NOAA Technical Memorandum NWS WR-100

A STUDY OF FLASH-FLOOD OCCURRENCES AT A SITE VERSUS OVER A FORECAST ZONE

Gerald Williams

Western Region Headquarters
Hydrology Division
Salt Lake City, Utah
August 1975

UNITED STATES
DEPARTMENT OF COMMERCE
Rogers C. B. Morton, Secretary /
NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator /
NATIONAL WEATHER
SERVICE
George P. Cressman, Director

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I. INTRODUCTION

A flash flood is a flood in which the rapid rise in stream level and the resulting inundation follows the observable causative event by about four hours or less. For rain-caused flash floods meteorology is complex, and limited amounts of real-time data make timely forecasts of exact location very difficult. Lack of reports of flash-flood occurrences adds to the difficulty. Many occur that are never reported to the National Weather Service (NWS).

This report describes some relations between probability of point rainfall amounts and probability of the same amounts falling some place within an area; i.e., point probability vs. areal probability. Analogously, the relationship between probability of flash-flood occurrences at sites and the probability of flash-flood occurrences somewhere within a forecast zone are also developed. Hopefully, this information will be useful in acquainting ourselves with some of the vagaries of compiling information to relate meteorologic data to observed flash floods.

II. THE PROBLEM

A 100-year point rainfall event in the West, at least 2.5 inches within 30 minutes, is unusual and spectacular. Because it is rare, techniques to forecast and design for it are limited. However, it is possible to enlarge the data base for these rare events by considering a large area rather than a single location. A rare event will occur many times more often over a 100-square-mile area than in one-square-mile area. In this paper we will be considering unusually heavy rainfall of short duration from convective activity and its closely related partner, flash floods.

The task of obtaining data on extreme rainfall and flash-flood events is compounded by the sparsity of observations in the flood-prone areas of the West. For example, in central Utah during the week of August 5, 1974, five flash floods occurred but were not reported to any NWS forecast offices. Others may have occurred but were not reported.

Another problem is the erratic nature of extreme rainfall. Schmidli [1] reports that the maximum recorded hourly precipitation for Arizona is 3.52 inches at Tempe Citrus Experiment Station, just a few miles from Phoenix; the highest ever measured at Phoenix Weather Service Forecast Office was 1.72 inches--less than half as much. Is this a valid difference? Or will Phoenix some day equal or exceed the record? During the "summer monsoon" in Arizona, flash floods occur nearly every day, but usually at different places. Can the places that have been spared so far be considered safe for the future? Not likely. Some locations are naturally more susceptible to flash floods than others, but each new storm brings a new combination of meteorological factors to bear on the various local exposures.

III. ESTIMATING VALUES FOR AN EXTREME EVENT

A 100-year point rainfall amount is only an estimate, the reason being that there are no adequate samplings of these extreme amounts and correct determination of return intervals. However, estimates of values for 100-year events have been made. For example, in southern Arizona evidence indicates that the 100-year, 1/2-hour point rainfall depth is near 2.50 inches. Osborn [2] used WBTP-40 [3] procedures to estimate this value for the following stations: Casa Grande 2.25 inches, Tucson 2.5 inches, and Tombstone 2.5 inches.

IV. RELATION BETWEEN POINT AND AREA OCCURRENCE

Certainly, extreme rainfall can be observed much more often if we expand our attention from a single rain gage to a network of gages over a large area. Flash floods show a similar relationship. A goodly amount of research data is available for Arizona, New Mexico, and Utah which could be applicable to many areas of western United States.

Osborn [2] using 1/2-hour precipitation amounts and working with the Agricultural Research Service, made comparisons and obtained similar results from studying two basins, one in Arizona and the other in New Mexico. Each study involved about 15 years of record, an area of about 60 square miles, and 95 and 65 rain gages, respectively.

Osborn presents evidence to support the condition that each rain gage be considered as an independent point. This assumption would allow for more than 1,000 gage years of record on the Walnut Gulch Basin in Arizona. It is likely that the same relation exists for the Alamogordo Basin in New Mexico for the 65 recording rain gages there.

The data he collected showed that a 100-year amount occurred eight times at various points in the two basins in the 15-year period. Five of these 1/2-hour events occurred in two storms, so actually only five storm situations were involved, an average of fewer than three storm situations for each basin. Thus, a 1/2-hour rainfall event which can be expected to occur only once in 100 - 200 years at a specific location was found to occur in each basin at least once in five years.

V. FLASH-FLOOD OCCURRENCES IN UTAH

Messrs. Butler and Marsell [4], in a United States Geological Survey study, compiled data on 836 flash floods reported in Utah in the 30-year period from 1939 through 1969. This is an average of 27 events per year. The NWS divides the state of Utah into 10 zones of roughly similar weather for purposes of forecasting. These zones cover mainly the populated areas, and so they tend to emphasize the valleys rather than the mountains. Flash-flood watches and warnings and other meteorological forecasts are issued for these zones. Table I shows how the 836 flash-flood occurrences were distributed by forecast zones. Many of the cases that fell in the unidentified areas outside of zones were assigned to a logical nearby zone.

It is evident that damaging flash flooding is a function of population density as well as rainfall amount. Damage from heavy rainfall in remote areas may not occur and if it does it may not be known or reported. Lesser amounts of rainfall in a populated area may cause heavy damage, and some cities may have several local watersheds that produce flash floods from a single storm situation. Flash floods occurring in areas with large populations generate more reports because of larger news coverage. For example, Zone 9 (Canyonlands and Lake Powell area) is much more susceptible to heavy rains than Zone 2 (Wasatch Front); yet, only 52 flash floods were reported in Zone 9 vs. 235 in Zone 2.

Table 2 is an analysis by zone of the relative chance of occurrence of a flash flood at a specific location (a random city) vs. the chance of occurrence in the zone as a whole. This is affected greatly by the size of the city and its population density. For example, at Salt Lake City, which experiences more flash floods than any other location, the chance of occurrence somewhere in the city is one-fourth as great as that for the zone as a whole. On the other hand, if all communities in Zone 2 are considered, the chance of a flash flood in a random community is only 1/40th of that for the zone.

Taking the data in Table 2 as a whole, the chance of a flash flood occurring in the zone averages about 15 times greater than that for a single community.

VI. APPLICATION TO METEOROLOGICAL FORECASTING

State of the science does not permit forecasting specific flash floods more than a few hours ahead for specific locations (watersheds). Sometimes it is possible to identify by radar or by visual observation an unusually heavy thundershower and its movement. This can form the basis for a flash-flood warning [5]. The warning must be disseminated to the public very rapidly (within minutes) because the event is developing by the time it is detected.

Though individual flash floods are hard to predict, it is feasible to identify certain situations favorable to heavy convective showers, and this forms the basis for a flash-flood watch. There are certain known flash-flood-prone areas, and flash-flood watches and warnings must take these into consideration. In spite of the best forecasting efforts, flash-flood watches and warnings will appear to be "crying wolf" unless occurrences over the entire zone or adjacent area are made known.

VII. SUMMARY AND CONCLUSIONS

The 100-year 1/2-hour amount of point rainfall probably may occur once every several years somewhere on a 60-square-mile basin. Flash-flood occurrences appear to exhibit similar relationships but over larger areas.

Errors in verification of flash-flood watches and warnings may occur when only known flash-flood occurrences are used. We may be able to improve on our forecast verification if all events are made known, and enhancement of accuracy in our forecast procedures is probable. Also, we may increase success in a community warning program if local officials and residents are adequately apprised of the number of occurrences not observed by them. Confidence in a flash-flood forecast may be enhanced.

VIII. REFERENCES

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[3] UNITED STATES WEATHER BUREAU TECHNICAL PAPER NO. 40. *Rainfall Atlas of the United States for Durations for 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years*, Prepared by D. M. Hersfield, U. S. Weather Bureau, Washington, D. C., 1961, 115 p.

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[5] NATIONAL WEATHER SERVICE OPERATIONS MANUAL, CHAPTER E-13.

TABLE 1

RECORDED FLASH FLOODS IN UTAH (1939-1969)

BY NWS FORECAST ZONES

Forecast Zone 1 Logan - Cache Valley	Flash Floods
Lewiston	0
Richmond	0
Logan	6
Hyrum	1
Clarkston	2
Mendon	1
Providence	1
Smithfield	2
	13

Forecast Zone 2 Wasatch Front	Flash Floods
Brigham City	6
Perry	1
Willard	4
Bountiful	12
Clearfield	2
Farmington	3
Kaysville	1
Layton	1
Sunset	1
Syracuse	1
Bingham	7
Bluffdale	1
Garfield	2
Granger	2
Herriman	2
Holladay	1
Kearns	2
Magna	6
Midvale	8
Murray	3
Riverton	1
Salt Lake City	73
Eden	1
Ogden	30
Pleasantview	1
Riverdale	1
Roy	1
Levan	7
Mona	2
Nephi	7
Alpine	5
	195

Forecast Zone 2 Wasatch Front (Cont'd)	Flash Floods
American Fork	4
Dividend	1
Elberta	4
Fairfield	1
Goshen	1
Lehi	6
Orem	3
Payson	1
Pleasant Grove	3
Provo	8
Spanish Fork	3
Springville	1
Thistle	3
Vivian Park	1
	235

TABLE 2

Approximate Expected Flash Flood Occurrences in Utah Forecast Zones[1]

(Author Summarized Data from Data presented in a USGS Report)

Zone	Expected Flash Flood Occurrences in Zone (No./Yr.)	Expected Flash Flood Occurrence in Random Community (Yrs. per Flood)	Frequency Difference Multiplicand (equals Increased Probability of Occurrence in Zone over Occurrence in a Random Community)
1	1/3	18	6
2	8	5	40
3	3	5	15
4	4	6	24
5	2	8	16
6	1	9	9
7	2	5	10
8	2	7	14
9	2	9	18
10	1	9	9

[1] Data are rounded to whole numbers from Table 1 values.

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