2. Early action should be taken to provide communicators positions with the establishment of the WSFO at Phoenix. This will alleviate the data collection problem.

3. Although items 1 and 2 offer a reasonable short-term solution to the major flash-flood problem, it is the opinion of the survey team that the long-range solution will require the design and installation of a network of automatic sensors that can make data directly available to the River District Office through radio or satellite telemetry.

## UPPER-AIR OBSERVATIONS

The upper-air observation stations for southwestern United States and northern Mexico are spaced 180 to 500 miles apart (fig. 19) and are scheduled to take observations at 12-hour inter-

vals (00 and 12Z). The observations from stations in the United States are transmitted directly on Service C while reports from the two Mexican stations are transmitted to NMC and Service C over international circuits via Mexico City.

During the 3-day period up to and including September 5, eight observations were missing on the six NMC 500-mb charts. The two Mexican stations, Empalme and Chihuahua, account for five of the missing observations. Reasons for these missing observations have not been determined. The Yucca Flat report was missing on two maps. Both missed reports can be attributed to a communication deficiency. Yucca Flat upper-air observations, which are part of the U.S. upper-air network, are transmitted on a local teletypewriter circuit to the Las Vegas Weather Service Office, where they are manually relayed to Service C. One report, 051200Z, was transmitted as scheduled by Las Vegas WSO, but apparently was lost in the system between Las Vegas and NMC. The 041200Z report was logged as relayed to Las Vegas WSO by Yucca Flat, but the log at Las Vegas WSO did not indicate receipt; therefore, the status is unknown.

One other communication deficiency was noted on September 6 when the Winslow report for 00Z was missing on the NMC 500-mb chart. This observation time occurred during the peak time of heavy precipitation and flash flooding. Investigations revealed that longline communications (including Service C) were intermittent Saturday afternoon and early Saturday evening. The intermittent operation was due to the effect of heavy precipitation on the telephone company's microwave installation on Mt. Elden near Flagstaff. Telephone company representatives refer to the condition as "rain fade." Special note of this situation is made because similar interruptions in the Associated Press wire services were experienced as noted elsewhere in the report.

**Findings**

1. The upper-air network and collection system functioned normally throughout the storm period except for some communications difficulties —the overly complex transmission arrangements at Yucca Flat and the apparent vulnerability of microwave longline services to weather conditions.

2. The spacing between upper-air stations in the path of NORMA averages over 400 miles (fig. 19), which is excessive even for synoptic scale description and analysis.

**Recommendations**

1. Direct transmission capability on Service C should be provided at the Yucca Flat observatory in order to improve the collection of their observations. It also is recommended that appropriate authorities and experts in communications be contacted regarding the effect of so-called "rain fade" on the telephone company's microwave systems. Since the majority of the NOAA National Weather Service longline communications systems are leased from telephone companies, we should fully understand the reliability of the systems insofar as microwave facilities are used.

2. National Weather Service Headquarters should proceed as rapidly as possible with present plans to establish an upper-air station on Guadalupe Island.

3. NOAA should seek the cooperation of the Department of the Army in establishing a regular network program at their Yuma test site. The Department of the Army makes upper-air observations in support of research projects at a test site 25 miles northeast of Yuma, Ariz. Present arrangements exist between the Meteorologist-in-Charge at Yuma and the Commanding Officer of the test site for one observation per day, when available and at the discretion of the test site, to be telephoned to Yuma for local use and transmission on Service C. Regular observations from this site would fill a significant "hole" in the network.

## RADAR WEATHER OBSERVATIONS

Radar weather observation coverage for Arizona is provided through joint NOAA/FAA Air Route Traffic Control (ARTC) radar surveillance programs, which are described in detail in *ESSA Technical Memorandum WBTM-WR-35*, December 1968. In brief, radar weather data are extracted from the several scopes in the Albuquerque and Palmdale ARTC Centers by National Weather Service radar observers and disseminated via facsimile, teletypewriter, and/or telephone. Radar coverage for Arizona is shown

in figure 20. Note that primary coverage of the major flood area was provided by the Phoenix Radar controlled at the Albuquerque Center.

*Facsimile*: A special radar facsimile (RAFAX) circuit is the primary means for data communication for each ARTC Center. Weather echo data from the several radars in each ARTC Center are composited and transmitted hourly on RAFAX to WSFOs (including ABQ) for immediate operational use and to the Salt Lake City ARTC Unit. At Salt Lake City, regional composites are prepared and transmitted to the Radar Unit at Kansas City (RADU) for inclusion on the national radar summary charts.

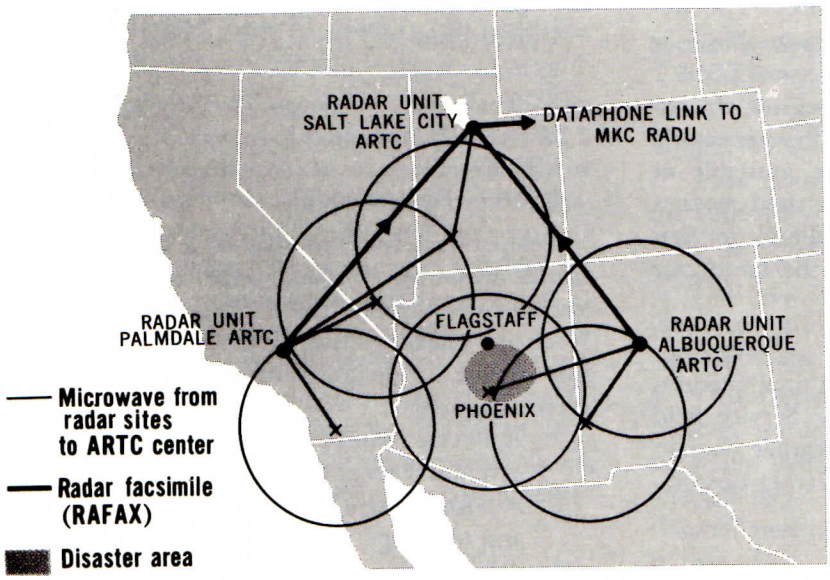



**FIGURE 20. Combined FAA Air Route Traffic Control (ARTC) and NOAA radar weather coverage for Arizona. Regional composites are prepared at Salt Lake City and transmitted to Kansas City Radar Analysis and Development Unit (MKC RADU) where they are included on national radar summary charts.**

These are transmitted 14 times per day on National Facsimile (NAFAX). WSFOs can request special overlays and data over the RAFAX system during critical weather situations. NAFAX is available at all WFOs in Arizona (including Phoenix and Flagstaff); RAFAX is not. RAFAX and RAWARC are planned for all major WSFOs. Funds were requested in the 1971 budget to upgrade the Phoenix WSO to WSFO status.

*Teletypewriter*: Composite radar messages (SD-1) are prepared at Kansas City (MKC) RADU in code form and transmitted over Service A whenever moderate or heavy precipitation is indicated. SD-1 coded radar messages are based on the actual radar graphics that are transmitted over RAFAX to MKC from the ARTC Centers, through the regional compositing center at Salt Lake City. The Radar Report and Warning Coordination teletypewriter network (RAWARC) is not available in Arizona.

*Telephone*: Telephone capability is provided for direct contact with WFOs, RDOs, and WSOs, and is utilized for coordination when issuing alerts or warnings. For example, on Friday afternoon, September 4, the Radar Meteorologist, Western Region, alerted the Albuquerque Radar Unit through Southern Region Headquarters to the potential of the Arizona situation. At 4:30 a.m. Saturday, September 5, ABQ radar called Flagstaff in regard to heavy precipitation echoes south of Flagstaff. Flagstaff in turn discussed the radar intelligence with Phoenix WSO, and it was included in a local release at Flagstaff and in the Arizona Summary prepared by Phoenix at 5:30 a.m.

### Findings

1. The operational system for providing radar support during the storm functioned normally. However, full utilization of radar support was not realized for two reasons: (a) The operational system does not provide radar data in the most usable form (RAFAX) to Arizona WSOs;

and (b) All field personnel have not been fully trained in the techniques and procedures for an application of radar data to flash-flood potential.

#### Recommendations

1. Budget items to provide both RAFAX and RAWARC at Phoenix WSFO should be given high priority in the next few months.

2. Greater stress should be given to the training of all National Weather Service field employees in the application of radar data to operational problems.

### SATELLITE OBSERVATIONS

Satellite weather data for the Arizona area are available at Phoenix once each day in the form of digitized mosaics that are transmitted over the National Facsimile Circuit (NAFAX). The mosaic that is transmitted at 9:20 p.m. MST is based on data from the 3:00 p.m. pass of ITOS 1 (Improved Tiros Operational Satellite). In addition, real-time pictures from the Automatic Picture Transmission (APT) are available at the Albuquerque WSFO. The digitized mosaics and APT together provide an excellent overview of cloud coverage and reinforce the large-scale weather analysis.

#### Findings

1. Both more frequent and real-time pictures are needed by National Weather Service field offices to better relate satellite weather data to radar weather data and surface weather observations.

#### Recommendations

1. Efforts should be continued to develop and incorporate satellite weather data into the present data system as recommended in *The Virginia Floods, August 19-22, 1969*, A Report to the Administrator, Environmental Science Services Administration, U.S. Department of Commerce, September 1969.

### COMMUNICATIONS SYSTEMS

Meteorological and hydrological data and information are collected and disseminated over a variety of communications systems, including teletypewriters, telephone, facsimile, and radio. The following systems are in use in Arizona and at the Weather Service Offices nearest the flood area—Phoenix, Flagstaff, and Winslow.

Teletypewriter Services A and C and National Facsimile Service (NAFAX) are available in all three offices for the exchange of basic data and guidance material in support of all NOAA Weather Service functions. Flagstaff receives but does not transmit on Service C. Communications systems in use at each of the three offices are described.

*Phoenix WSO*: A local NOAA Weather Wire Service teletypewriter system serves the 12 subscribers listed below:

Arizona Public Service (gas company)
Arizona Automobile Association
Salt River Project (water district)
State Department of Civil Defense
*Arizona Highway Patrol
Republic and Gazette (Associated Press)
United Press (UPI)
KOOL—Radio and TV
KOY—Radio
**KTAR—Radio and TV
KTVK—TV
KPHO—Radio and TV

Telephone service consists of a 20-line automatic answering system, three manually answered lines through the FTS Centrex, and the National Warning System (NAWAS). The 20-line system is designed to provide service in three categories:

1. A 10-line system for the Phoenix local forecast and current data.
2. A 5-line system for Arizona State forecasts and warnings.
3. A 5-line system for Arizona current weather summary.

Of the three FTS lines, two are unlisted—one for mass media use and one for data collection—and the third line is listed and used primarily for administration. The NAWAS system links the Phoenix WSO with 31 public offices throughout the State, including County Sheriffs, Civil Defense Offices, and the Department of Public Safety.

*Flagstaff WSO*: There is one local telephone line with FTS access 5 days per week (8 a.m. to

* Transmits highway information to all subscribers.
** Operates the Arizona Broadcasters System for servicing affiliates throughout Arizona that do not have press wire service.

5 p.m.) through the Veterans Administration switchboard. Direct radio broadcasts are made over two stations, KCLS and KCYN, three times per day—at 7:10 a.m., 12:10 p.m., and 5:10 p.m. KCLS is an NBC affiliate; KCYN is nonaffiliated.

*Winslow WSO*: There is one local telephone line for all purposes. Direct radio broadcasts are made over radio station KINO at 7:45 a.m. (7 days per week), 12:10 p.m. (5 days per week), 5:55 p.m. (6 days per week, recorded at 3:15 p.m.) and 9:30 p.m. (7 days per week).

#### Findings

The communications systems exhibited several deficiencies during the storm period. For the most part, these deficiencies were mentioned in the previous discussions of data collection. They are summarized here to identify the need for remedial action.

1. The telephone company long-line service to northern and eastern Arizona is dependent on a microwave installation, on Mt. Elden north of Flagstaff, that is vulnerable to heavy precipitation and strong winds. During the afternoon of September 5, intermittent outages occurred in the following: teletypewriter Services A and C and NAFAX at Flagstaff and Winslow; Associated Press wire service at radio station KVWM, Show Low; and the telephone line at Flagstaff, which was out for 35 minutes (12:40 to 1:15 p.m.). A Service C outage at Winslow prevented transmission of their 0600Z upper-air observation.

2. The single telephone lines serving Weather Service Offices at Flagstaff and Winslow are inadequate for the necessary coordination calls during storm periods. The WSFO at Albuquerque, including the Radar Unit, and the WSO at Phoenix experienced difficulty getting through with radar and warning coordination calls.

3. Over two-thirds of the surface observations in Arizona are collected manually by telephone. This is particularly true at Phoenix, where the economy of the Federal Telecommunications System (FTS) and NAWAS has encouraged the establishment of a manually collected system that taxes the local staff capability during critical weather. The collected data are all essential, but are not sufficient for flash-flood type events. The overall solution is not readily apparent.

4. Maximum utilization of radar data during the storm period was hampered by the lack of a drop on the radar facsimile circuit (RAFAX) and RAWARC.

#### Recommendations

The Disaster Survey Team, from its review of deficiencies in communications systems during the storm period, recommends:

1. That Western Region Headquarters review the reliability of leased-line services as they involve microwave transmission;

2. That the Flagstaff and Winslow WSOs be provided unlisted telephone lines for forecast and warning coordination;

3. That further review of data requirements in Arizona consider (a) including a modern data collection system (with telemetered data from selected sites) and (b) establishing a communications position to perform data collection duties; and

4. That National Weather Service, and the Regional Headquarters, in establishing the Phoenix WSFO, give high priority to communications support (RAFAX, RAWARC, and positions).

forecasts and statements indicated possible flash floods.

The early morning forecasts on Saturday September 5 indicated a decrease in showers and thundershowers; however, radar reports, and observer reports from small communities in Arizona, led to continuation of the flash-flood potential statements by Phoenix. These statements also included a caution note that people in campers and trailers should be alert to the risk of flooding in normally dry canyons and desert washes. In addition, the local forecast issued by the Flagstaff WSO and broadcast over three local radio stations called for "Cloudy with rain locally heavy at times and occasional thunderstorms through Sunday . . ."

As additional data were received by the Phoenix and Flagstaff WSOs, the forecasts and statements were worded in a more ominous fashion.

At 12:10 p.m. Sunday, Flagstaff issued a direct radio broadcast warning for motorists to restrict travel and seek high ground. This was relayed by telephone to the U.S. Forest Service, County Sheriff, County Civil Defense office, and the three local radio stations.

At 2 p.m. Phoenix issued a flash-flood warning for Maricopa, Yavapai, Gila, and Coconino Counties. It was distributed immediately via NWWS and individual telephone calls to State officials and radio stations in the critical area. This warning served as the stimulus for action throughout the central and northern part of the State. For example, the Duty Officer at the Department of Public Safety (DPS) called in the Commander and his entire staff, and their communications center was augmented by 8 additional communicators. Additional highway patrolmen were dispatched into the critical area. The staff at the Department of Public Safety stated that, from their viewpoint, the forecasts, warnings, and other weather and river information relayed to them by the Weather Bureau were invaluable. They stated that messages were timely and easily understood. At the county level, the flash-flood warning was acted upon in a very positive manner by most county sheriffs and county Civil Defense officials. In Yavapai County, deputies were sent into all sections of the county to warn people who were in or close to streams and washes. However, some key local officials in one very critical area did not receive the warning as it passed through State and county communication channels.

It was difficult, because of lack of internal Weather Service communications and because of extremely high local workloads, to coordinate warnings between the Arizona WSOs and the Albuquerque WSFO. This lack of communications made it necessary for each WSO to operate almost independently.

The warnings were transmitted by UPI and AP to all local radio stations in each network, and by Radio KTAR (the prime network station of the Arizona Broadcasting System) to stations of that network. Thus many radio stations received the warning from their affiliated network as well as by telephone from a WSO. Most radio stations responded to the emergency by broadcasting the warnings, forecasts, and related information at frequent intervals.

**FINDINGS**

1. The dissemination of weather statements and warnings pertaining to heavy rain and flooding was quite complete and timely.

2. In addition to distributing the written, formal warnings, both Phoenix and Flagstaff WSOs made special telephone contacts with officials who were responsible for emergency actions in their areas.

3. Actions to provide aid and rescue services to flooded areas were taken, and in several cases were initiated, as a result of the statements and warnings issued by the Phoenix and Flagstaff WSOs.

4. Most radio stations broadcast available statements and warnings promptly.

**RECOMMENDATIONS**

1. Better means of communications, such as the NOAA Weather Wire Service, should be established between the WSOs in Arizona, and with the WSFO.

## CHAPTER 6

# Service Benefits

For many outdoor recreationists and their families Labor Day weekend represents the last 3-day camping holiday of the season. The disaster area, the central mountain section of Arizona, is a camper's paradise. Four National Forests, the Prescott, Coconino, Tonto, and Sitgreaves, have numerous campgrounds. There also are many private camp sites. Summer homes abound in the wooded areas and along creeks. Within the disaster area, there are camping accommodations for thousands of people using trailers, campers, tents, or cabins for their overnight excursions. Typically, on 3-day weekend holidays, when weather is favorable, campgrounds are filled to overflowing by Friday night or Saturday morning. Although the weather in central Arizona on Friday, September 4, was unsettled and wet in some areas, it was not generally unpleasant in the afternoon and evening. However, campers did not turn out in expected numbers for the Labor Day holiday. Campground-use figures tabulated at our request by the recreation staff of the National Forests showed that the early Labor Day weekend use, while varying from place to place, was only about 65 percent of capacity. Large numbers of campers stayed home. Among the contributing reasons were the early warnings of impending heavy rain and very high potential for flash floods—issued on Friday September 4. The weather forecasts, summaries, and broadcasts from the Phoenix and Flagstaff Weather Service Offices on Friday, September 4, heralded a wet weekend, and a potentially very dangerous one weatherwise, for traveler and outdoorsman.

In an interview between a member of the survey team and Mr. Harold Harper, staff recreation official for the Sitgreaves National Forest, Mr. Harper stated:

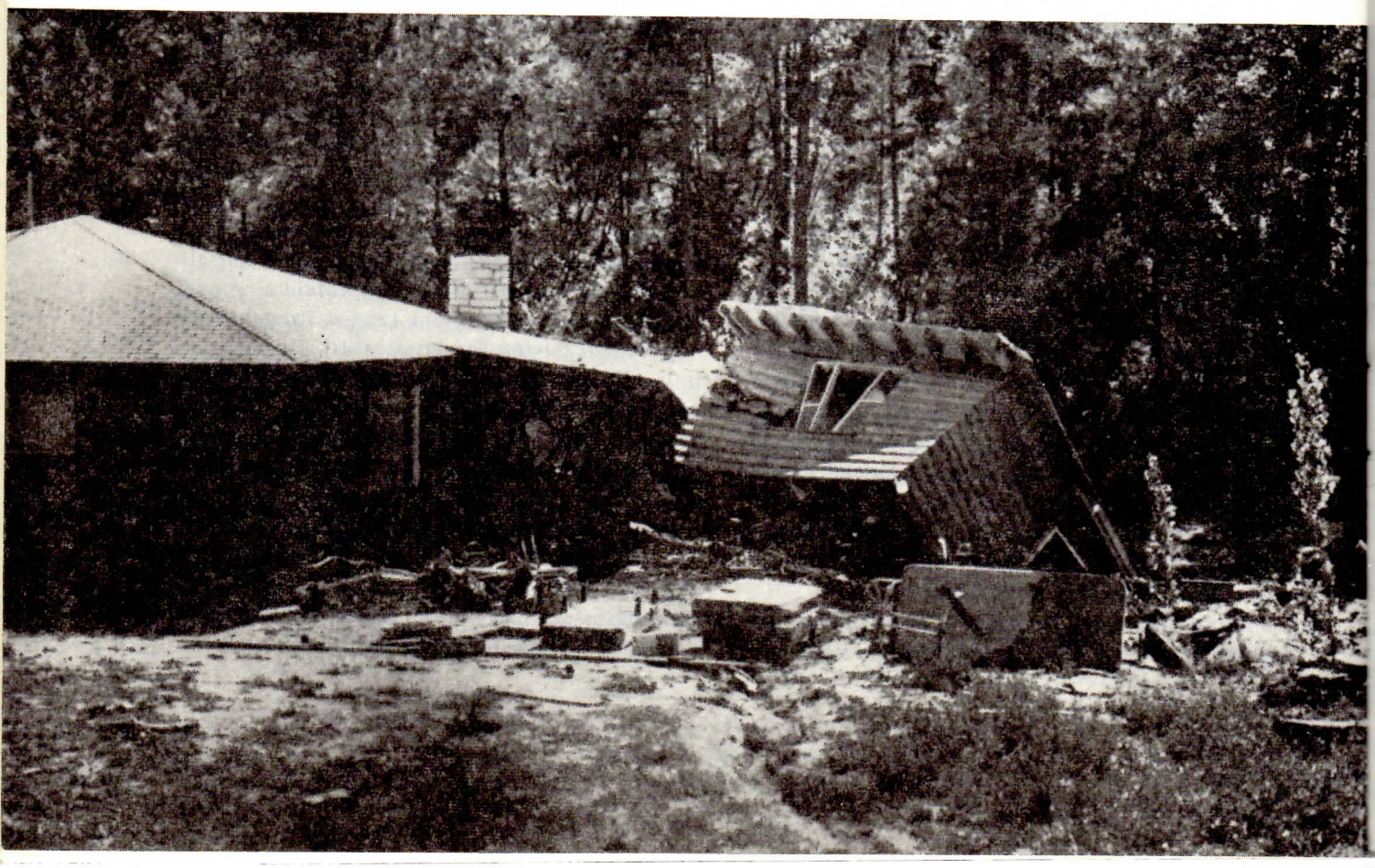
> "It was indeed fortunate that our campgrounds were not filled to overflowing as is the usual case at the start of the Labor Day weekend. During overcrowding, when improved campsites are filled, campers spread out into areas along creeks where flooding is a much greater hazard than in our established campgrounds. Unquestionably the absence of scattered camps in marginal safety areas made rescue operations during the flooding easier and in all likelihood lessened the loss of life."

Rescue operations in the disaster area were carried out by public and law officials, aided by volunteer rescue organizations. According to Ron McDaniel, Deputy Sheriff at Payson, there were 350 persons engaged in the search for dead or missing in the Tonto Creek drainage area after the flooding. The body of one flood victim was not discovered until a week after the tragedy.

Awareness of the Saturday afternoon flood warnings by law enforcement and other officials (in the disaster area) who were conducting and planning rescue operations ranged from having no word to having the latest word. In one case it is not certain that the county sheriff's office relayed the 2 p.m. flood warning to the appropriate deputy's office which was located in the center of the area where flooding was most serious.

Recreation staff and district rangers who supervise campground areas in the National Forests were, in many cases, not aware of the flood warnings issued early in the afternoon. The communications link to many of those who were

Kohl's Ranch area; upper Tonto Creek near junction of Horton Creek.



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"on the scene" and engaged in rescue work, and those who were about to be engaged in rescue work, could have been more effective. A notable exception was the Department of Public Safety (highway patrol). The following quotation is from a report by Lt. G. Blair, Communications Officer, of the Arizona Department of Public Safety, Phoenix, to Major J. W. Monschein of the same organization:

"1. The Phoenix office of the Department of Public Safety received a communication from the Phoenix Weather Bureau at 1355 hours on September 5th, 1970. The message arrived over the DPS Weather Wire terminal and advised of a possible flood in the Verde Valley, Oak Creek, Beaver Creek, Cottonwood, Cornville, Camp Verde, and Sedona areas. The DPS responded by originating an all points bulletin (APB) advising local jurisdictions of the hazard. The weather wire warning was cited word-for-word in the APB. There was response time of 13 minutes associated with the APB.

"2. An addendum to the APB was sent 19 minutes later and advised all Arizona Police Agencies of the possibility of flash floods in Maricopa, Yavapai, Coconino, and Gila counties.

"3. These two messages spelled out the possible scope of the storm, and accurately predicted the geographic areas that would be hardest hit. Undoubtedly, this warning allowed local authorities to issue community warnings, to alert and mobilize rescue personnel, and to warn potential travelers away from danger areas. Lives were saved."

Actions taken by individuals outside of the National Weather Service to warn of the serious conditions that existed were commendable. At the height of the flooding in the eastern portion of the disaster area, the following warning was issued by an official of the Sitgreaves National Forest, Holbrook, Ariz., after telephoning the Winslow WSO about 8 p.m., September 5, and discussing the weather forecast with Mrs. Kennedy who was on duty that evening. This emergency report, at 8:30 p.m., was telephoned direct to seven radio stations, one each in Show Low and Winslow, two in Flagstaff, and three in Phoenix:

"Emergency Report on Flood Conditions from the Sitgreaves National Forest. Over 5 inches of rain in the vicinity of the Rim Lakes has flooded many road areas including portions of State Highway 260. Portions of the Rim Road leading to Woods Canyon Lake have been washed out. Forest officers are in the field assisting recreationists who might be experiencing difficulties. Persons planning to travel to the Rim Country are urged to defer their plans in that direction. All persons in the area hearing this newscast are asked to stay in place. Flood waters from the heavy showers are expected to recede soon. Weather forecasts indicate possibility of continuing showers for the next 24 hours, but lessening thereafter."

**FINDINGS**

1. Caution warnings concerning high flash-flood and heavy rain potential for the Labor Day weekend deterred many from spending an outdoor weekend in the disaster area.

2. Lack of crowding in the campground areas of central Arizona probably was a factor in minimizing loss of life during the floods.

3. Flood warnings were not uniformly received by all "on-the-scene" officials who were engaged in rescue operations, especially many of the Forest Service recreation and District Ranger staff.

4. Recreation staff at the Heaquarters of Prescott, Tonto, and Sitgreaves National Forests all enthusiastically advocated a closer working relationship with the National Weather Service to alert them to severe weather and flood events.

**RECOMMENDATIONS**

1. A better and more direct means should be developed to relay severe weather warnings to U.S. Forest Service staff who are on duty in outdoor recreation areas, or who live in those areas.

Flood debris along Tonto Creek near Kohl's Ranch. (Courtesy Ed Wiggins, ***The Mesa Tribune***, Mesa, Ariz.)

Kohl's
Mesa

## APPENDIX A

# Chronology of Forecasts, Statements, and Warnings

Zone forecasts for Arizona are issued every 6 hours by the Albuquerque, N. Mex., Weather Service Forecast Office. For distribution to Arizona news media and the public, these forecasts are retransmitted on the NOAA Weather Wire by Phoenix WSO. In addition, every 3 hours the Phoenix WSO prepares and transmits an Arizona Weather Summary on the NOAA Weather Wire to provide the latest weather news of interest and significance to the news media and the public. (The weather summaries issued by Phoenix WSO are not included in the chronology of forecasts, statements, and warnings, because they are not considered part of the warning system. However, their value in "setting the stage" for a wet weekend in Arizona was significant and they are quoted in part throughout the report.) Frequently AP and UPI writers prepare their own weather-news stories from the total information available to them. One such story, released at 11:54 a.m. MST on September 4 is included in the listing because it highlighted the flash-flood potential for the Labor Day weekend in the State and contributed to the effectiveness of official National Weather Service (formerly Weather Bureau) forecasts and statements. Local forecasts for Flagstaff and Phoenix are included because heavy rain and flash floods occurred Saturday, September 5, in and near both cities.

**September 4, 1970**

0900 MST*—Flagstaff and vicinity: Considerable cloudiness with showers or thundershowers, some heavy, through Saturday.

1000—North Central Mountains, Mogollon Rim, and White Mountains: . . . Thundershowers . . . flash flood potential high . . . Occasional showers and thunderstorms, locally heavy today and early tonight. Decreasing clouds and showers later tonight. Partly cloudy with scattered afternoon and evening thundershowers on Saturday. Cooler today.

1000—Greater Phoenix area: Considerable cloudiness today with some periods of sunshine and cooler. Showers and thundershowers in the area. Variable cloudiness tonight and Saturday with chance for thundershowers.

1154—Weather Story on UPI Wire (from 8 and 11 a.m. Phoenix Weather Summaries): A rainy Labor Day weekend appears to be in store for most of Arizona. The Weather Bureau says tropical moisture is still feeding into the State from the Gulf of California and locally heavy rains have been reported from numerous stations this morning. Tucson accumulated 1.12 inches in the past 24 hours. In the Phoenix area, precipitation during the night

* Mountain Standard Time is used throughout appendix A.

and early morning hours ranged from more than an inch in the western portion of the valley to 0.30 of an inch at the airport. The Weather Bureau said the outlook is for continued heavy cloudiness and intermittent showers throughout the State at least through Saturday. Locally heavy rains can be expected in all mountain regions, and travelers were alerted to be on the watch for flash flooding in highway dips and desert washes. Temperatures around the State have been much cooler today because of the cloud cover and rains. Little change in temperature pattern is expected until Sunday. HT1154AMST 9/4 . . .

1600—North Central Mountains, Mogollon Rim, and White Mountains: . . . Thundershowers . . . flash flood potential high . . . General rainfall tonight with heavy rain accumulations. Clouds and rainfall diminishing Saturday and Sunday with warmer days.

1600—Greater Phoenix area: Mostly cloudy tonight becoming partly cloudy Saturday. Showers and thundershowers in the area through Saturday. Sunday mostly fair and a little warmer.

1700—Flagstaff and vicinity: Considerable cloudiness with showers and thundershowers, some heavy, through Saturday.

2100—Greates Phoenix area: Partly cloudy tonight and Saturday with showers in the area. Mostly sunny and a little warmer Sunday.

2200—North Central Mountains, Mogollon Rim, and White Mountains: . . . flash flood potential high . . . Scattered showers tonight. Scattered showers and thundershowers again Saturday decreasing Sunday. Rising daytime temperatures.

**September 5, 1970**

0400—Greater Phoenix area: Cloudy with occasional showers through mid-morning. Partly cloudy by afternoon with chance for thundershowers today and tonight. Showers and clouds decreasing on Sunday. Warmer daytime temperatures.

0430—North Central Mountains, Mogollon Rim, and White Mountains: Considerable cloudiness with scattered showers and thundershowers today and tonight. Showers and clouds decreasing on Sunday. Warmer daytime temperatures.

0500—Flagstaff and vicinity: Mostly cloudy with showers and occasional thunderstorms through Sunday.

0700—Greater Phoenix area: Intermittent rain this morning. Partial clearing this afternoon but showers and thunderstorms likely by late afternoon or evening. Possible heavy rainfall today. Decreasing cloudiness and shower activity tonight and Sunday with considerable sunshine and warmer Sunday.

0900—Flagstaff and vicinity: Cloudy with rain locally heavy at times and occasional thunderstorms through Sunday.

0900—Greater Phoenix area: Shower alternating with periods of sunshine this afternoon. Chance for a thunderstorm by late afternoon. Risk of heavy rainfall. Showers gradually diminishing tonight becoming mostly sunny and warmer by Sunday.

1000—North Central Mountains, Mogollon Rim, and White Mountains: . . . flash flood potential high. . . . Considerable cloudiness with occasional showers and thunderstorms locally heavy this afternoon and early tonight. Locally windy this afternoon. Showers and cloudiness decreasing later tonight. Partly cloudy breezy and continued cool Sunday with scattered afternoon thunderstorms.

—Telephone alerts by Flagstaff WSO:

1000—(a) Local office of Arizona Highway Patrol, indicated continued heavy rain expected. Requested reports available to AHP.

1015—(b) Coconino County Sheriff's Office, indicated continued heavy rain expected.

1100—(c) County Civil Defense Director, telephoned at his home to relay concern about excessive rains and flooding.

1210—Direct radio broadcast by Flagstaff WSO via local stations: For the last 24 to 36 hours moisture has been moving into Arizona from Mexico. Remnants of a tropical storm off lower California have supplied lots of moisture. Rain has been falling over the State all morning. Conditions are not getting any better. Holiday travelers will do well to stay where you are or seek high ground. The heavy rain has not yet arrived. So many times we are warning of flash floods, but this is even worse. Motorists, restrict your travel, get off the highways. Secondary roads will be impassable for travel.

1230—Flagstaff: Telephone line out; after 1315 intermittent service restored.

1400—Flood Warning by Phoenix RDO—effective immediately until 10 p.m. for Verde Valley and Oak Creek, Beaver Creek area, Cottonwood, Cornville, Camp Verde and Sedona area.

Continued heavy rains over the Oak Creek and Sycamore Creek Basins and Beaver Creek Basin have caused flooding on these streams. Oak Creek is running almost up to the base of the bridge at Sedona and still rising.

Several crests are likely on the Verde from each of these streams this evening and tonight. At present it is not possible to determine the exact timing or height of each crest.

All interests along the Verde from Cottonwood to Camp Verde and on its tributaries in this area should expect the river to rise during the evening and night . . . probably above flood stage.

All interests should listen for later warnings and bulletins.

1400—Flood Warning by Flagstaff WSO:

—Flood Warning for Coconino County effective 1400: Flooding expected all drainages in Coconino County. All streams rising rapidly. Two to five inches rain received so far, at least one more expected this afternoon. Heavy runoff continuing 12 to 18 hours.

1420—Flash Flood Warning by Phoenix RDO, effective now until 10 p.m. for Maricopa County, Yavapai County, Coconino County, and Gila County.

Continued heavy rains over these counties have caused extensive runoff into streams and washes. More heavy rains are forecast for this evening and further rises may take place tonight.

Many dips and unbridged river crossings have become very dangerous due to high water, and some have become impassible. Also highways have been littered with debris and mud.

A flood warning is in effect for the Verde Valley, Sedona area due to flooding in the main streams accumulating from flash flooding of the tributaries and side washes. Other rivers in the state will probably not reach flood stage, but will have an appreciable rise in runoff tonight and Sunday.

Motorists should not attempt to cross flooded streams or highway dips, and all interests along major streams should listen for later warnings and advices.

1530—Flood Warning from Phoenix RDO: Heavy rains in the Bradshaws and in the vicinity of Cordes Junction will cause the Aqua Fria River to rise rapidly. Persons in the Black Canyon area should be alert to this danger. . .

Heavy rains also are occurring in the headwaters of New River and will cause the stream to rise rapidly. All interests should be alert to this danger.

1600—North Central Mountains, Mogollon Rim, and White Mountains: . . . flash flood potential continues very high. . . . Heavy rainfall rim section eastward tonight mainly southern slopes. Decreasing cloudiness and turning colder north-central tonight. Partly cloudy Sunday with showers decreasing and mainly in eastern section. Monday clearing and warmer.

1600—Greater Phoenix area: Intermittent showers, a few locally heavy, tonight. Partly cloudy Sunday with showers again developing. Fair and warmer Monday.

1700—Flagstaff and vicinity: Cloudy with rain, locally heavy at times, and occasional thunderstorms through Sunday.

1830—Flood Warning by Phoenix RDO: Flood warnings are issued for the Hassayampa River from Wickenburg south to the Gila River. Heavy rains above Wickenburg in the Bradshaws and persistent locally heavy rains south of Wickenburg will bring rapidly rising waters along this part of the river. All interests should be alert to this danger.

1840—Food Warning by Phoenix RDO—Flash Flood Warning for Pinal County: Heavy rains are causing extensive runoff throughout central Arizona into streams and washes. More heavy rains are forecast for tonight. Highway dips may become dangerous due to the high water and some roads may become impassible. This warning should remain in effect throughout the night.

Oak Creek Canyon area. (Courtesy *The Arizona Sun*, Flagstaff, Ariz.)

*The*

## APPENDIX B

# Summary of Disaster Survey Team Visits

This summary lists the news media, emergency service, civil defense, and other organizations personally visited by Lloyd H. Magar, Harry L. Elser, and A. L. Zimmerman of the field survey team. Most of these contacts were made on September 9, 10, and 11, 1970.

**Phoenix**

1. Arizona Department of Public Safety (Highway Patrol)
2. Arizona Department of Civil Defense and Emergency Planning
3. Associated Press
4. United Press International
5. KTAR TV/AM/FM (Prime Network Station For Arizona Broadcasting System)
6. KOOL TV/AM/FM
7. KPHO Radio
8. The Arizona Republic (daily newspaper)
9. USFS Tonto National Forest Headquarters
10. USGS Phoenix Subdistrict Office
11. Salt River Project Office

**Prescott**

1. Mayor
2. City Manager
3. Chief of Police
4. County Department of Emergency Services, Yavapai
5. KYCA Radio
6. KENT Radio
7. USFS Prescott National Forest Headquarters

**Flagstaff**

1. County Civil Defense Director, Coconino
2. Deputy Sheriff's Office
3. KAFF Radio
4. KEOS Radio
5. KCLS Radio

**Holbrook**

1. County Civil Defense Director, Navajo
2. City Manager
3. City Police Department
4. USFS Sitgreaves National Forest Headquarters
5. KDJI Radio

**Globe**

1. KIKO Radio
2. Sheriff's Office

**Show Low**

1. City Police Department
2. KVWM Radio

**Winslow**

1. City Civil Defense Director

**Cottonwood**

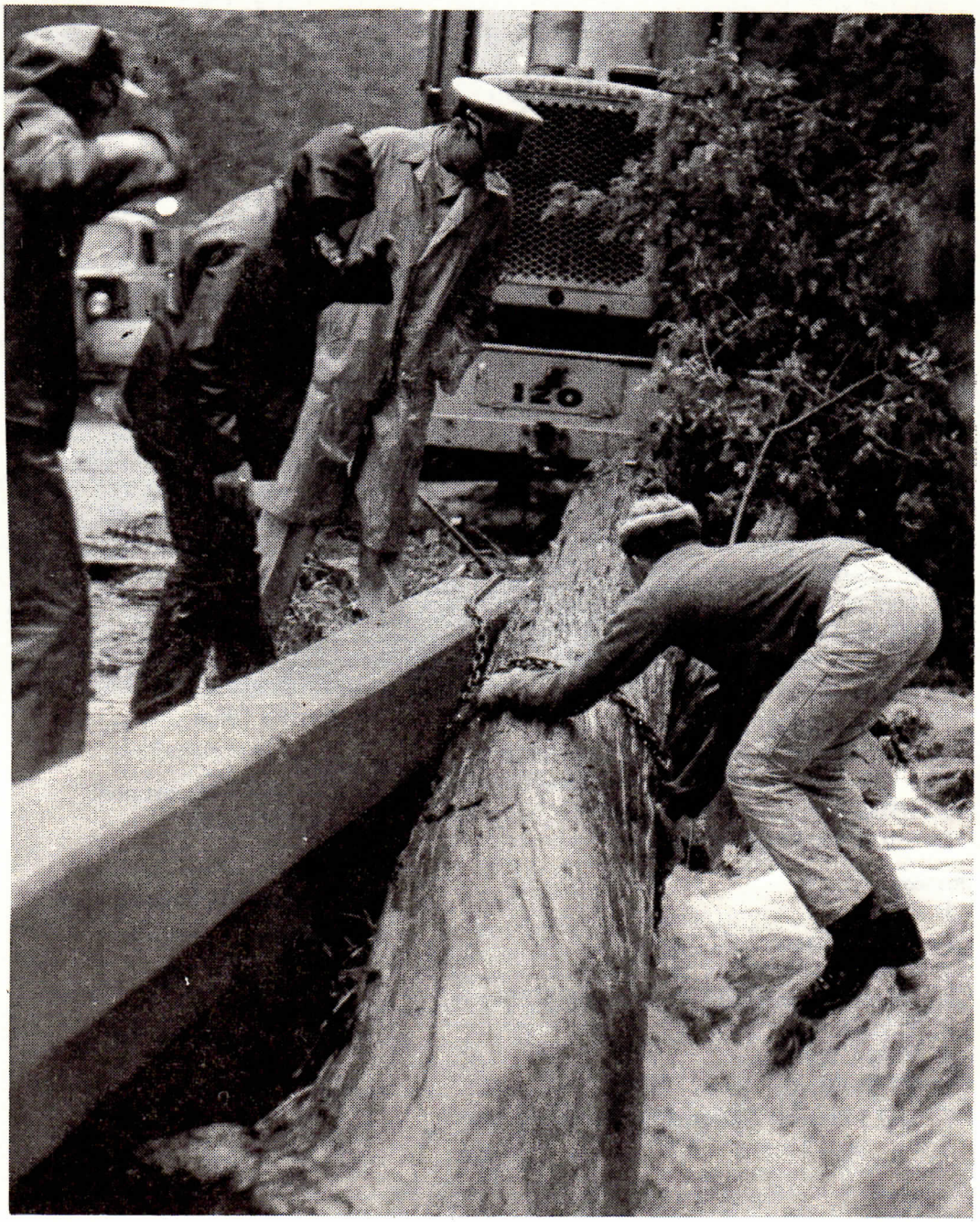
1. KVIO Radio

**Sedona**

1. USFS Ranger Station

**Payson**

1. Deputy Sheriff's Office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Oak Creek Canyon area. (Courtesy *The Arizona Sun*, Flagstaff, Ariz.)



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