TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle "The Use of Rainfall Characteristics in Developing Methods for Reducing Wet Weather Accidents in Texas"		5. Report Date July 1975 6. Performing Organization Code
7. Author(s) Kenneth D. Hankins		8. Performing Organization Report No. 135-4
9. Performing Organization Name and Address State Department of Highways & Public Transportation P. O. Box 5051 Austin, Texas 78763		10. Work Unit No. 11. Contract or Grant No. Study 1-10-70-135
12. Sponsoring Agency Name and Address State Department of Highways & Public Transportation P. O. Box 5051 Austin, Texas 78763		13. Type of Report and Period Covered Interim Aug. 69 - July 75 14. Sponsoring Agency Code

15. Supplementary Notes

Research done in cooperation with FHWA, DOT; Study Title "Definitions of Relative Importance of Factors Affecting Vehicle Skids"

16. Abstract

This report was developed to provide a basis for further study of wet weather accidents. A method evolved to determine the percent of time the pavement is wet, leading to the development of a wet weather accident rate. A study of rainfall intensities was made. The average 85th percentile rainfall intensity of eighteen weather stations was found to be 0.14 inches per hour, based on measurements of a one-hour duration. When extrapolated to a five minute duration, the 0.14 inch per hour intensity was found to be increased to 0.50 inch per hour. The 0.50 inch per hour intensity was termed the "Average 85th Percentile Rainfall Intensity Based on a Five Minute Duration" and is suggested for use in design for skid resistance studies.

17. Key Words	18. Distribution Statement
Percent of Time of Wet Pavement, Wet Weather Accident Rates, Skid Resistance, Pavement Surface Water Depth, Design Rainfall Intensity	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-69)

THE USE OF RAINFALL CHARACTERISTICS IN DEVELOPING METHODS FOR REDUCING WET WEATHER ACCIDENTS IN TEXAS

BY

Kenneth D. Hankins

Research Report 135-4

"Definition of Relative Importance
of Factors Affecting Vehicle Skids"
Research Study No. 1-10-70-135

Conducted By

State Department of Highways and Public Transportation
Transportation Planning Division, Research Section
and
Texas Transportation Institute

In Cooperation with the

U. S. Department of Transportation
Federal Highway Administration

July 1975

ACKNOWLEDGMENTS

The research reported herein was conducted under the supervision of Mr. John F. Nixon, Engineer of Research, and the general supervision of Mr. Phillip L. Wilson, State Planning Engineer, Transportation Planning Division.

Acknowledgment is extended to Mr. Cliff Bell who conceived a method of estimating percent wet time which was adopted herein.

Acknowledgment is also given to Mr. Jon Underwood and Mr. Richard Tyler who performed the analysis and to Mr. James Wyatt and Mr. Joel Young who developed the computer program for yearly reporting.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

This report reveals studies which were made of Environmental Data Service rainfall records. It was desired to (1) develop a method of determining wet weather accident rates and (2) develop a rainfall intensity to be used for design purposes.

(1) In order to use data which exists in the Department more effectively in the study of wet weather accidents, Environmental Data Service rainfall records were studied and a method of determining the percent of time that highway surfaces are wet was formulated. Using the "percent wet time", wet weather accident rates were developed. It is recommended that wet weather accident rates be calculated for each control - section in the state and reported annually.

(2) Determinations of rainfall intensity were made for each hour of rainfall in 1969 for eighteen weather stations found in various locations in Texas. Groupings were made of the rainfall intensities and the number of occurances were found for each group. Frequency distribution plots were made and the 85th percentile rainfall intensity for a one hour measurement period was found for each location. The average 85th percentile rainfall intensity based on a one hour measurement period was found to be 0.14 inch per hour. The 0.14 inch per hour value was then extrapolated to an estimated intensity based on a five minute duration. The 85th percentile rainfall intensity based on a five minute duration was found to be 0.50 inch per hour and this value is recommended for design use.

A design rainfall intensity can be used along with the pavement surface texture, drainage length and pavement cross-slope to predict pavement surface water depth. Surface water depths may be used in further studies of tire-pavement friction.

IMPLEMENTATION

It is recommended that implementation consist of providing annually, wet weather accident rate information in addition to the "total" accident rate information presently being provided.

It is suggested that 0.50 inch per hour be used as a "design" rainfall intensity in conjunction with the following equation which was developed in Project 2-8-69-138:

$$d = 3.38 \times 10^{-3} (1/T)^{-.11} (L)^{.43} (I)^{.59} (1/S)^{.42} - T$$

where d= average water depth above the top of texture (in.)
T= average texture depth (in. - putty impression)
L= drainage - path length (ft.)
I= rainfall intensity (in./hr.)
S= cross-slope (ft./ft.)

Since the tire-pavement friction is influenced to some degree by surface water depth, the surface water depth may be calculated for a surface in question. Further implementation could include reporting skid numbers at a design water depth.

BACKGROUND

In order to advance the knowledge of contributing factors of wet pavement vehicular accidents, it has become necessary to develop information concerning wet weather accident rates. Accident rates as determined by the Texas SDH & PT in cooperation with the Department of Public Safety are stated as "number of accidents per one hundred million vehicle miles" and may be calculated using the following equation:

$$\text{Acc. Rate} = \frac{\text{No. of Acc. X } 10^8}{\text{Daily Vehicle Miles X Time Period of Study}}$$

Previously reported rates have concerned all vehicular accidents (wet plus dry) and generally the "Time Period of Study" has been one year or 365 days. In order to develop a wet weather accident rate, changes would be necessary in "No. of Acc." and "Time of Study", or the following equation could be used:

$$\text{Wet Weather Acc. Rate} = \frac{\text{No. of Wet Acc. X } 10^8}{\text{Daily Vehicle Miles X Wet Time Period of Study}}$$

To calculate a Wet Weather Accident Rate all information needed is available in previous reports by D-10 and D-18 with the exception of the "Wet Time Period of Study".[1,2] The "Wet Time Period of Study" should be based on one year in order that wet and dry (or total) accident rates for a given section of highway may be compared. The "Wet Time Period of Study" may be calculated using the following equation:

Wet Time Period of Study = % Wet Time X 365 (days per year)

The % Wet Time (or percent of time that the pavement surface is wet) is a nebulus item and at the outset is was believed that only approximate values could be obtained. However, the seriousness of the wet pavement accident problem is beleived to be sufficient grounds to accept approximate values in lieu

(Note - Number in parenthesis refer to numbers in Reference) of having no basis of comparison what-so-ever. Therefore one of the objects of this report is to indicate a method of determining approximate "Percent Wet Times" and of calculating Wet Weather Accident Rates.

In general, it is well known that vehicular stopping distances are increased in wet weather driving as compared to those in dry weather. However, the variations in stopping distances due to variations in pavement wetness or rainfall variation is not so well defined. In an effort to better define this problem recent studies have developed methods of predicting the water depth on the pavement surface by equating surface water depth as a function of Rainfall Intensity, Pavement Texture, Drainage Length and Cross Slope Rate.[3] For any given location, Pavement Texture, Drainage Length and Cross Slope may be determined from measurements; however, Rainfall Intensity is an act of nature which varies considerably. Therefore it becomes necessary to study rainfall intensities in Texas and to develop an intensity for design purposes. The second objective of this report is to reveal a method of determining a design rainfall intensity.

Method of Analysis - Percent Wet Time

In 1967, Bell developed the following method of determining the % Wet Time.[4] This method was used in the determinations reported herein.

The data from monthly reports forwarded to the State Department of Highways and Public Transportation by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, were used and eighteen weather stations scattered throughout the state were selected for study. An example of a monthly report may be found in Figure 1.[5]

The hours of wet pavement were determined by using the following procedure:

(1) The National Weather Service presently has a listing of the hourly rainfall measurements for each month. Traces of rain within a certain hour are also tabulated.

(2) On a given day, if a string of consecutive hours of trace rainfall occurs with no measureable rainfall (.01 or greater) within this string, then the first and last hours are not counted.

(3) If within a string of consecutive rainfall measurements there occurs an hour of measureable rainfall, then the last hour of trace rainfall is counted. The first hour again is not counted.

(4) If the first hour of a string of measurements is a measureable rain (.01 or greater) then the first hour is counted and every other hour of rain in that string, traces included, are counted.

(5) If the last hour of a string of measurements is a rainfall of .01 inch or greater then that hour is counted plus one additional hour to allow for drying time.

A UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

LOCAL CLIMATOLOGICAL DATA

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

WACO, TEXAS
NATIONAL WEATHER SERVICE OFC
MUNICIPAL AIRPORT
MAY 1973

Latitude 31° 37' N Longitude 97° 13' W Elevation (ground) 501 ft Standard time used CENTRAL WBAN #13959

Date	Temperature °F: Maximum	Minimum	Average	Departure from normal	Average dew point	Degree days Base 65°: Heating	Cooling	Weather types on dates of occurrence (1 Fog, 2 Heavy fog X, 3 Thunderstorm, 4 Ice pellets, 5 Hail, 6 Glaze, 7 Duststorm, 8 Smoke, Haze, 9 Blowing snow)	Snow, ice pellets or ice on ground at 06AM In.	Precipitation: Water equivalent In.	Snow, ice pellets In.	Avg station pressure In. Elev. 508 feet m.s.l.	Wind: Resultant direction	Resultant speed m.p.h.	Average speed m.p.h.	Fastest mile: Speed m.p.h.	Direction	Sunshine: Hours and tenths	Percent of possible	Sky cover Tenths: Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	82	69	76	4	69	0	11	1 3 8	0	.01	0	29.27	17	17.8	18.0	28	17			7	9	1
2	73	57	65	-7	53	0	0		0	0	0	29.55	35	9.1	11.2	22	34			7	6	2
3	74	48	61	-11	44	4	0		0	0	0	29.74	36	9.1	9.4	16	34			0	0	3
4	75	47*	61	-11	47	4	0		0	0	0	29.63	16	6.1	7.5	15	16			1	0	4
5	76	56	66	-6	57	0	1	1 8	0	.75	0	29.44	16	12.9	13.2	21	16			9	8	5
6	77	66	72	-1	67	0	7	1 3 8	0	.11	0	29.18	17	17.3	17.5	25	17			9	10	6
7	81	60	71	-2	56	0	6		0	0	0	29.20	25	6.8	10.1	17	24			0	1	7
8	83	57	70	-3	57	0	5		0	0	0	29.40	15	2.4	3.5	9	14			0	0	8
9	86	64	75	2	61	0	10		0	0	0	29.37	17	12.5	12.9	20	17			0	0	9
10	89	63	76	3	65	0	11	8	0	0	0	29.35	18	13.6	13.8	20	17			1	1	10
11	90	70	80	6	71	0	15	3 8	0	.10	0	29.34	18	13.1	13.2	32	34			5	6	11
12	77	59	68	-6	59	0	3	3	0	.11	0	29.54	01	10.6	13.2	23	01			9	8	12
13	78	57	68	-6	47	0	3		0	0	0	29.69	01	8.3	9.2	16	04			7	7	13
14	68	53	61*	-13	48	4	0		0	.01	0	29.76	33	8.0	8.6	22	34			9	9	14
15	76	51	64	-10	46	1	0		0	0	0	29.78	33	7.2	7.6	14	35			5	4	15
16	80	51	66	-9	51	0	1		0	0	0	29.59	19	7.5	7.6	16	20			0	0	16
17	82	54	68	-7	50	0	3		0	0	0	29.47	36	3.1	9.1	14	34			0	0	17
18	90	54	72	-3	55	0	7		0	0	0	29.32	17	9.1	9.2	18	18			4	2	18
19	93*	66	80	5	63	0	15		0	0	0	29.22	17	14.4	14.7	17	17			0	0	19
20	90	70	80	5	68	0	15		0	0	0	29.24	17	14.0	14.4	20	16			4	5	20
21	89	71	80*	5	66	0	15		0	T	0	29.25	17	15.5	15.7	30	18			4	6	21
22	85	66	76	0	64	0	11		0	0	0	29.27	16	13.3	13.5	21	18			5	6	22
23	86	67	77	1	66	0	12	3	0	.05	0	29.25	17	11.2	11.7	21	18			8	7	23
24	87	65	76	0	68	0	11	1 3	0	.02	0	29.18	16	5.0	6.9	20	18			7	6	24
25	86	64	75	-1	67	0	10	1 3	0	2.00	0	29.13	14	7.9	17.0	37	36			9	9	25
26	88	64	76	-1	69	0	11	1	0	0	0	28.94	17	15.4	15.7	21	18			9	7	26
27	84	63	74	-3	57	0	9	1	0	0	0	28.98	31	8.1	11.9	20	34			0	1	27
28	81	60	71	-6	52	0	6		0	0	0	29.27	30	13.0	13.2	21	30			1	1	28
29	87	58	73	-4	55	0	8		0	0	0	29.46	31	.9	6.5	12	36			0	0	29
30	87	60	74	-4	58	0	9		0	0	0	29.50	15	7.5	7.8	16	14			3	2	30
31	87	62	75	-3	62	0	10		0	0	0	29.43	15	5.7	6.3	12	15			2	1	31
	Sum	Sum				Total	Total			Total	Total	For the month						Total	% for month	Sum	Sum	
	2567	1872				13	225			3.16	0	29.38	17	4.9	11.3	37	36			125	122	
	Avg.	Avg.	Avg.	Dep.	Avg.	Dep.	Dep.			Dep						Date	25	Possible		Avg.	Avg.	
	82.8	60.4	71.6	-2.7	59	13				-1.41										4.0	3.9	

Number of days				Season to date	
Maximum Temp.		Minimum Temp.		Total	Total
≥ 90° ‡	≤ 32°	≤ 32°	≤ 0°	2677	297
4	0	0	0	Dep.	Dep.
				647	

Number of days	
Precipitation ≥ .01 inch	9
Snow, ice pellets ≥ 1.0 inch	0
Thunderstorms	7
Heavy fog X	0
Clear 14	Partly cloudy 10 Cloudy 7

Greatest in 24 hours and dates: Precipitation 2.00 25; Snow, ice pellets 0

Greatest depth on ground of snow, ice pellets or ice and date: 0

HOURLY PRECIPITATION (Water equivalent in inches)

Date	A.M. 1	2	3	4	5	6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	Date
1	T						T	T	T						.01										1
2																									2
3																									3
4																									4
5																		T	.20	.52	.01	.02	T	T	5
6	T	T	T	T	T	T	T	T	T	T			T	T						.07	.04	T			6
7																									7
8																									8
9																									9
10																									10
11																							.06	.04	11
12	.10	.01	T																						12
13																									13
14													T	.01	T										14
15																									15
16																									16
17																									17
18																									18
19																									19
20																									20
21						T							T	T											21
22																									22
23																		T	.05	T	T	T			23
24																						.02	T		24
25								T	T							T	.57	.68	T		.32	.43	T		25
26																									26
27																									27
28																									28
29																									29
30																									30
31																									31

- * Extreme temperatures for the month. May be the last of more than one occurrence.
- – Below zero temperature or negative departure from normal.
- ‡ ≤ 70° at Alaskan stations.
- + Also on an earlier date, or dates.
- X Heavy fog restricts visibility to ¼ mile or less.
- T In the Hourly Precipitation table and in columns 9, 10, and 11 indicates an amount too small to measure.

The season for degree days begins with July for heating and with January for cooling.
Data in columns 6, 12, 13, 14, and 15 are based on 8 observations per day at 3-hour intervals.
Wind directions are those from which the wind blows. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. Figures for directions are tens of degrees from true North; i.e. 09 = East, 18 = South, 27 = West, 36 = North and 00 = Calm. When directions are in tens of degrees in Col. 17, entries in Col. 16 are fastest observed 1-minute speeds. If the / appears in Col. 17, speeds are gusts.
Any errors detected will be corrected and changes in summary data will be annotated in the annual summary.

Subscription Price: Local Climatological Data $ 2.00 per year including annual issue if published, foreign mailing 75¢ extra. Single copy: 20¢ for monthly issue, 15¢ for annual summary. Make checks payable to Department of Commerce, NOAA. Send payments and orders to National Climatic Center, Federal Building, Asheville, North Carolina 28801.

I certify that this is an official publication of the National Oceanic and Atmospheric Administration, and is compiled from records on file at the National Climatic Center, Asheville, North Carolina 28801.

William H. Haggard
Director, National Climatic Center

SUMMARY BY HOURS

Hour Local time	Sky cover tenths	Station pressure In.	Averages: Temperature Air °F	Wet bulb °F	Dew Pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind: Direction	Speed m.p.h.
00	4	29.38	67	62	59	76	10.6	18	7.2
03	4	29.37	64	60	58	81	8.4	18	4.6
06	5	29.39	62	59	57	85	9.1	19	4.1
09	4	29.43	72	64	60	67	12.2	18	3.2
12	4	29.41	79	67	60	53	13.4	18	5.4
15	4	29.36	81	67	59	49	13.8	18	5.3
18	3	29.33	79	66	58	51	12.4	16	5.3
21	3	29.37	70	63	59	69	10.4	16	4.7

USCOMM — NOAA — ASHEVILLE 300

EXAMPLE OF RAINFALL DATA
Figure 1

The following example illustrate these principles:

Day	Hours 1	2	3	4	5	6	Wet Pavement Hours
1	T	T	T	T	T		3
2	T	.01	T	T	T	T	5
3	T	.01	T	T	.01	T	5
4	.01	T	T	T			4
5	T	T	T	.01			4
6	.01	T		T	.01	T	4
7	T	T		T	T	T	1
8	T	.01		T	T	.01	5
9	.01	T	T	T	T	.01	7

The rational used in developing the procedure given above is composed of three items. First, if there is a measureable amount of rainfall, it is assumed that the surface will be wet up to one hour after rainfall ceases. Second, if there is a measureable amount of rainfall followed by a trace of rainfall, the surface will be dry one hour after the measureable rainfall ceases. Third, trace measurements of rainfall are considered to be very slight amounts in which the pavement could be considered to be dry at the the beginning and ending of a "trace" rainfall queue.

The National Weather Service also lists the Total Annual Rainfall observed at the weather station and there appeared to be a relationship between the Wet Time and the Total Annual Rainfall. This relationship is found in Figure 2. Further investigation indicated the National Weather Service maintained weather stations which collected Total Annual Rainfall information in every county in Texas, but hourly records were not available at each of these locations. However, the Weather Bureau State Climatologist prepares a contour map of

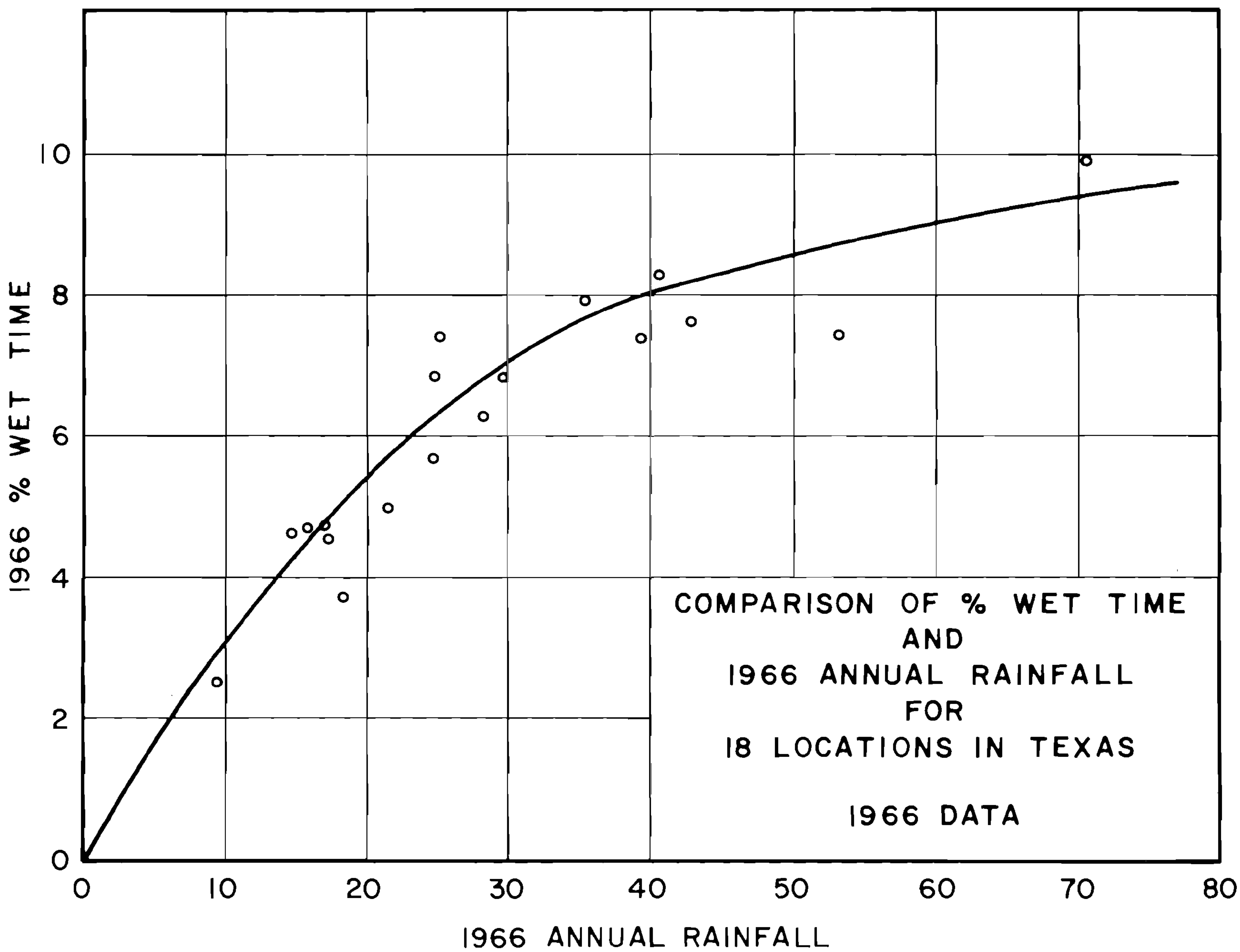
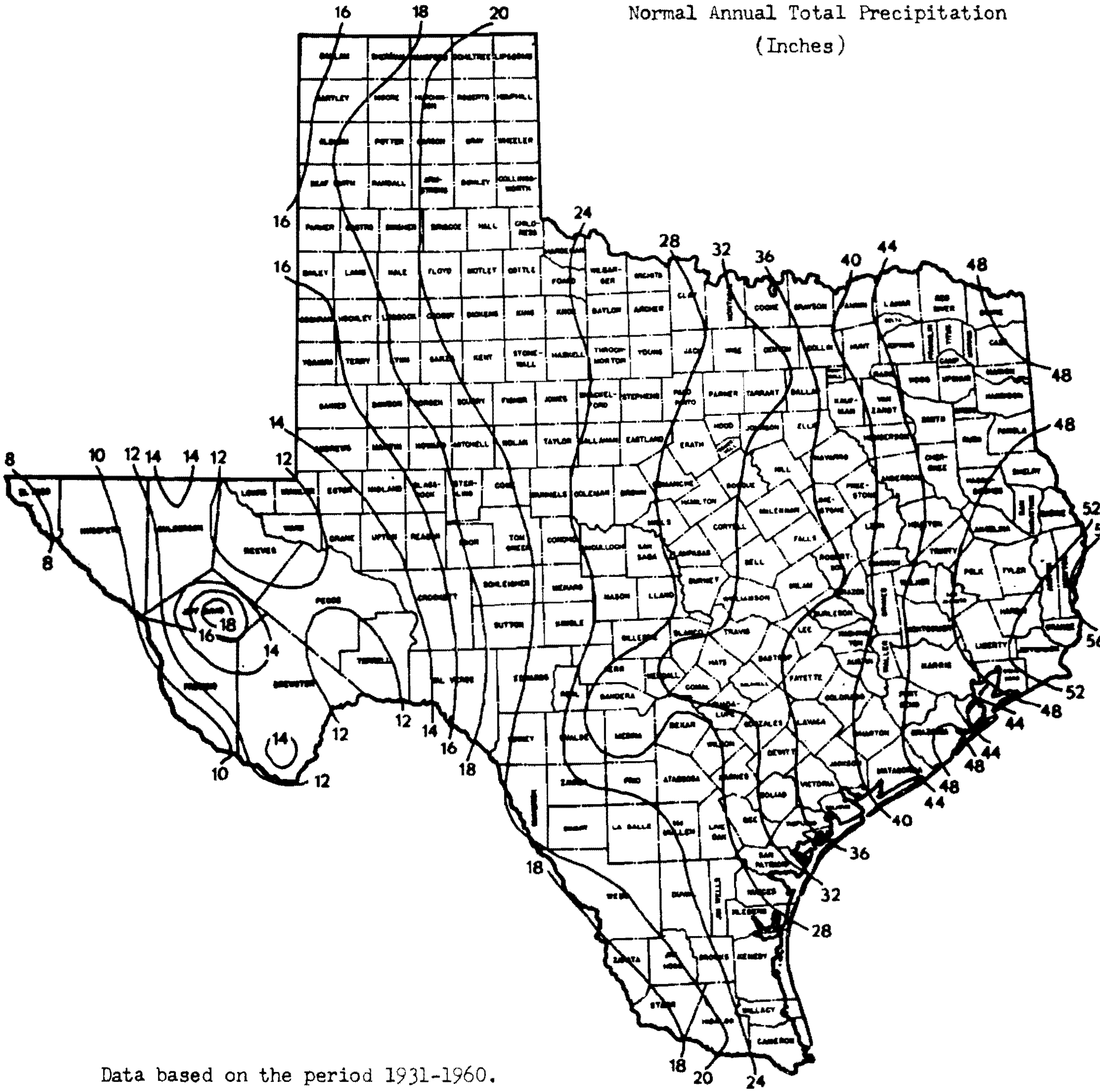

1966 % WET TIME
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
1966 ANNUAL RAINFALL
COMPARISON OF % WET TIME
AND
1966 ANNUAL RAINFALL
FOR
18 LOCATIONS IN TEXAS
1966 DATA

FIGURE 2

the Normal Annual Total Precipitation which is based on thirty year averages (See Figure 3). A decision was made to use the relationship found in Figure 2 to predict the % Wet Time using the Total Annual Rainfall averages found on the contour map of Figure 3. This decision was made in order that % Wet Time values for each county could be obtained.

October 1968 577.21.1

Normal Annual Total Precipitation
(Inches)



Data based on the period 1931-1960.

WEATHER BUREAU STATE CLIMATOLOGIST
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
3600 MANOR ROAD, AUSTIN, TEXAS

CONTOUR MAP OF ANNUAL RAINFALL VALUES
Figure 3

Method of Analysis - Design Rainfall Intensity

The data from monthly reports forwarded to the Department by the Weather Bureau were used and eighteen weather stations scattered throughout the state were arbitrarily selected for study.[(5)] At each weather station the hourly records were studied for each month of the year (1969 records were used). The amount of precipitation falling during each hour of the day was recorded and maintained at each station. The amount of hourly precipitation was considered to be the rainfall intensity in inches per hour.

The analysis consisted of establishing rainfall intensity groupings and recording the number of times during the year the hourly precipitation (intensity) fell in a specific group. As expected, there are many occasions (hours) which the intensity is low but only few occasions which large heavy hourly rainfall is recorded. By plotting the number of occasions of which a certain rainfall occurred ("Number of Hours on Which Rain Occurred") vs. the "Rainfall Intensity" grouping, estimates of "Percentiles of Occurance" may be established. Plots of this relationship may be found for each of the eighteen locations in Figures 4 through 21.

It was believed that the amount of rainfall measured in a one hour time increment lacked sufficient accuracy to predict the worst condition expected on Texas pavements in terms of water depth. In other words, the amount of water measured in a one hour duration might have occurred in a short time period within the hour. It was decided to report rainfall intensity for a five minute duration. The five minute duration was arbitrarily selected, however, it was believed that the five minute period would include the heavier rainfall periods while still allowing sufficient time for water drainage across the pavement surface to reach the "worst" condition. Data was found by which intensities of a five minute durations could be extrapolated.

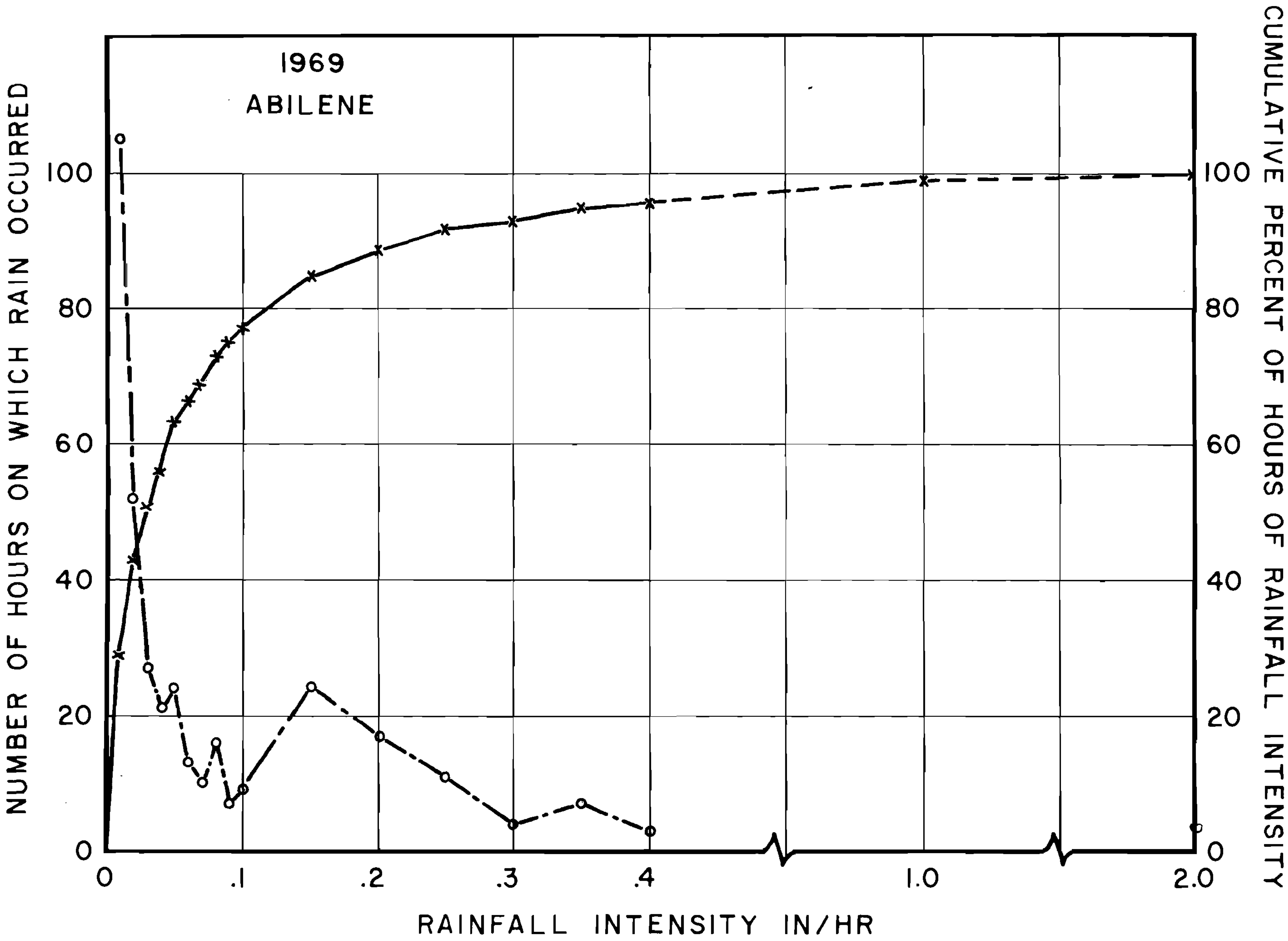

1969
ABILENE
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 4

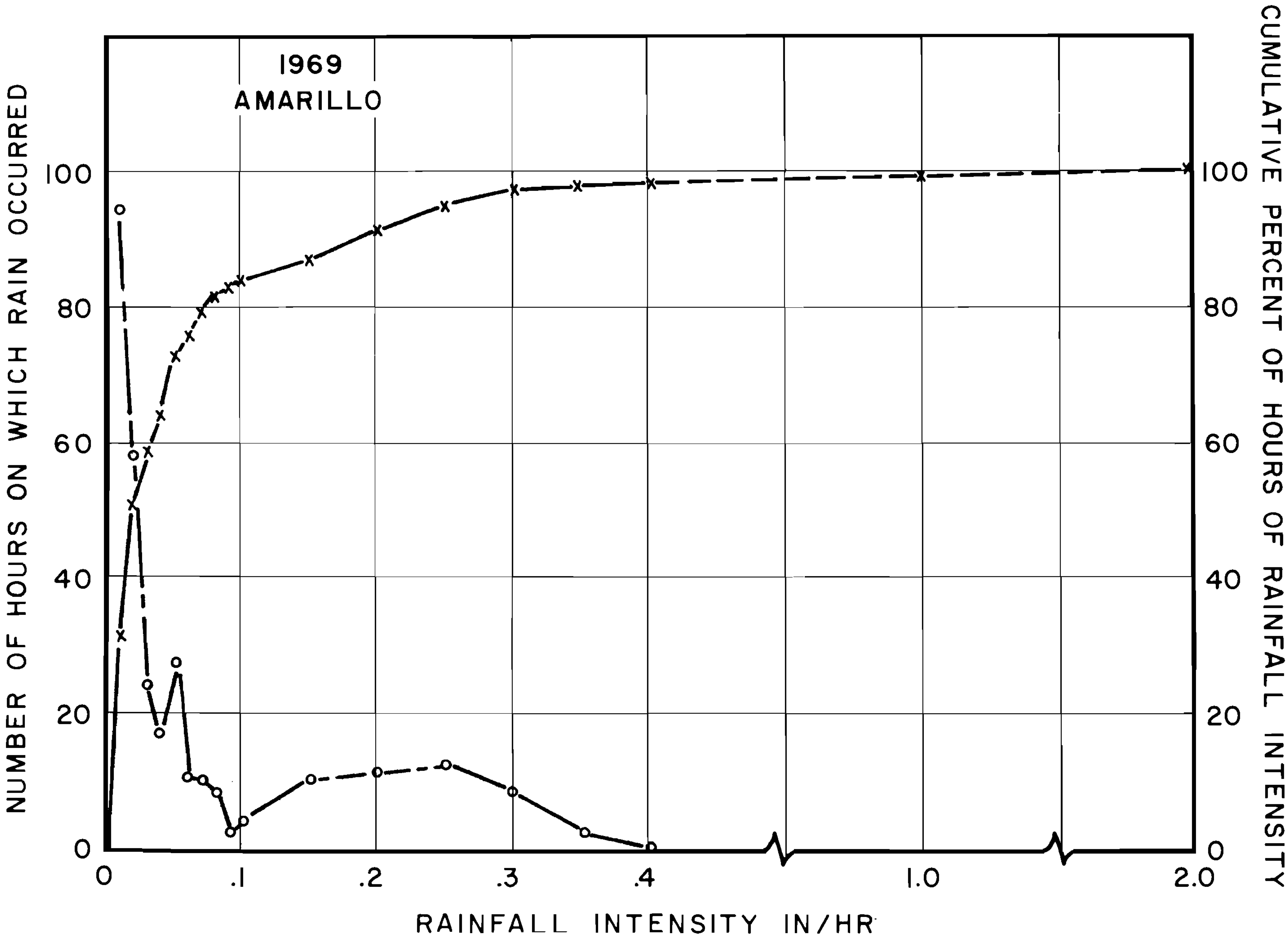

1969
AMARILLO
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
RAINFALL INTENSITY IN/HR
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0

FIGURE 5

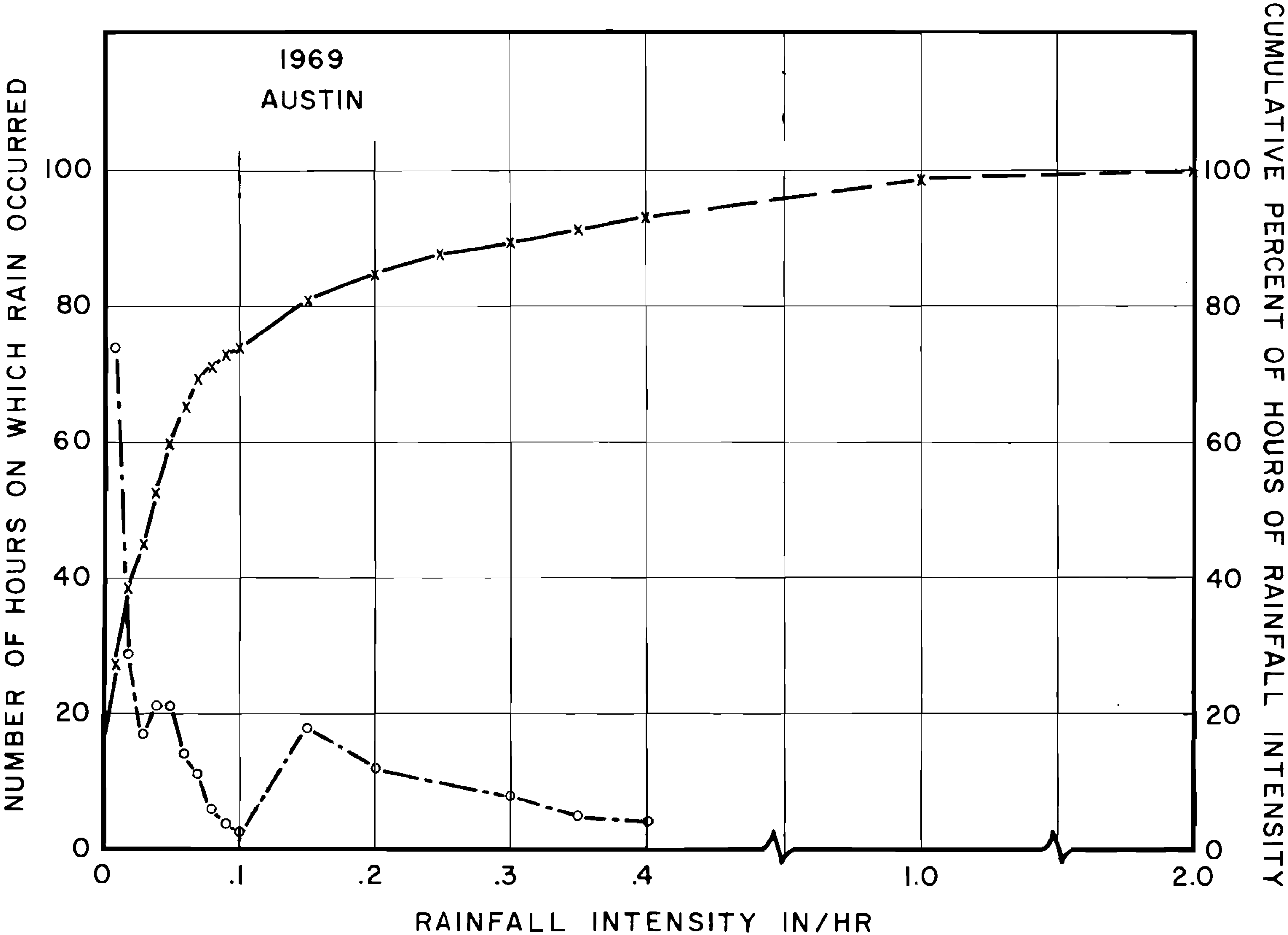

1969
AUSTIN
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 6

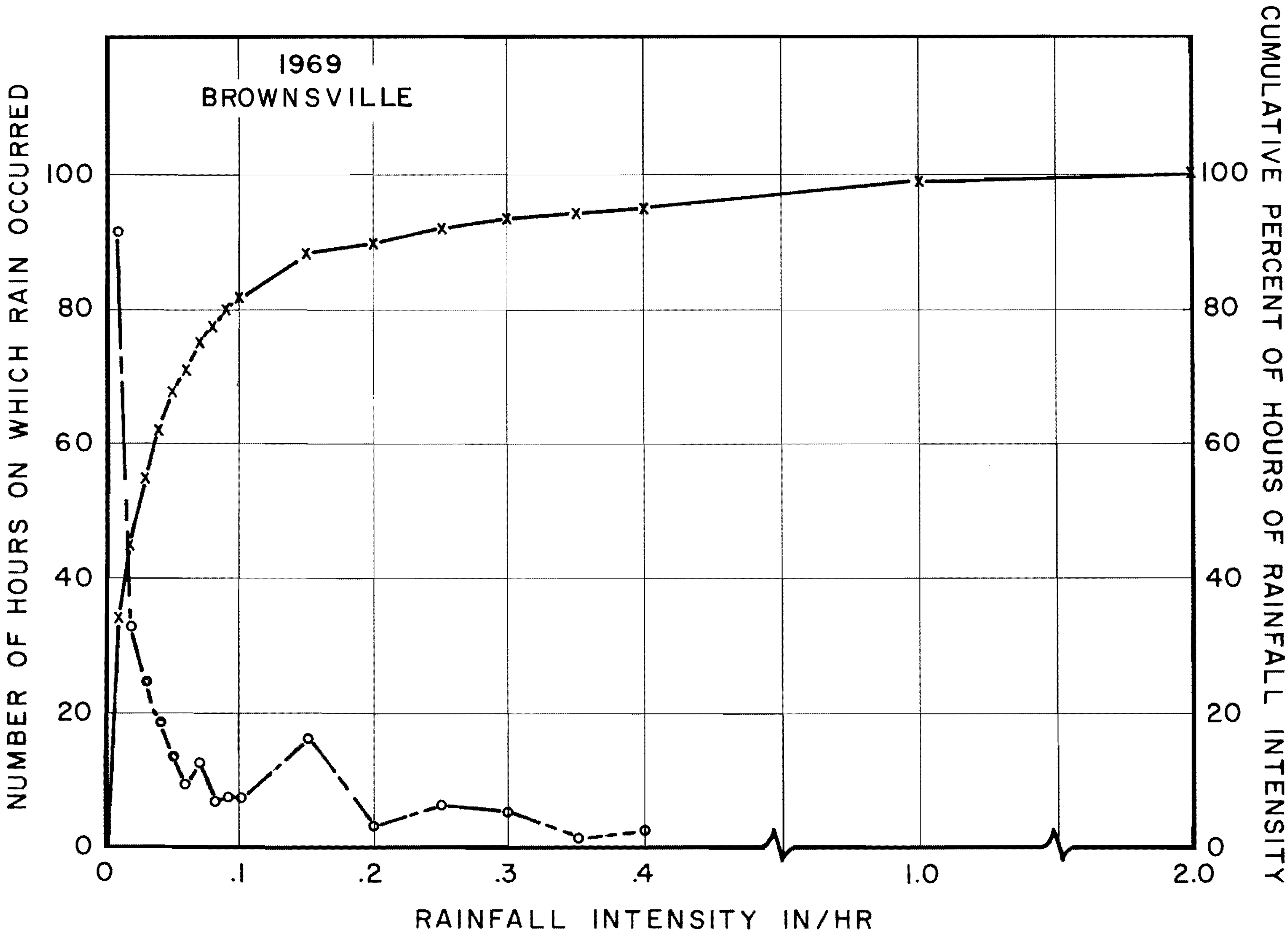

1969
BROWNSVILLE
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
RAINFALL INTENSITY IN/HR
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0

FIGURE 7

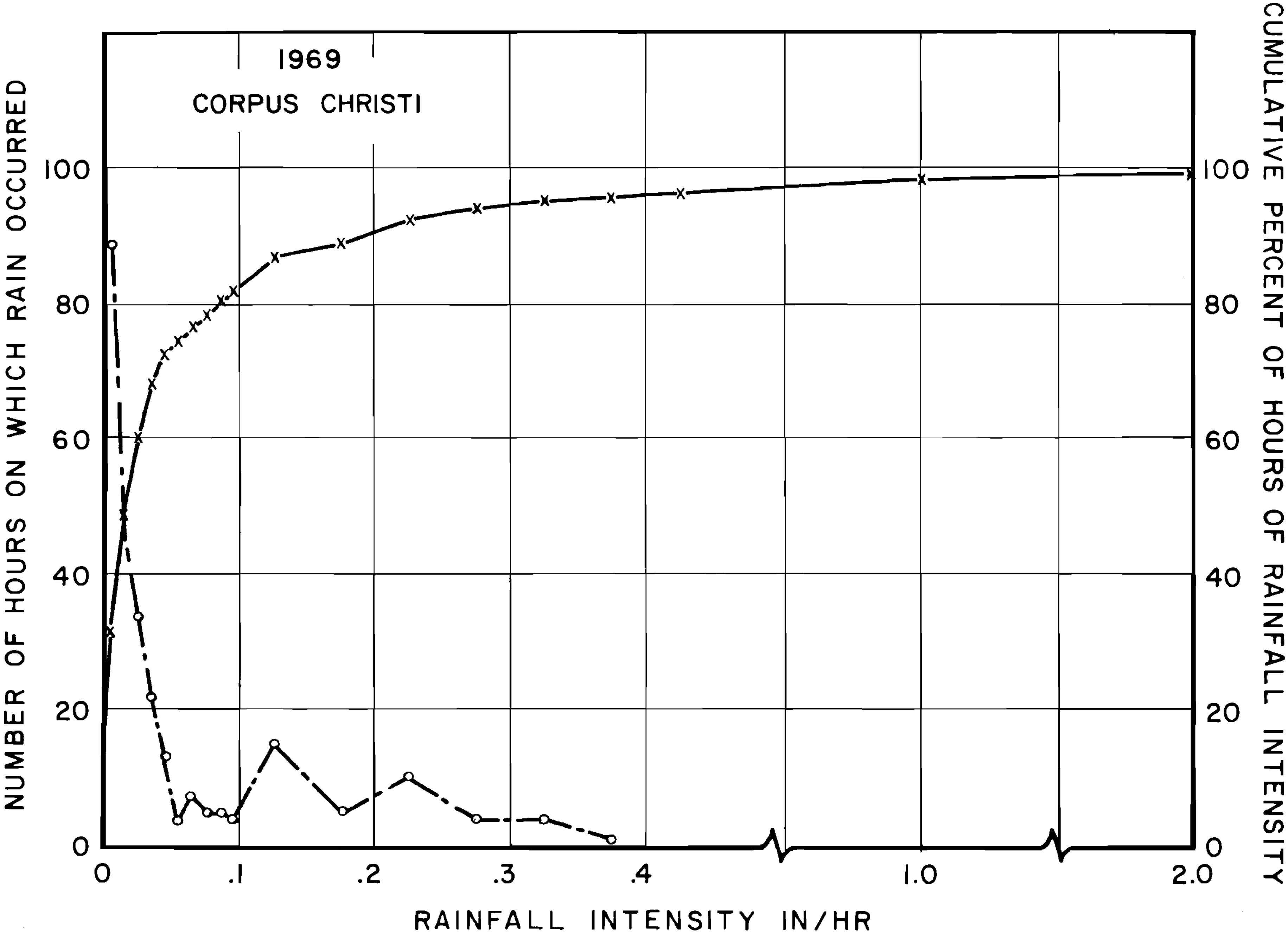

1969
CORPUS CHRISTI
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 8

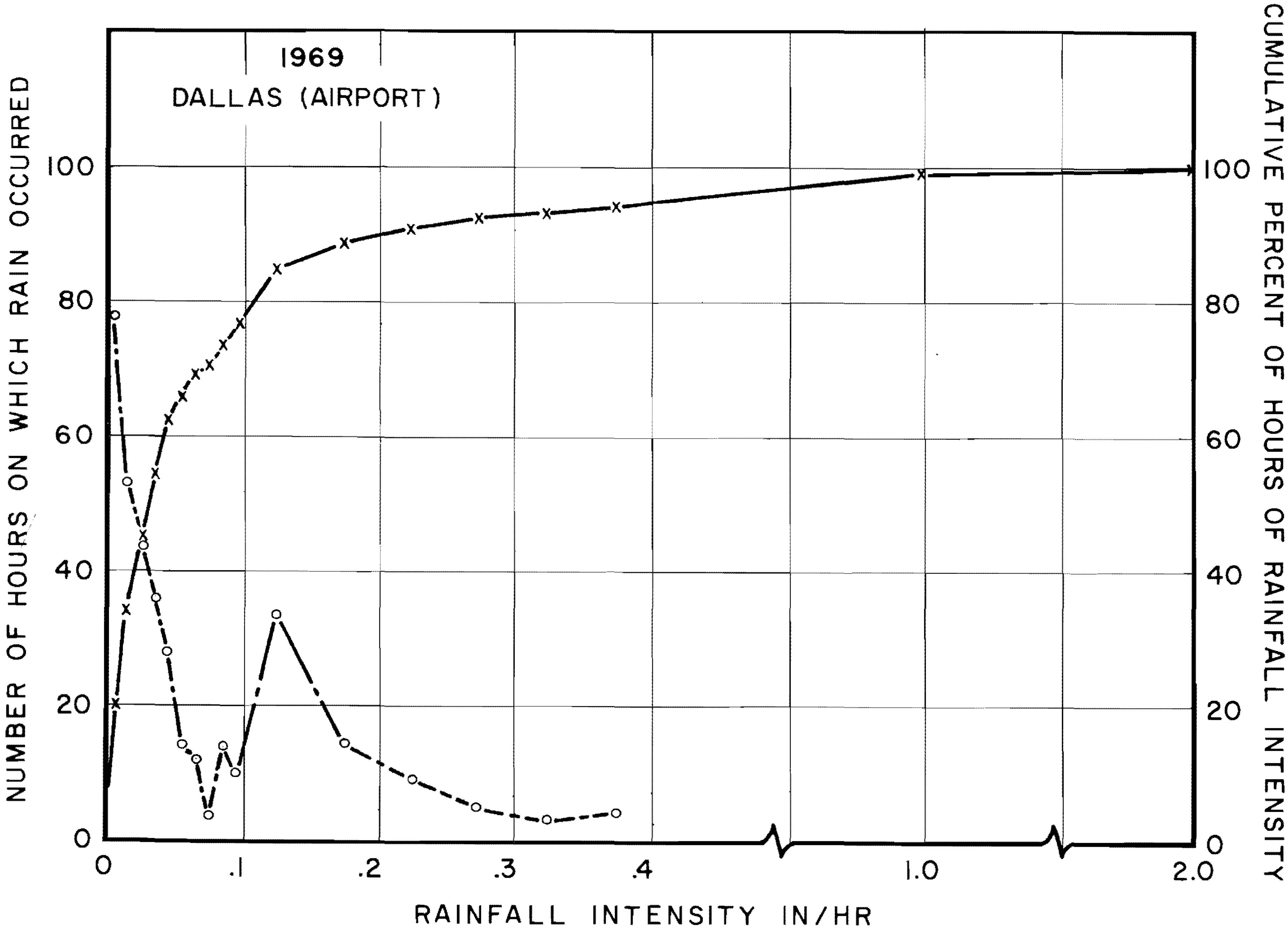

1969
DALLAS (AIRPORT)
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 9

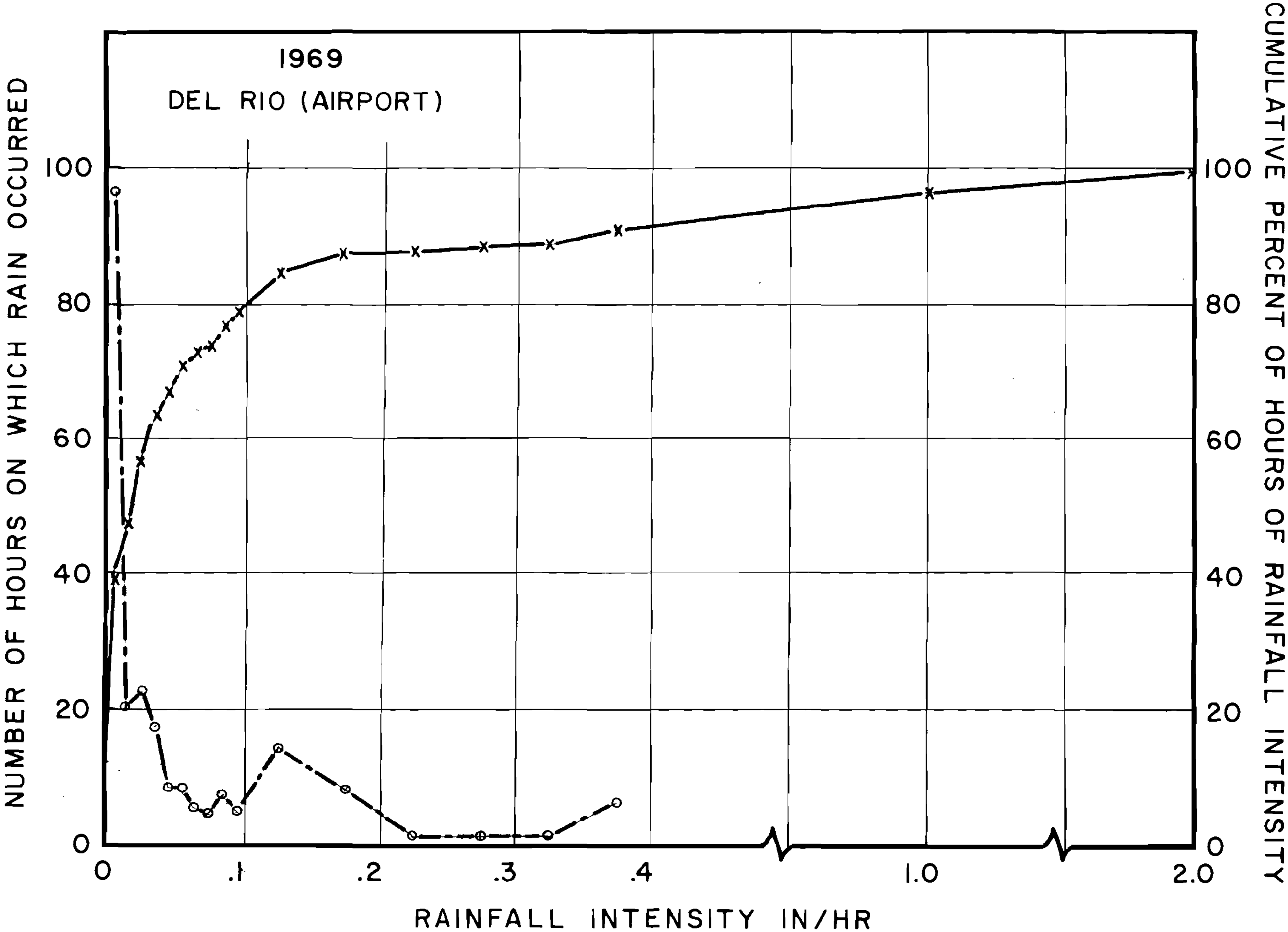

1969
DEL RIO (AIRPORT)
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 10

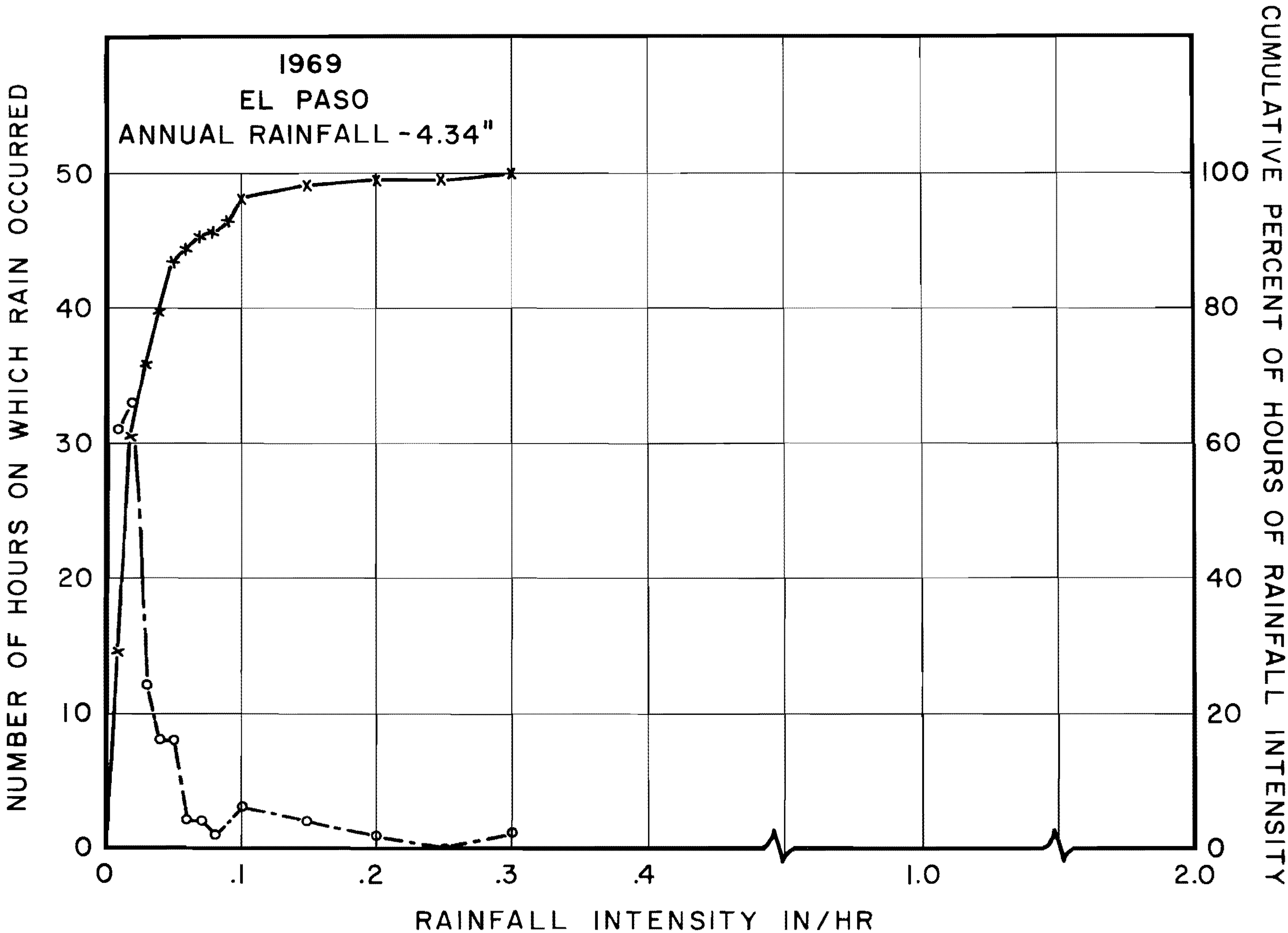

1969
EL PASO
ANNUAL RAINFALL - 4.34"
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
RAINFALL INTENSITY IN/HR
0
10
20
30
40
50
20
40
60
80
100
.1
.2
.3
.4
1.0
2.0

FIGURE II

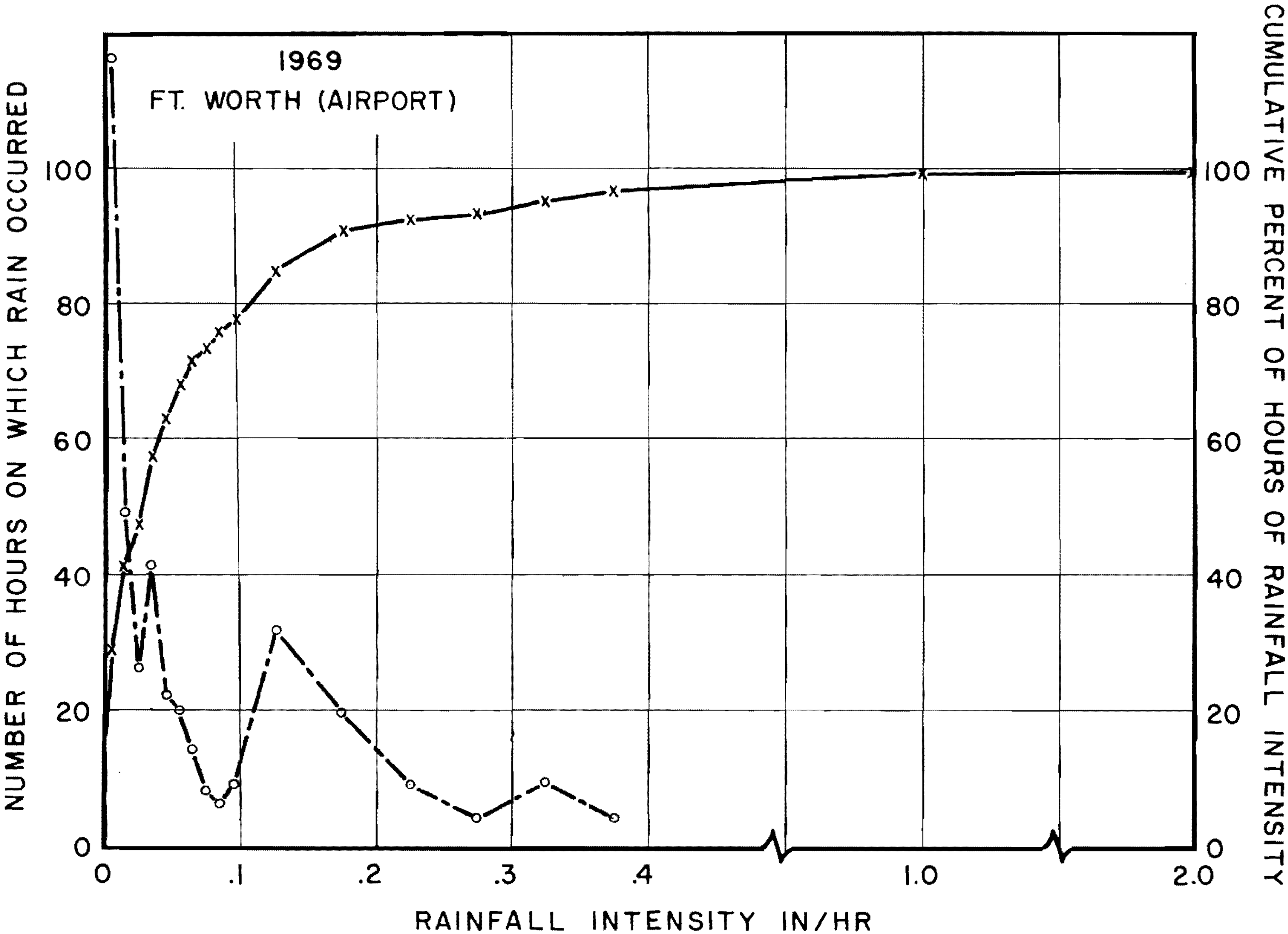

1969
FT. WORTH (AIRPORT)
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
RAINFALL INTENSITY IN/HR
0
20
40
60
80
100
.1
.2
.3
.4
1.0
2.0

FIGURE 12

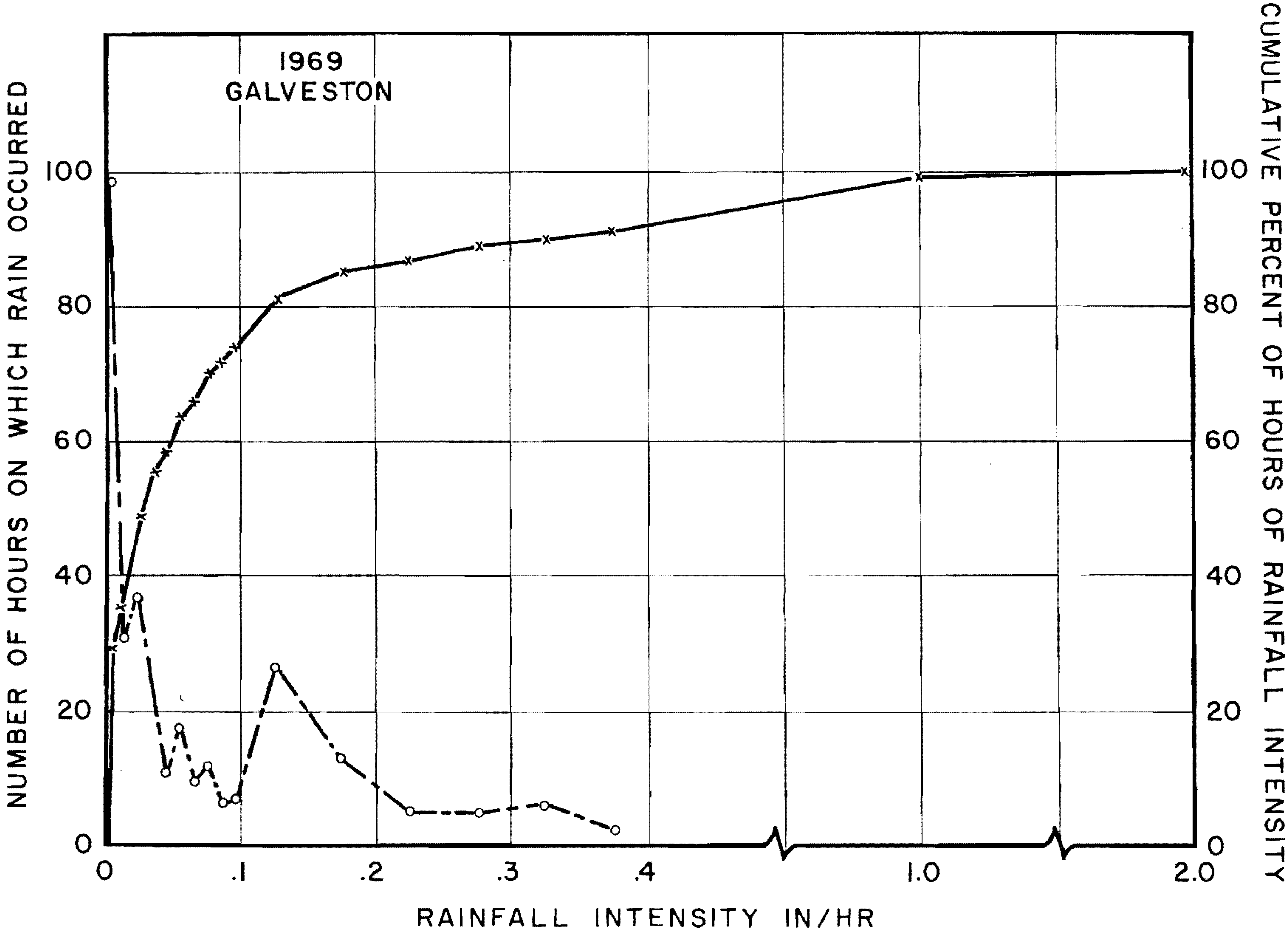

1969
GALVESTON
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
100
80
60
40
20
0
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 13

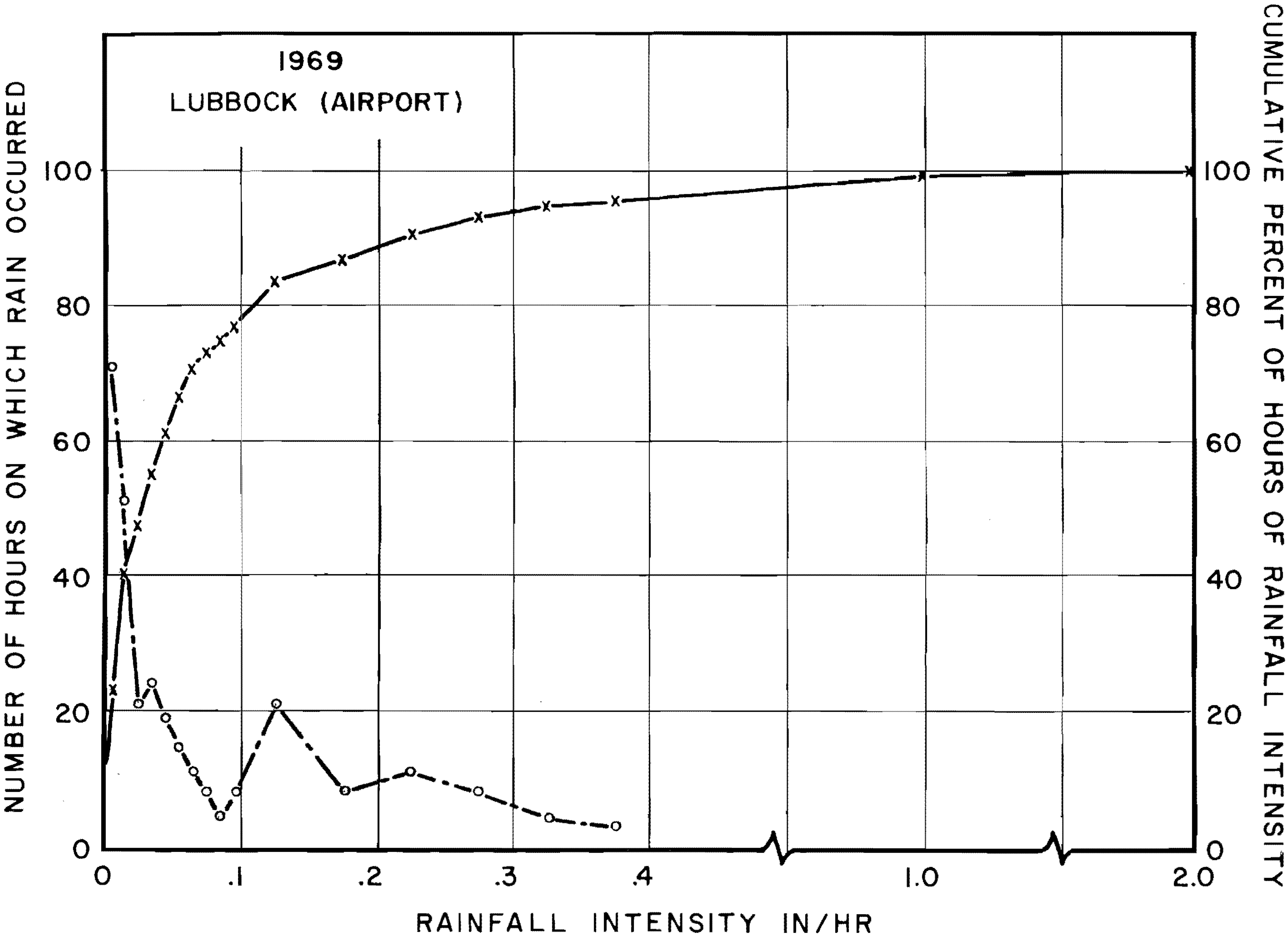

1969
LUBBOCK (AIRPORT)
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 14

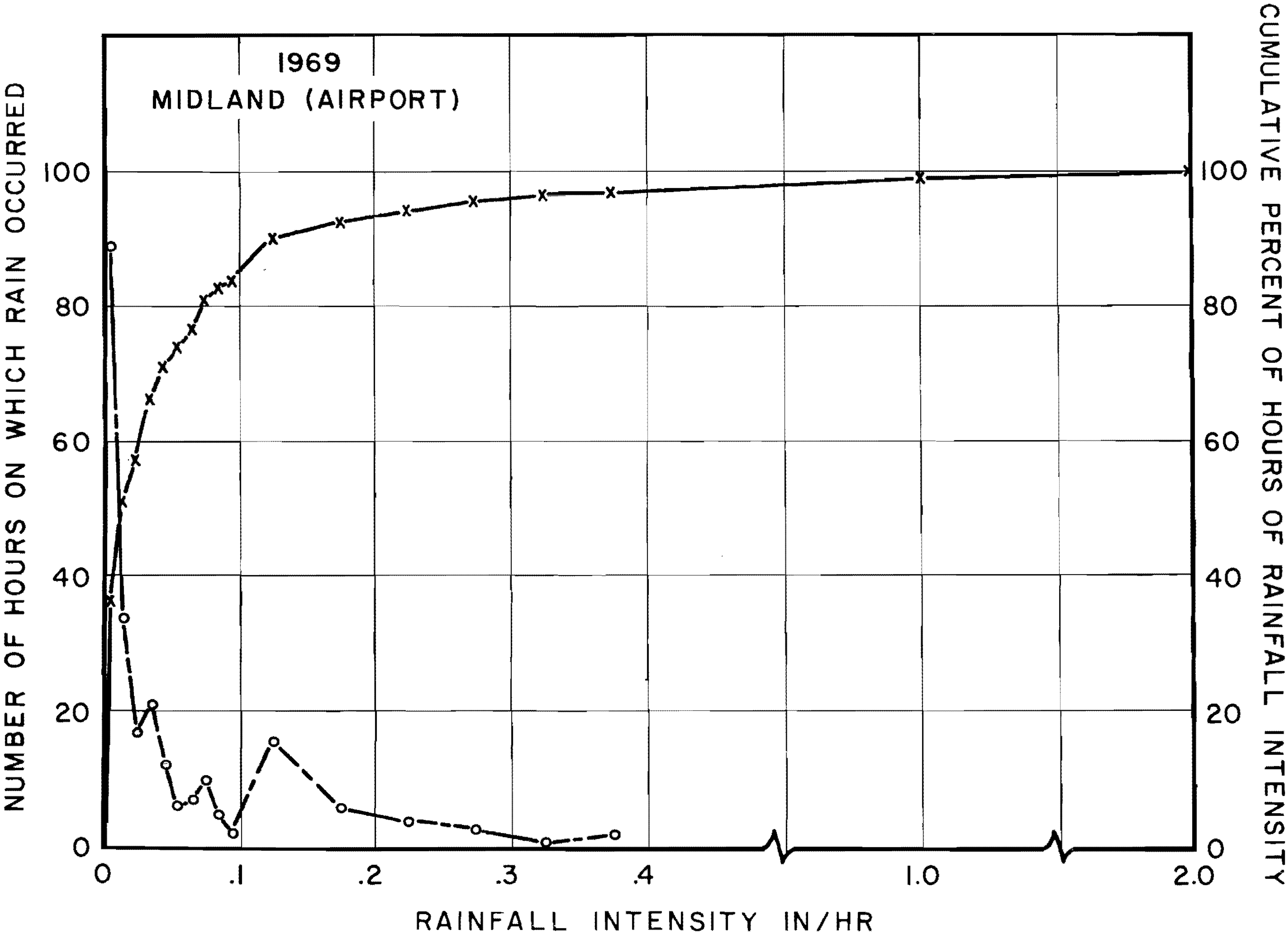
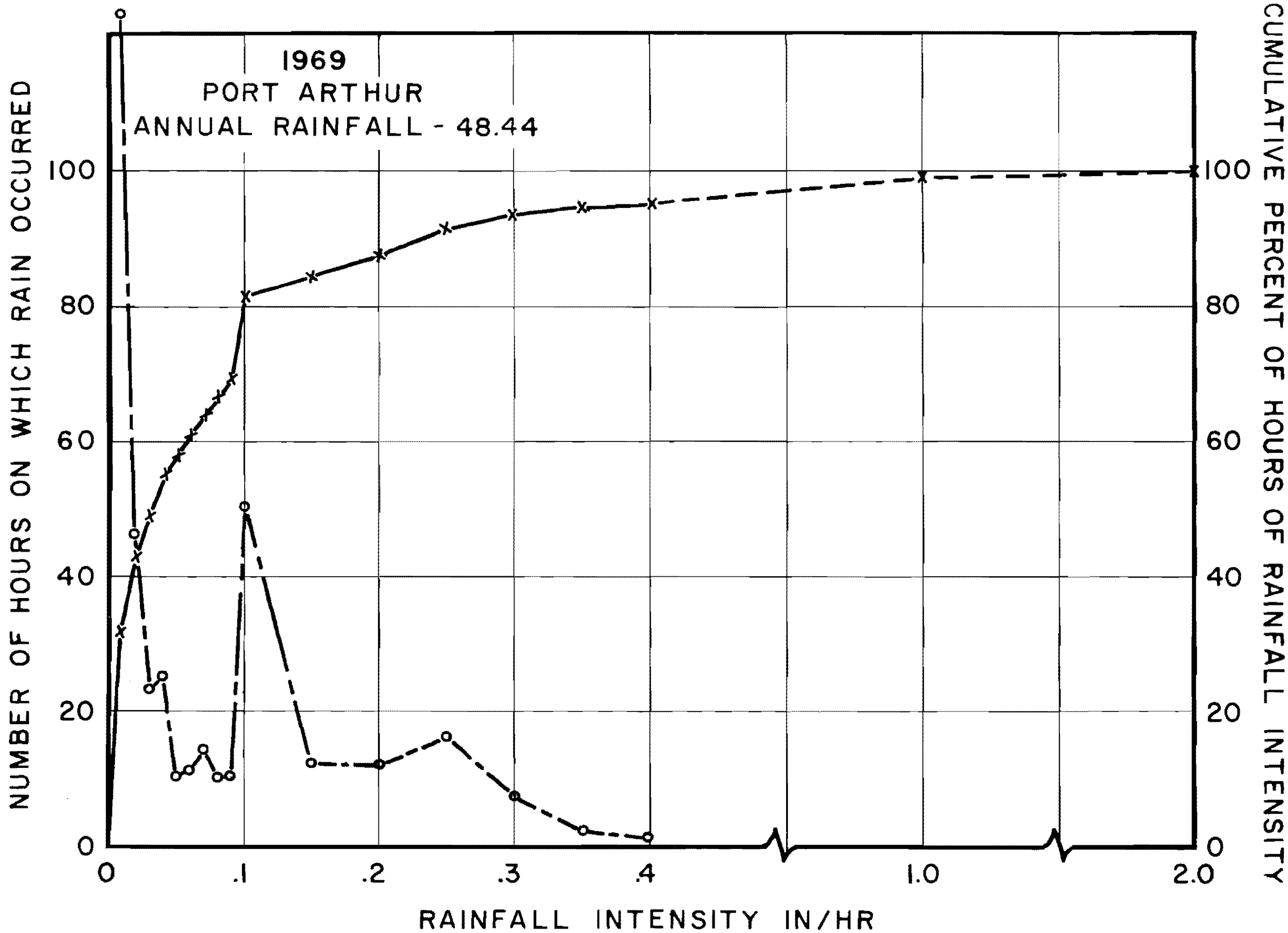

1969
MIDLAND (AIRPORT)
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
100
80
60
40
20
0
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 15



1969
PORT ARTHUR
ANNUAL RAINFALL - 48.44
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 16

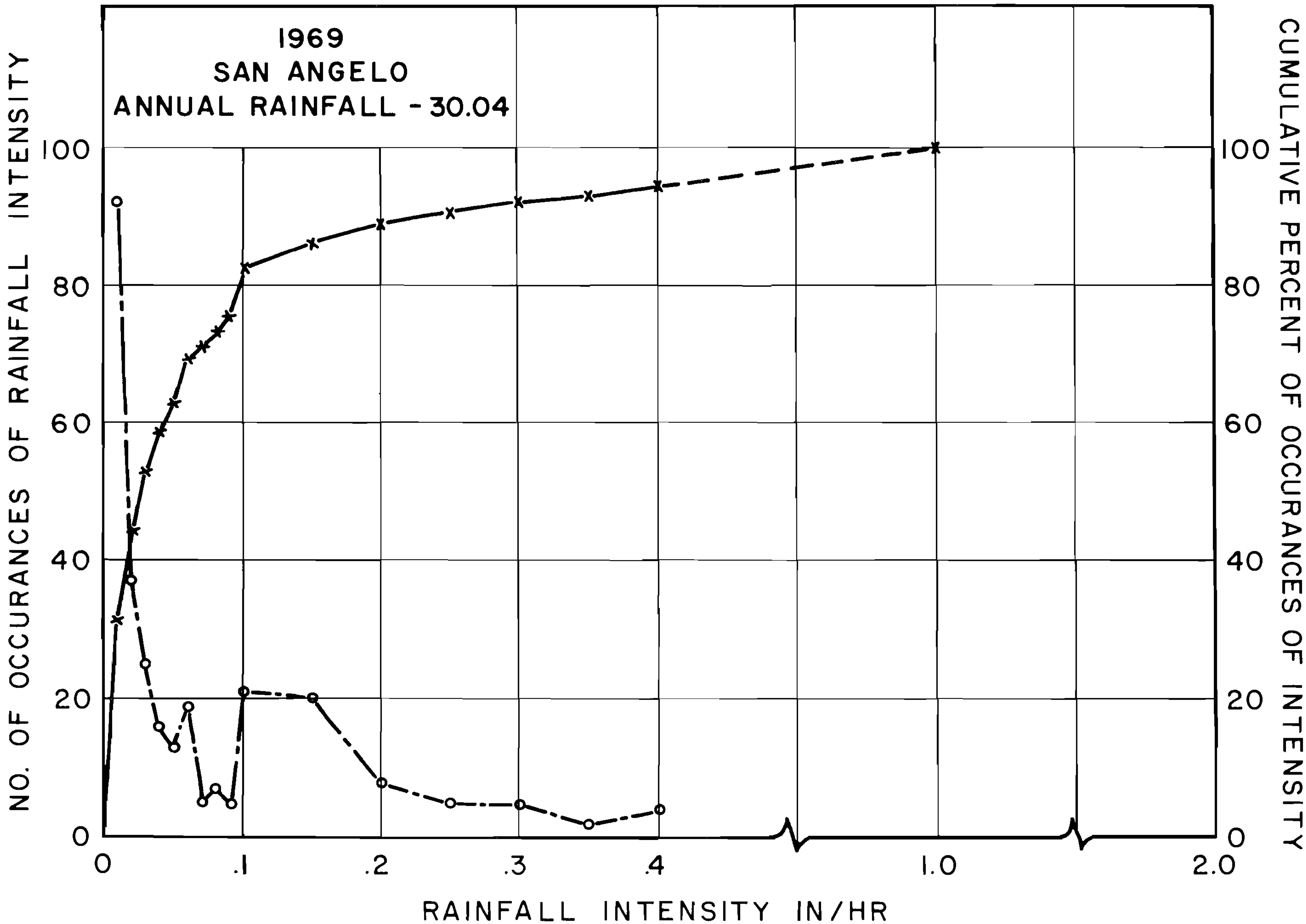

1969
SAN ANGELO
ANNUAL RAINFALL - 30.04
NO. OF OCCURANCES OF RAINFALL INTENSITY
CUMULATIVE PERCENT OF OCCURANCES OF INTENSITY
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 17

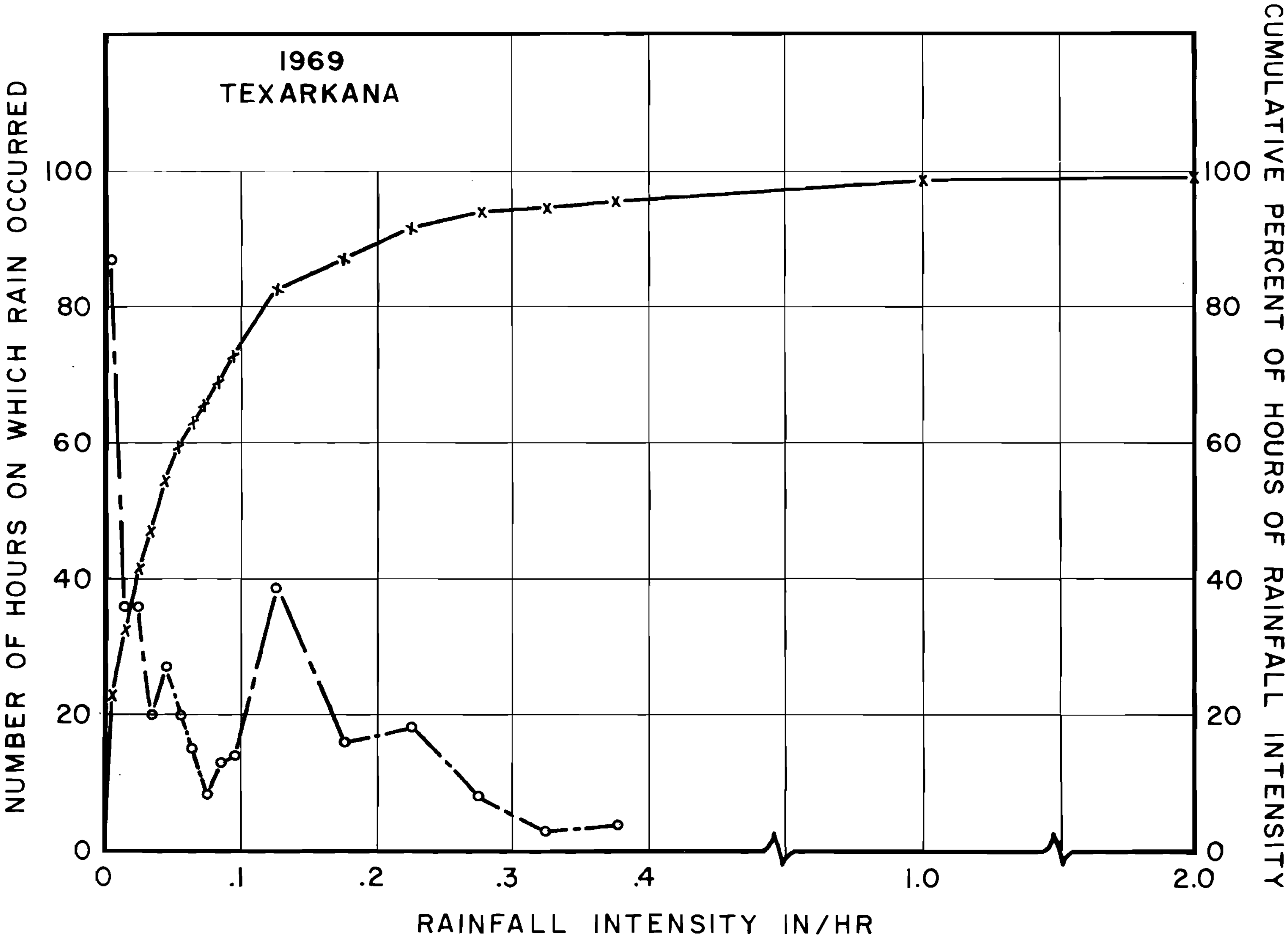

1969
TEXARKANA
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 18

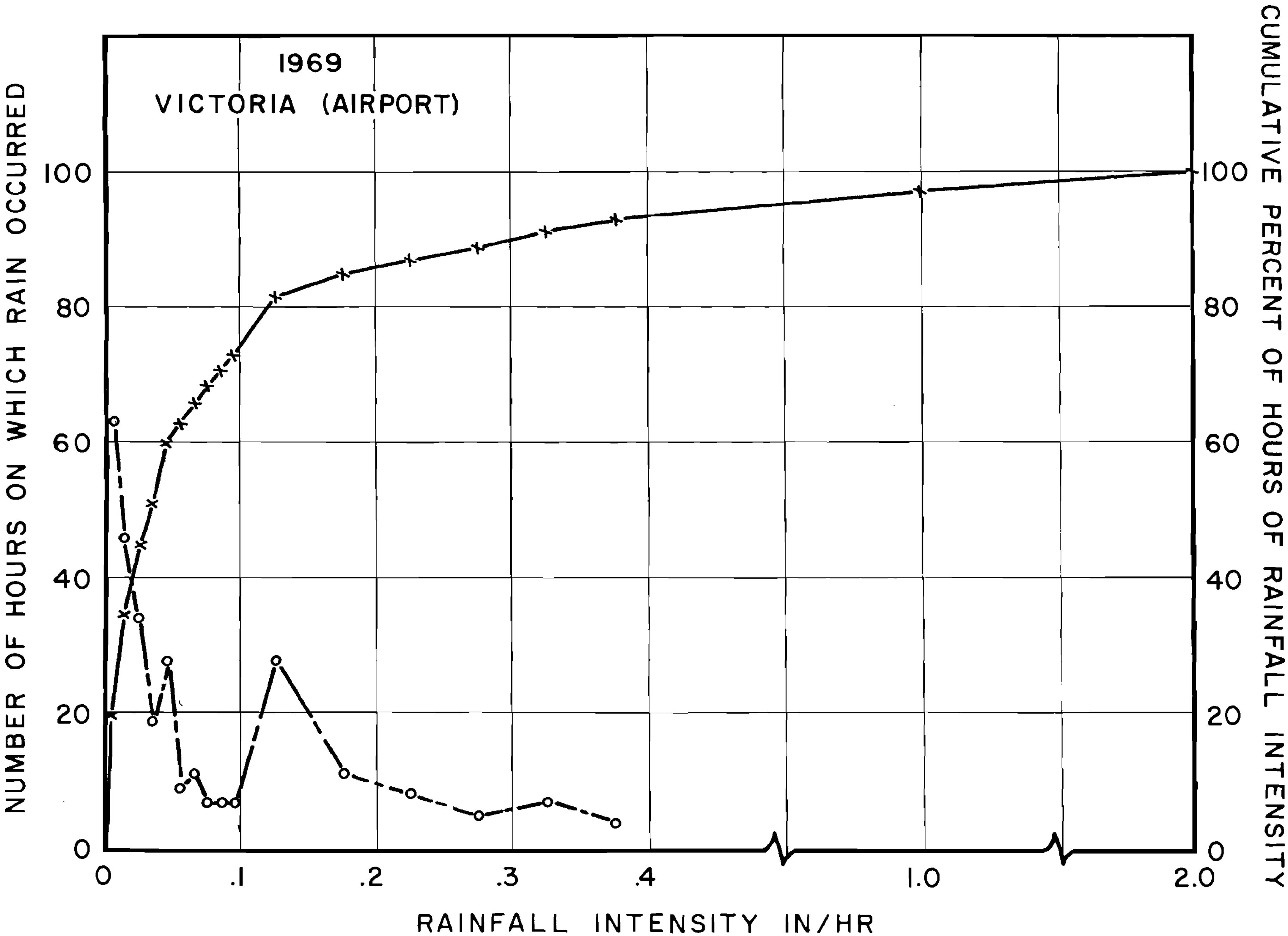

1969
VICTORIA (AIRPORT)
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 19

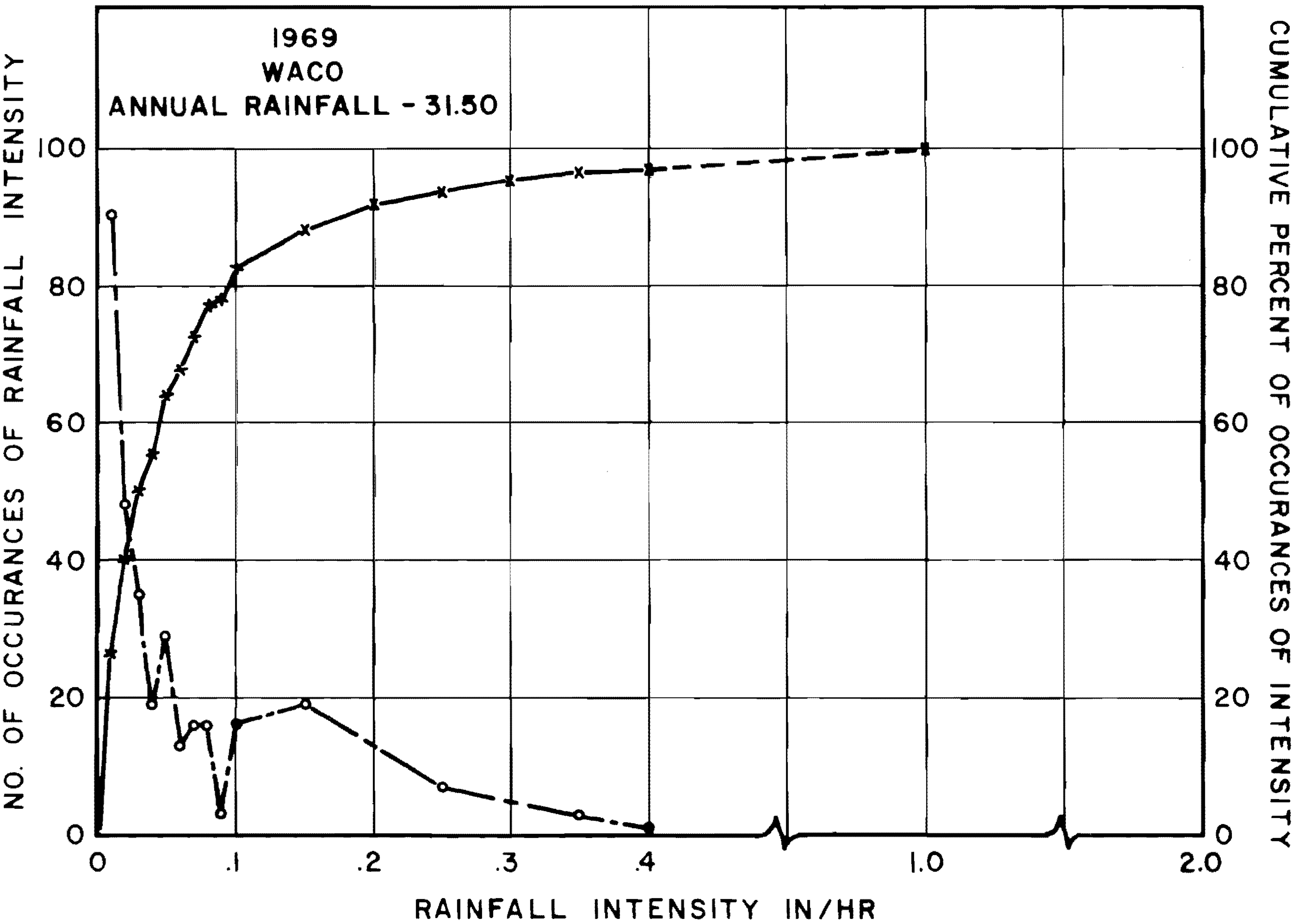
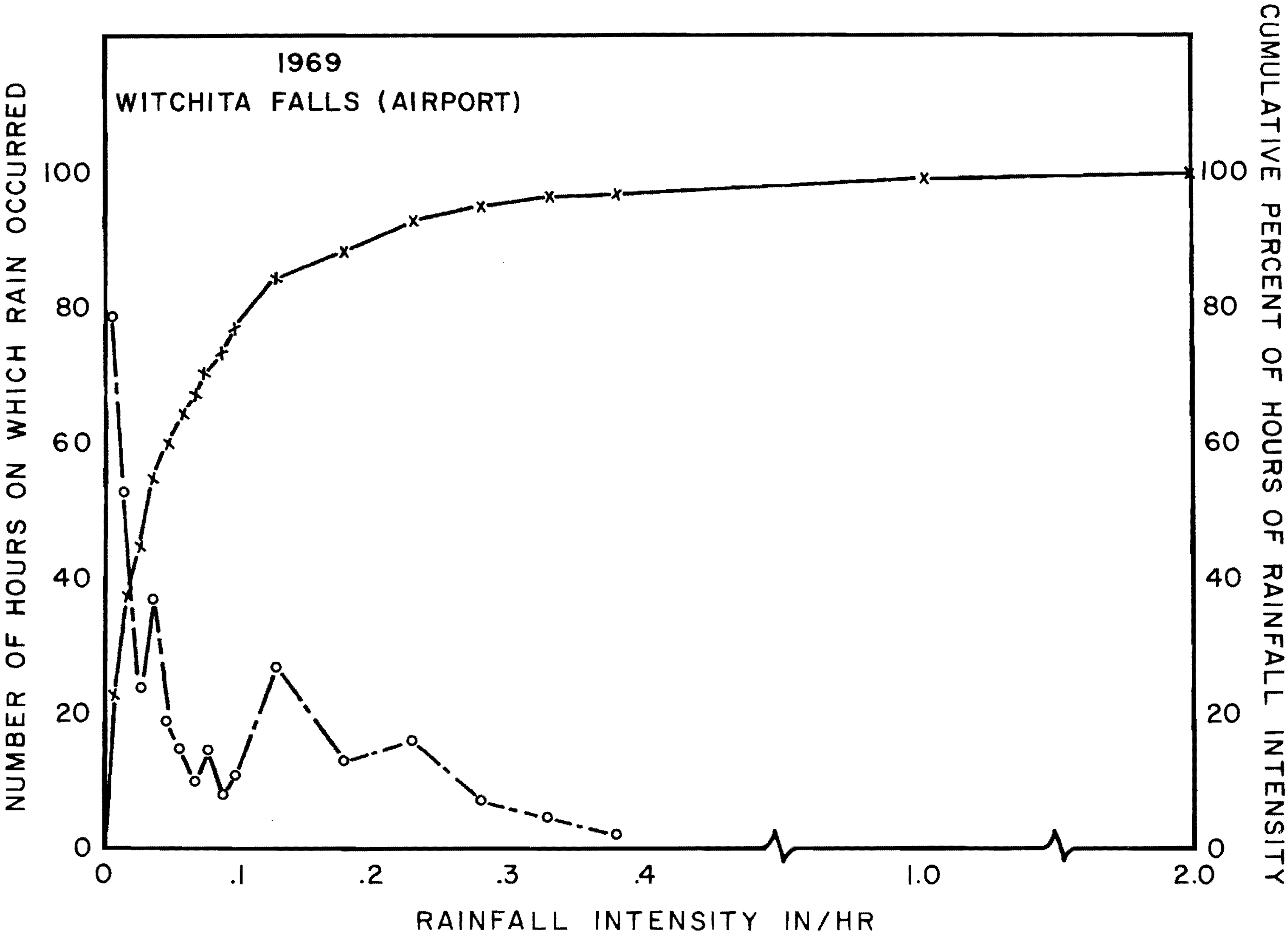

1969
WACO
ANNUAL RAINFALL - 31.50
NO. OF OCCURANCES OF RAINFALL INTENSITY
CUMULATIVE PERCENT OF OCCURANCES OF INTENSITY
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 20



1969
WITCHITA FALLS (AIRPORT)
NUMBER OF HOURS ON WHICH RAIN OCCURRED
CUMULATIVE PERCENT OF HOURS OF RAINFALL INTENSITY
0
20
40
60
80
100
0
.1
.2
.3
.4
1.0
2.0
RAINFALL INTENSITY IN/HR

FIGURE 21

Results of Analysis - Percent Wet Time

The results of the analysis (of % Wet Time for eighteen weather stations) may be found in Table I. Note that the % Wet Time ranges from a low of 2.51 % at El Paso to a high of 9.90% at Port Arthur. As stated previously, the % Wet Time information developed from the sample of eighteen weather stations was correlated with the Total Annual Rainfall at each of the eighteen weather stations as shown in Figure 2. Then the Total Annual Rainfall (average yearly based on the period 1931-1960) for each county was obtained from Figure 3. A % Wet Time for each county was determined by using the Total Annual Rainfall found in Figure 3 and using the correlation curve in Figure 2. The predictions of the % Wet Time for each county may be found in Table II.

TABLE I
Percent Wet Time For 18 Locations
In Texas

	LOCATION	1969 ANNUAL RAINFALL	% WET TIME
1.	AMARILLO	14.91 in.	4.65 %
2.	DEL RIO	17.39 in.	4.57 %
3.	AUSTIN	25.19 in.	7.40 %
4.	CORPUS CHRISTI	29.89 in.	6.85 %
5.	BROWNSVILLE	24.67 in.	6.83 %
6.	ABILENE	21.77 in.	4.95 %
7.	DALLAS	42.97 in.	7.60 %
8.	EL PASO	9.24 in.	2.51 %
9.	FT. WORTH	39.29 in.	7.35 %
10.	PORT ARTHUR	70.67 in.	9.90 %
11.	WACO	28.05 in.	6.28 %
12.	TEXARKANA	40.99 in.	8.30 %
13.	MIDLAND	16.99 in.	4.68 %
14.	WICHITA FALLS	24.62 in.	5.65 %
15.	LUBBOCK	18.42 in.	3.67 %
16.	GALVESTON	53.08 in.	7.41 %
17.	SAN ANGELO	15.82 in.	4.63 %
18.	VICTORIA	35.47 in.	7.87 %

TABLE OF AVERAGE YEARLY RAINFALL
(Based On Data From 1931-1960)

Dist. No.	Co. No.	County Name	Annual Rainfall	% Wet Time	Dist. No.	Co. No.	County Name	Annual Rainfall	% Wet Time	Dist. No.	Co. No.	County Name	Annual Rainfall	% Wet Time	Dist. No.	Co. No.	County Name	Annual Rainfall	% Wet Time
10	1	Anderson	42	8.2	25	65	Donley	21	5.5	16	129	Karnes	30	7.0	7	192	Reagan	16	4.6
6	2	Andrews	15	4.4	21	66	Kenedy	26	6.4	18	130	Kaufman	38	7.9	22	193	Real	24	6.1
11	3	Angelina	49	8.6	21	67	Duval	24	6.1	15	131	Kendall	32	7.3	1	194	Red River	46	8.4
16	4	Aransas	36	7.7	23	68	Eastland	27	6.6	21	66	Kenedy	26	6.4	6	195	Reeves	12	3.7
3	5	Archer	26	6.4	6	69	Ector	13	3.9	8	132	Kent	21	5.5	16	196	Refugio	36	7.7
4	6	Armstrong	20	5.4	22	70	Edwards	20	5.4	15	133	Kerr	28	6.7	4	197	Roberts	21	5.5
15	7	Atascosa	26	6.4	18	71	Ellis	36	7.7	7	134	Kimble	23	5.9	17	198	Robertson	36	7.7
12	8	Austin	40	8.0	24	72	El Paso	8	2.6	25	135	King	22	5.7	18	199	Rockwall	38	7.9
5	9	Bailey	16	4.6	2	73	Erath	29	6.8	22	136	Kinney	20	5.4	7	200	Runnels	22	5.7
15	10	Bandera	30	7.0	9	74	Falls	35	7.6	16	137	Kleberg	26	6.4	10	201	Rusk	46	8.4
14	11	Bastrop	36	7.7	1	75	Fannin	42	8.2	25	138	Knox	24	6.1	11	202	Sabine	51	8.7
3	12	Baylor	25	6.2	13	76	Fayette	37	7.8	1	139	Lamar	45	8.3	11	203	San Augustine	50	8.6
16	13	Bee	30	7.0	8	77	Fisher	21	5.5	5	140	Lamb	17	4.8	11	204	San Jacinto	48	8.5
9	14	Bell	33	7.4	5	78	Floyd	21	5.5	23	141	Lampasas	30	7.0	16	205	San Patricio	30	7.0
15	15	Bexar	28	6.7	25	79	Foard	24	6.1	15	142	LaSalle	23	5.9	23	206	San Saba	27	6.6
14	16	Blanco	32	7.3	12	80	Fort Bend	44	8.3	13	143	Lavaca	37	7.8	7	207	Schleicher	19	5.2
8	17	Borden	18	5.0	1	81	Franklin	46	8.4	14	144	Lee	36	7.7	8	208	Scurry	20	5.4
9	18	Bosque	32	7.3	17	82	Freestone	39	7.9	17	145	Leon	40	8.0	8	209	Shackelford	25	6.2
19	19	Bowie	48	8.5	15	83	Frio	25	6.2	20	146	Liberty	50	8.6	11	210	Shelby	49	8.6
12	20	Brazoria	48	8.5	5	84	Gaines	15	4.4	9	147	Limestone	37	7.8	4	211	Sherman	17	4.8
17	21	Brazos	38	7.9	12	85	Galveston	44	8.3	4	148	Lipscomb	21	5.5	10	212	Smith	45	8.3
24	22	Brewster	13	3.9	5	86	Garza	20	5.4	16	149	Live Oak	27	6.6	2	213	Somervell	31	7.1
25	23	Briscoe	21	5.5	14	87	Gillespie	28	6.7	14	150	Llano	27	6.6	21	214	Starr	18	5.0
21	24	Brooks	24	6.1	7	88	Glasscock	16	4.6	6	151	Loving	11	3.4	23	215	Stephens	26	6.4
23	25	Brown	27	6.6	16	89	Goliad	34	7.5	5	152	Lubbock	18	5.0	7	216	Sterling	18	5.0
17	26	Burleson	37	7.8	13	90	Gonzales	33	7.4	5	153	Lynn	18	5.0	8	217	Stonewall	22	5.7
14	27	Burnet	30	7.0	4	91	Gray	21	5.5	17	154	Madison	41	8.1	7	218	Sutton	19	5.2
14	28	Caldwell	35	7.6	1	92	Grayson	38	7.9	19	155	Marion	47	8.5	5	219	Swisher	19	5.2
13	29	Calhoun	38	7.9	10	93	Gregg	46	8.4	6	156	Martin	16	4.6	2	220	Tarrant	31	7.1
8	30	Callahan	25	6.2	17	94	Grimes	41	8.1	14	157	Mason	25	6.2	8	221	Taylor	23	5.9
21	31	Cameron	25	6.2	15	95	Guadalupe	32	7.3	12	158	Matagorda	43	8.2	6	222	Terrell	12	3.7
19	32	Camp	46	8.4	5	96	Hale	19	5.2	22	159	Maverick	21	5.5	5	223	Terry	17	4.8
4	33	Carson	20	5.4	25	97	Hall	22	5.7	23	160	McCulloch	25	6.2	3	224	Throckmorton	25	6.2
19	34	Cass	48	8.5	9	98	Hamilton	30	7.0	9	161	McLennan	34	7.5	19	225	Titus	46	8.4
5	35	Castro	18	5.0	4	99	Hansford	19	5.2	15	162	McMullen	24	6.1	7	226	Tom Green	20	5.4
20	36	Chambers	50	8.6	25	100	Hardeman	24	6.1	15	163	Medina	29	6.8	14	227	Travis	33	7.4
10	37	Cherokee	45	8.3	20	101	Hardin	52	8.7	7	164	Menard	22	5.7	11	228	Trinity	47	8.5
25	38	Childress	23	5.9	12	102	Harris	46	8.4	6	165	Midland	15	4.4	20	229	Tyler	51	8.7
3	39	Clay	28	6.7	19	103	Harrison	46	8.4	17	166	Milam	35	7.6	19	230	Upshur	46	8.4
5	40	Cochran	16	4.6	4	104	Hartley	17	4.8	23	167	Mills	28	6.7	6	231	Upton	14	4.1
7	41	Coke	20	5.4	8	105	Haskell	23	5.9	8	168	Mitchell	19	5.2	22	232	Uvalde	24	6.1
23	42	Coleman	25	6.2	14	106	Hays	33	7.4	3	169	Montague	31	7.1	22	233	Val Verde	16	4.6
18	43	Collin	38	7.9	4	107	Hemphill	22	5.7	12	170	Montgomery	46	8.4	10	234	Van Zandt	42	8.2
25	44	Collingsworth	22	5.7	10	108	Henderson	41	8.1	4	171	Moore	18	5.0	13	235	Victoria	37	7.8
13	45	Colorado	39	7.9	21	109	Hidalgo	20	5.4	19	172	Morris	47	8.5	17	236	Walker	45	8.3
15	46	Comal	33	7.4	9	110	Hill	34	7.5	25	173	Motley	22	5.7	12	237	Waller	42	8.2
23	47	Comanche	29	6.8	5	111	Hockley	17	4.8	11	174	Nacogdoches	48	8.5	6	238	Ward	11	3.4
7	48	Concho	22	5.7	2	112	Hood	30	7.0	18	175	Navarro	37	7.8	17	239	Washington	39	7.9
3	49	Cooke	34	7.5	1	113	Hopkins	45	8.3	20	176	Newton	54	8.8	21	240	Webb	20	5.4
9	50	Coryell	32	7.3	11	114	Houston	44	8.3	8	177	Nolan	21	5.5	13	241	Wharton	41	8.1
25	51	Cottle	23	5.9	8	115	Howard	20	5.4	16	178	Nueces	28	6.7	25	242	Wheeler	22	5.7
6	52	Crane	13	3.9	24	116	Hudspeth	10	3.2	4	179	Ochiltree	20	5.4	3	243	Wichita	27	6.6
7	53	Crockett	16	4.6	1	117	Hunt	42	8.2	4	180	Oldham	18	5.0	3	244	Wilbarger	25	6.2
5	54	Crosby	20	5.4	4	118	Hutchinson	20	5.4	20	181	Orange	55	8.9	21	245	Willacy	25	6.2
24	55	Culberson	13	3.9	7	119	Irion	18	5.0	2	182	Palo Pinto	28	6.7	14	246	Williamson	33	7.4
4	56	Dallam	16	4.6	2	120	Jack	28	6.7	19	183	Panola	47	8.5	15	247	Wilson	28	6.7
18	57	Dallas	35	7.6	13	121	Jackson	39	7.9	2	184	Parker	29	6.8	6	248	Winkler	12	3.7
5	58	Dawson	17	4.8	20	122	Jasper	52	8.7	5	185	Parmer	17	4.8	2	249	Wise	29	6.8
4	59	Deaf Smith	18	5.0	24	123	Jeff Davis	16	4.6	6	186	Pecos	12	3.7	10	250	Wood	45	8.3
1	60	Delta	45	8.3	20	124	Jefferson	53	8.8	11	187	Polk	49	8.6	5	251	Yoakum	15	4.4
18	61	Denton	32	7.3	21	125	Jim Hogg	20	5.4	4	188	Potter	19	5.2	3	252	Young	26	6.4
13	62	DeWitt	34	7.5	16	126	Jim Wells	26	6.4	24	189	Presidio	12	3.7	21	253	Zapata	18	5.0
25	63	Dickens	21	5.5	2	127	Johnson	32	7.3	1	190	Rains	43	8.2	22	254	Zavala	24	6.1
22	64	Dimmit	22	5.7	8	128	Jones	23	5.9	4	191	Randall	19	5.2					

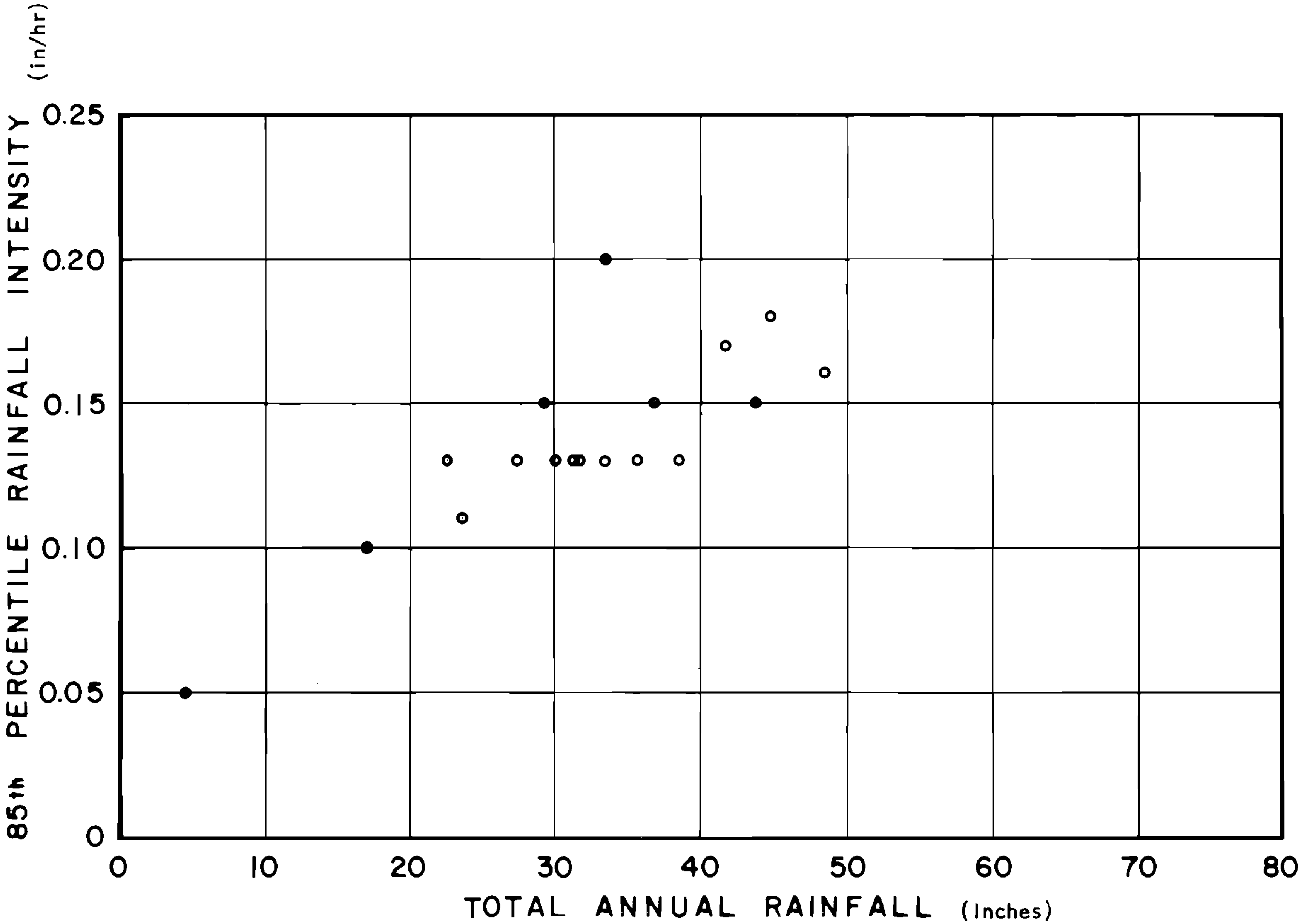
TABLE II
AVERAGE ANNUAL RAINFALL AND PERCENT WET TIME BY COUNTY

Results of Analysis - Design Rainfall Intensity

The 85th percentile value was arbitrarily selected as a design rainfall intensity. In only 15% of rainfall occurances could the intensity be expected to exceed the design intensity. Table III is a list of the 85th percentile rainfall intensities for each of the 18 weather stations selected.

If the Total Annual Rainfall is compared with the 85th percentile rainfall intensity, it may be found that a general trend exists (See Figure 22). In other words, there is a possibility that light rainfalls (smaller intensities) generally occur in arid areas of the state with less total precipitation, but the data does not show an excellent relationship between the two variables. Therefore, it is suggested that the 85th percentile rainfall intensities for the 18 locations be averaged and this value be used for further study. The average 85th percentile rainfall intensity for a one hour measurement period was found to be 0.14 inch per hour.

The distribution of rainfall within a one hour period may be found in Table IV.[6] Table IV indicates the intensity in a five minute duration may be expected to be 3.48 times the average intensity for a one hour measurement period. This means that 29 percent of the rainfall measured within a one hour time period may be expected to fall within a five minute period in the hour. Therefore, the Average 85th Percentile Rainfall Intensity Based on a Five Minute Duration Period may be expected to be 0.50 inch per hour (3.48 X 0.14 inch/hr. = 0.49 or ~0.50 inch per hour).



RELATIONSHIP OF 85th PERCENTILE INTENSITY AND ANNUAL RAINFALL

FIGURE 22

TABLE III

85th PERCENTILE RAINFALL INTENSITY
FOR SEVERAL LOCATIONS

Location	85th Percentile Intensity (in./hr)	Annual Rainfall (in.)
Abilene	0.15	36.84
Amarillo	0.13	22.55
Austin	0.20	33.59
Brownsville	0.13	27.35
Corpus Christi	0.11	23.57
Dallas	0.13	38.55
Del Rio	0.13	33.22
Fort Worth	0.13	35.69
Galveston	0.17	41.79
Lubbock	0.15	29.19
Midland	0.10	16.94
Texarkana	0.15	43.87
Victoria	0.18	44.64
Wichita Falls	0.13	31.61
El Paso	0.05	4.34
Port Arthur	0.16	48.44
San Angelo	0.13	30.04
Waco	0.13	31.50

TABLE IV

MAXIMUM RAINFALL INTENSITY VARIATIONS WITHIN ONE HOUR

Duration of Rainfall Minutes	Maximal Amount of Rain Compared with One Hour Value	Maximal Intensity of Rainfall Compared with One Hour Value
5	0.29	3.48
10	0.45	2.70
15	0.57	2.28
30	0.79	1.58
60	1.00	1.00

After Ivey and Lehtipuu Report 135-3, "Rainfall and Visibility - The View from Behind the Wheel."

Discussion of Results - Percent Wet Time

It would be economically prohibitive to determine the Wet Time for every area of every highway considering the cost of maintaining stations. In large general rainfalls (say fall or winter precipitations) covering large areas, the use of weather stations to represent the county may be justified, but rain showers covering small local areas (say spring or summer precipitation) upset the theory behind the recommendations to be offered. However, it can be assumed that as many local showers fall in the area including the weather station as fall in any other area.

It should be noted that no attempt was made to study or make measurements of the actual drying time of a pavement surface after the surface was wet. Measurements could be made and a study in this area would be most interesting. It is believed that pavement temperature, humidity, ambient temperature, and traffic volumes (vehicle passages) are some of the variables which should be considered in such a study. However, one of the items which would necessarily be defined is : at what point is the pavement considered wet or conversally, once wet, when is a pavement dry? In any event, such a study would be costly and for this study it was believed that such cost would not be justified by the benefit to be derived.

Discussion of Results - Design Rainfall Intensity

The analysis and results of this study are based on a small amount of data and with selective decisions and judgement. The results are considered adequate for use considering the man hours and cost of manually developing additional data.

The selection of weather stations should not concern the reader. They were purposely selected to represent climatological areas of the State and the process should be similar to stratified sampling. However, a larger number of locations would be better.

The 85th percentile rainfall intensity is a matter of judgement. Any percentile could be selected, but the 85th percentile seems to be one which is selected for design most often. Most wet pavement accidents could occur at intensities greater than the 85th percentile. These facts are not known and due to the measurement methods available the facts may not be known for many years.

It should be noted that no rainfall intensity, based on hourly measurements, was found greater than about 3 inches per hour. Very large rainfall intensities have been noted for short time periods. Therefore, the decision was made to extrapolate the intensities from an hourly measurement period to a five minute period. The five minute time period was selected because of the data shown in Table IV but also because of the drainage characteristics of a pavement surface. When the water from a rain initially strikes a pavement surface, little water depth may be noted because the water would flow around the texture asperities or through internal voids. However, with continued water application, increases in depth would be noted. Texture hinders runoff and internal voids may reach drainage capacity. Due to these considerations, a five minute period was selected as an estimate of the worst condition with respect to pavement drainage.

Recommendations

Realizing the inherent inaccuracies in the above analysis it is recommended that:

1. % Wet Time be predicted from the Total Annual Rainfall using Figure 2.
2. An average thirty year record of the Total Annual Rainfall be used as the Total Annual Rainfall value and the contour map found in Figure 3 be used to determine the Total Annual Rainfall value for each County in Texas.
3. The % Wet Time be determined and used for each county to calculate the Wet Weather Accident Rate.
4. The Wet Weather Accident Rates be calculated for each Control-Section on a yearly basis and distributed to Departmental personnel along with the total accident rate.

A computer program has been devised to accomplish the above recommendations and an example of the output may be found in Figure 23.

At the present time, skid resistance measurements are obtained using certain selected test conditions. An example may be tests conforming with ASTM E 274 which specifies skid trailer tests using selected speed(s), tires and watering conditions. With this type of test procedure pavements may be ranked as to skid resistance characteristics. However, little information is developed by which actual wet weather skidding accident events may be studied. Additional information is needed for a better knowledge of skid resistance developed on pavement surfaces. There is a need to study and design pavement surfaces for some of the worst skid resistance conditions that a driver-vehicle may expect. Examples of poor skid resistance conditions which would effect pavement design are (1) tires with low tread depths and (2) large water

COUNTY - AVG ANNUAL RAINFALL =42. INCHES DISTRICT PAGE 1

HIGHWAY	CONT	SEC	LENGTH IN MILES	DAILY VEHICLE MILES	FATAL-ITIES	FAT. ACC.	FAT.+ INJ ACC.	TOTAL ACC.	FATALITY RATE	FATAL ACC RATE	FATAL + INJURY RATE	TOTAL RATE	TOT WET ACC	% WET TIME	WET ACCIDENT RATE	RATIO WET RATE TO TOTAL RATE
SH			8.25	26450	1	1	2	12	10.4	10.4	20.7	124.3	1	7.8	132.2	1.06
SH			11.00	116985	3	3	33	133	7.0	7.0	77.3	311.5	17	7.8	508.2	1.63
US			6.89	30674	0	0	5	13	0.0	0.0	44.7	116.1	0	7.8	0.0	0.0
IH			11.10	119381	1	1	12	36	2.3	2.3	27.5	82.6	6	7.8	175.8	2.13
US			8.93	16288	0	0	4	11	0.0	0.0	67.3	185.0	3	7.8	644.1	3.48
SH			4.53	6068	0	0	2	13	0.0	0.0	67.9	441.5	1	7.8	433.5	0.98
FM			5.58	4659	0	0	1	5	0.0	0.0	58.8	294.0	1	7.8	750.6	2.55
FM			3.63													
FM			3.20													
			6.83	11065	0	0	8	22	0.0	0.0	198.1	544.7	2	7.8	632.1	1.16
FM			26.52	14294	0	0	2	15	0.0	0.0	38.3	287.5	3	7.8	734.0	2.55
FM			9.94	5775	0	0	1	4	0.0	0.0	47.4	189.8	0	7.8	0.0	0.0
SP			0.76	3153	0	0	0	2	0.0	0.0	0.0	173.8	0	7.8	0.0	0.0
FM			7.22	1689	0	0	0	1	0.0	0.0	0.0	162.2	0	7.8	0.0	0.0
FM			25.36	20009	0	0	9	21	0.0	0.0	123.2	287.5	4	7.8	699.1	2.43
FM			5.74	867										7.8		
FM			6.19	2296	0	0	1	2	0.0	0.0	119.3	238.7	0	7.8	0.0	0.0
FM			1.70	1720	0	0	1	1	0.0	0.0	159.3	159.3	0	7.8	0.0	0.0
FM			5.44	1838	0	0	0	3	0.0	0.0	0.0	435.3	0	7.8	0.0	0.0
FM			8.04	1222										7.8		
FM			9.14	1618										7.8		
FM			13.73	4929	0	0	1	5	0.0	0.0	55.6	277.9	0	7.8	0.0	0.0
FM			6.07	2167	0	0	1	1	0.0	0.0	126.4	126.4	0	7.8	0.0	0.0
FM			9.58	3171	0	0	1	3	0.0	0.0	86.4	259.2	0	7.8	0.0	0.0

EXAMPLE OF ACCIDENT RATE INFORMATION

Figure 23

depths on the pavement surface. By measuring tire tread depths in actual operating conditions or water depths in expected rainfall conditions, design criteria may be developed.

Through previous research efforts, a model has been developed to predict pavement water depth. It has been found that pavement water depth may be predicted by rainfall intensity, runoff slope, runoff length and texture. The last three variables may be established by the design engineer. Rainfall intensity is a function of nature and a design intensity must be established by a study of environmental conditions. This study is included herein.

5. It is recommended that the design rainfall intensity be considered as 0.50 inch per hour.

Conclusions

Reduction in accidents is apparently a slow process which at times seems nill because vehicular miles of travel accumulate faster than reduction in the number of accidents. Because of this fact accident rates and particularly wet weather accident rates are needed for comparison purposes. The major study accomplished by District or safety personnel should be the comparison of wet to dry rates on the same highway. It has been found that the % Wet Time varies from around 2 to 10 percent across the state. Wet Weather Accident Rates are generally 2 to 4 times higher than the Total Accident Rate and Wet Weather Accident Rates can be found as much as 10 times higher than the Total Accident Rate.

REFERENCES

1. "Highway Traffic Accident Tabulation and Rates by Control and Section", State Dept. of Highways and Public Transportation, Division of Maintenance Operations, Traffic Engineering Section, yearly.
2. "Highway Traffic Accident Analysis-Accident Detail Listing", State Dept. of Highways and Public Transportation, Division of Maintenance Operations, Traffic Engineering Section, yearly.
3. Gallaway, Bob M.; Schiller, Robert E. Jr.; and Rose, Jerry G.; "The Effects of Rainfall Intensity, Pavement Cross Slope, Surface Texture, and Drainage Length on Pavement Water Depths", Research Report 138-5; State Department of Highways and Public Transportation, and Texas Transportation Institute May 1971.
4. Bell, Cliff; "Computer Program for Analysis of the Frequency of Wet Pavement Curve Accidents", unpublished, 1967.
5. "Local Climatological Data", Environmental Data Service, U. S. Department of Commerce, National Oceanic and Atmospheric Administration.
6. Ivey, Don L. and Lehtipuu, Eero K.; "Rainfall and Visibility - The View From Behind the Wheel", Research Report 135-3, State Department of Highways and Public Transportation, Texas Transportation Institute, August 1974.