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EXCESSIVE PRECIPITATION IN ARKANSAS.

By H. S. COLE, Meteorologist.

[Weather Bureau, Little Rock, Ark., Sept. 6, 1921.]

SYNOPSIS.

The following article is based upon all excessive precipitation records at Bentonville, Fort Smith, and Little Rock, the three regular Weather Bureau stations in Arkansas, and at Memphis, Shreveport, and Vicksburg, three near-by stations. Extreme rates, average rates for consecutive five-minute periods, and number of occurrences for different rates and different periods of time are tabulated. Curves are prepared showing these extremes, averages, and number of occurrences, also curves showing the number of tabulations of excessive precipitation by months and curves showing the number of times per year different rates for different periods have occurred. The data and curves are explained in the test.

The following article was prepared to meet the needs of engineers, contractors, agriculturists, and other persons whose business is affected by excessive precipitation.

All records of excessive precipitation at Bentonville, Fort Smith, Little Rock, Memphis, Shreveport, and Vicksburg were used. The data were tabulated and the means, extremes, and the number of times of occurrence determined. Curves were drawn showing the extremes, averages, cumulative amounts, frequency of stated rates in given times and the number of times excessive precipitation occurred at the different stations in the different months.

Precipitation records from automatic instruments at Bentonville are available for the past 15 years, at Fort Smith for 19 years, and at Little Rock for 24 years, covering the central, western, and northwestern portions of the State very well, but there are no other stations in Arkansas with such records. Fortunately, however, Memphis, with a 24-year record, is just across the Mississippi River; Shreveport, with a 19-year record, is 35 miles south of the southwest corner of the State; and Vicksburg, with a 24-year record, is 45 miles south and slightly east of the southeast corner. It is thought that the records of these stations are fairly representative of conditions in Arkansas. The greater portion of the data was obtained from the published reports of the Chief of the Weather Bureau and the MONTHLY WEATHER REVIEW; the data that could not be obtained from these were kindly furnished by the officials in charge of the stations mentioned.

The data used are from tipping-bucket rain-gages, the rainfall being recorded in hundredths of an inch on timed sheets. It may be well to explain that the limit at which precipitation is considered as "excessive" by the Weather Bureau is fixed at 0.25 of an inch or more in five minutes, 0.30 inch in 10 minutes, 0.35 inch in 15 minutes, etc., the limit increasing 0.05 for each successive five minutes. The rate is considered excessive even if it does not equal the rate stated in the first few periods if it equals or exceeds that rate later. The tabulation does not begin until the rate equals 0.05 inch in five minutes and ends as soon as the rate falls below this value unless it falls below for only a short time, then becomes excessive again. Precipitation is also considered excessive when 1 inch occurs in 1 hour or 2.50 inches in 24 hours.

All available excessive precipitation data for the stations mentioned were tabulated in chronological order by months and the amounts for the 5-minute periods up to 60 minutes were determined. The greatest amount for any 5-minute period, 10-minute period, etc., was obtained for each station as shown in Table 1. This table is in the form in which such data are used in the Weather Bureau, but runoff formulæ for small areas and short periods of excessive precipitation require the precipitation in rate per hour instead of amounts that occur in short periods. For this reason the data in Table I and other data except for 24-hour periods were reduced to rate per hour.

The average rate per hour for the consecutive 5-minute periods for the first 60 minutes of the excessive periods was determined, the results being shown in Table 2.

TABLE 1.—*Greatest precipitation ever recorded in 5 minutes, 10 minutes, etc.*

	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.	24 hr.
Bentonville (1906–1920)	0.75	1.20	1.58	1.62	1.72	1.84	1.84	1.99	2.09	2.15	2.23	2.32	2.41	2.73	5.10
Fort Smith (1902–1920)	0.57	0.97	1.14	1.29	1.52	1.73	1.79	1.92	2.01	2.03	2.06	2.31	2.70	2.70	5.14
Little Rock (1897–1920)	0.50	0.82	1.12	1.34	1.62	1.92	2.12	2.23	2.29	2.29	2.42	2.60	2.84	3.23	9.58
Memphis (1897–1920)	0.78	1.01	1.08	1.26	1.39	1.45	1.45	1.57	1.69	1.79	1.97	2.33	2.50	2.84	9.30
Shreveport (1902–1920)	0.59	0.95	1.20	1.54	1.76	2.00	2.23	2.43	2.57	2.72	3.15	3.61	4.34	5.13	8.45
Vicksburg (1897–1920)	0.74	1.10	1.37	1.73	2.02	2.30	2.56	2.68	2.82	2.94	3.11	3.27	3.52	3.94	7.99
Greatest any station	0.78	1.20	1.58	1.73	2.02	2.30	2.56	2.68	2.82	2.94	3.15	3.61	4.34	5.13	9.58

TABLE 2.—*Average rate per hour for consecutive 5-minute periods.*

	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	55 min.	60 min.
Bentonville (1906–1920)	2.16	2.28	1.56	1.44	1.56	1.32	1.32	1.20	1.32	0.96	0.84	0.84
Fort Smith (1902–1920)	1.80	1.92	1.68	1.44	1.20	1.20	0.96	0.96	0.96	0.72	0.84	0.60
Little Rock (1897–1920)	1.80	2.04	1.68	1.56	1.32	1.20	1.08	0.96	1.08	0.96	1.08	0.96
Memphis (1897–1920)	1.68	1.92	1.56	1.20	1.20	1.08	1.08	0.96	0.96	1.08	1.20	0.72
Shreveport (1902–1920)	2.04	2.16	2.02	1.68	1.44	1.20	1.32	1.32	1.32	1.20	1.20	0.72
Vicksburg (1897–1920)	1.92	2.28	1.80	1.56	1.32	1.20	1.20	1.32	1.20	1.08	0.96	0.96
Average six stations	1.92	2.19	1.80	1.56	1.32	1.20	1.20	1.20	1.08	0.96	0.96	0.96

TABLE 3.—*Number of times given rate per hour occurred for 10 minutes, 30 minutes, 1 hour.*

Rate per hour.	Bentonville. Number of times—	Fort Smith. Number of times—		Little Rock. Number of times—		Memphis. Number of times—		Shreveport. Number of times—		Vicksburg. Number of times.	
	1906–1920.	1906–1920.	1902–1920.	1906–1920.	1897–1920.	1906–1920.	1897–1920.	1906–1920.	1902–1920.	1906–1920.	1897–1920.
For 10 minutes:											
6.00	1	0	(0)	0	(0)	1	(1)	0	(0)	3	(4)
4.80	4	1	(1)	0	(0)	1	(1)	6	(6)	4	(7)
3.60	17	5	(7)	11	(20)	6	(10)	32	(38)	33	(50)
2.40	80	45	(52)	65	(105)	45	(84)	108	(138)	125	(193)
1.20	190	153	(181)	247	(370)	222	(333)	266	(349)	356	(556)
For 30 minutes:											
4.00	0	0	(0)	0	(0)	0	(0)	1	(1)	1	(1)
3.60	1	0	(0)	0	(0)	0	(0)	1	(2)	1	(1)
2.80	5	3	(3)	0	(4)	0	(1)	9	(11)	8	(13)
2.00	19	8	(9)	13	(27)	10	(17)	34	(44)	39	(61)
1.20	75	46	(56)	83	(133)	74	(117)	96	(126)	132	(207)
.80	107	85	(103)	147	(219)	124	(192)	143	(192)	194	(294)
For 1 hour:											
3.00	0	0	(0)	0	(0)	0	(0)	1	(1)	1	(1)
2.50	0	0	(0)	0	(0)	0	(0)	1	(2)	1	(3)
2.00	2	3	(3)	1	(4)	0	(0)	6	(9)	5	(8)
1.50	7	6	(6)	5	(10)	6	(7)	16	(22)	25	(36)
1.00	31	15	(18)	31	(53)	20	(37)	45	(64)	62	(99)
.60	80	58	(72)	93	(146)	78	(129)	104	(136)	145	(223)

The number of 10-minute periods with precipitation at the rate of 1.20 inches per hour or more, 2.40 inches per hour or more, etc., was determined, also the number of 30-minute periods with a rate of 0.80 inch or more per hour, 1.20 inches or more per hour, etc., and the number of 60-minute periods with a rate of 0.60 inch or more per hour, 0.80 inch or more, etc., the data being found in Table 3. For the purpose of comparison such data should be for the same period at all stations. The record at Bentonville is for the period 1906 to 1920, so the data at all stations were obtained for that period, the numbers for the entire period at each station being inclosed in parentheses. The number of 24-hour periods with 1 inch or more precipitation, 2 inches or more, etc., was determined as in Table 4. The data for this table are for the 15-year period and for the entire period of record, the latter being in parentheses.

The number of times excessive precipitation was tabulated at the different stations is shown by months in Table 5, the data being for 15 years.

TABLE 4.—*Number of times given rate per 24 hours occurred.*

Rate per 24 hours.	Bentonville. Number of times.	Fort Smith. Number of times.		Little Rock. Number of times.		Memphis. Number of times.		Shreveport. Number of times.		Vicksburg. Number of times.	
	1906–1920	1906–1920	1897–1920	1906–1920	1897–1920	1906–1920	1897–1920	1906–1920	1897–1920	1906–1920	1897–1920
9.00	0	0	(0)	1	(1)	1	(1)	0	(0)	0	(0)
8.00	0	0	(0)	1	(1)	1	(1)	1	(3)	0	(0)
7.00	0	0	(0)	1	(1)	2	(2)	3	(6)	1	(3)
6.00	0	0	(0)	1	(2)	3	(3)	3	(6)	1	(4)
5.00	1	2	(3)	3	(4)	3	(5)	4	(7)	3	(8)
4.00	4	3	(8)	6	(9)	7	(13)	7	(12)	10	(17)
3.00	12	6	(18)	15	(24)	15	(27)	14	(24)	33	(45)
2.00	28	23	(49)	45	(73)	43	(68)	37	(55)	72	(100)
1.00	147	112	(197)	190	(300)	187	(300)	174	(264)	282	(342)

TABLE 5.—*Number of times excessive rate was tabulated, by months (1906 to 1920).*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Bentonville	2	2	1	7	14	19	16	12	13	6	2	0	94
Fort Smith	1	3	2	5	13	12	9	13	10	7	2	0	77
Little Rock	5	2	6	17	11	16	18	20	13	11	7	1	127
Memphis	3	4	4	14	15	14	13	22	14	14	5	2	125
Shreveport	1	3	8	15	20	17	11	20	7	6	5	5	118
Vicksburg	12	10	13	22	9	13	21	17	12	9	7	7	152

TABLE 6.—*Number of occurrences per year.*

Rate per hour.	Bentonville (15 years).	Fort Smith (19 years).	Little Rock (24 years).	Memphis (24 years).	Shreveport (19 years).	Vicksburg (24 years).
10-MINUTE PERIODS.						
6.00	0.07	.00	0.00	0.04	0.00	0.17
4.80	0.27	0.05	0.00	0.04	0.32	0.29
3.60	1.13	0.37	0.08	0.42	2.00	2.08
2.40	5.30	2.70	4.40	3.50	7.30	8.00
1.20	12.70	9.50	15.40	13.90	18.40	23.20
30-MINUTE PERIODS.						
4.00	0.00	0.00	0.00	0.00	0.05	0.04
3.60	0.07	0.00	0.00	0.00	0.11	0.04
2.80	0.33	0.16	0.17	0.04	0.58	0.54
2.00	1.30	0.50	1.10	0.70	2.30	2.50
1.20	5.00	3.00	5.50	4.90	6.60	8.60
0.80	7.10	5.40	9.10	8.00	10.10	12.20
60-MINUTE PERIODS.						
3.00	0.00	0.00	0.00	0.00	0.05	0.04
2.50	0.00	0.00	0.00	0.00	0.11	0.12
2.00	0.13	0.16	0.17	0.00	0.47	0.33
1.50	0.47	0.32	0.42	0.29	1.16	1.50
1.00	2.10	1.00	2.20	1.50	3.40	4.10
0.60	5.30	3.70	6.00	5.30	7.10	9.30
24-HOUR PERIODS.						
Rate per 24 hours.	(15-year.)	(24-year.)	(24-year.)	(24-year.)	(24-year.)	(24-year.)
9.00	0.00	0.00	0.04	0.04	0.00	0.00
8.00	0.00	0.00	0.04	0.04	0.12	0.00
7.00	0.00	0.00	0.04	0.08	0.25	0.12
6.00	0.00	0.00	0.08	0.12	0.25	0.17
5.00	0.07	0.12	0.17	0.21	0.29	0.33
4.00	0.27	0.33	0.38	0.54	0.50	0.71
3.00	0.80	0.08	1.10	1.10	1.10	1.90
2.00	1.90	2.00	3.00	2.80	2.30	4.20
1.00	9.80	8.20	12.50	12.50	11.00	14.20

The average number of occurrences per year of the different rates for the 10-minute, 30-minute, 60-minute, and 24-hour periods at the six stations is shown in Table 6. The table shows the length of record used in each case. As these numbers are averages for the different stations and are not desired so much for comparison as for showing what has occurred during the period of observation, the record for the 24 years was used where available, for a shorter period where necessary.

The data for a number of individual storms from which the greatest rates on record were obtained were converted into rate per hour for use in preparing curves of the first set. The broken lines of this set of curves show the greatest rates of precipitation per hour on record at each of the stations for 5 minutes, 10 minutes, etc., up to 120 minutes. The rates per hour during the storms in which the greatest rates occurred are charted on the axes with the greatest rates on record, solid line curves being used. It will be noted that the curves for the greatest rates on record do not usually coincide with the curves of the storms in which they occur, but that they do usually touch or come near them at some point. Vicksburg is the only station at which the curves coincide for the first five minutes. This is because the greatest rate for five minutes does not usually occur in the first five minutes after the excessive rate begins. When charted in the individual storms the greatest rate for five minutes is combined with the lower rates preceding. The greatest rates for the different periods are not found in any one storm at any station, the short periods being found in one storm, the longer ones in other storms. At Little Rock the greatest rates for the 5, 10, and 15 minute periods are found in the storm of May 29, 1900; those for 20 and 25 minutes occurred on May 21, 1898; those for 30, 35, 40, and 45 minutes on July 11, 1903; those for 50, 55, and 60 minutes, on August 9–10, 1915; for 65 and 70 minutes, May 5, 1907; and for the remainder, on April 9, 1913.

For many purposes the amounts of precipitation in short periods are desirable, and for such cases we have placed an insert in the upper right-hand corner of the rectangles for the first set of curves and have drawn curves for the greatest amounts in 5 minutes, 10 minutes, etc., up to 120 minutes for each of the stations. Such curves are frequently called cumulative or mass curves, and indicate much more plainly the variation in the rate of fall at a given time than curves for rate per hour.

It may be of advantage to know in what portion of the shower the heaviest precipitation has occurred. For this purpose the curves of the second set were prepared from the data in Table 2, showing the average rate per hour for the successive 5-minute periods. These curves show that the rate usually increases rapidly the first 5 minutes, continues high for about 10 minutes, decreases rapidly the next 5 minutes, then decreases slowly until the rate ceases to be excessive. The curve for the data at Bentonville is higher in the first three periods that those at the other stations. This is due to the fact that excessive precipitation at that place nearly always occurs in connection with a thunderstorm of the Plains States type—intense for a few minutes, then over. The surface air becomes intensely heated in summer, causing strong convective currents, which result in the intense thunderstorms of that section; but the moisture of the air is insufficient to build up the extensive thunderstorms, such as occur farther southeast. Moderate precipitation frequently occurs at Fort Smith and Bentonville in winter, but these places are cut off from the easterly to southerly winds to a great extent by the mountains, causing much lighter rainfall at that season than occurs farther southeast.

Remarks on Table 5.—Excessive precipitation was recorded very few times from November to April, none having been recorded at Fort Smith and Bentonville in December. The number of times was large at all stations from April to August, the largest number being 22 times at Memphis and Vicksburg, the former in August, the latter in April. Fort Smith is the only station at which the greatest number of tabulations of excessive precipitation occurs in the month having the greatest monthly precipitation, and at this station data for a longer period changes it to another month.

It is a well-known fact that monthly and annual precipitation increases from northwestern Arkansas toward the southeast, but it is plain from the curves of sets one, two and three[1] that the greatest rates for short intervals do not. The geographic distribution for short intervals is very irregular. The first set of curves shows that the greatest rate for a 5-minute period is 9.36 inches per hour at Memphis; the next greatest, 9 per hour at Bentonville, Vicksburg being third, with 8.88 inches. The greatest rate for a 10-minute period was 7.20 inches per hour at Bentonville, the second highest being 6.66 inches per hour at Vicksburg. The greatest rate for a 30-minute period was 4.60 inches per hour at Vicksburg; the next greatest, 4 inches at Shreveport. If we accept the record at Fort Smith for August 7–8, 1898, before the tipping-bucket record at that place began, the greatest rate on record at that station for one hour is 3.25 inches; Shreveport being a close second, with 3.15 inches; Vicksburg third, with 3.11 inches. Memphis, the station having the greatest rate per hour for five minutes, has the least for one hour, 1.97 inches. The greatest rate per hour for two hours is 2.56 inches at Shreveport, 1.97 inches being recorded at Vicksburg for the same period. The greatest amount for any 24-hour period on record

[1] Third set not reproduced: EDITOR.

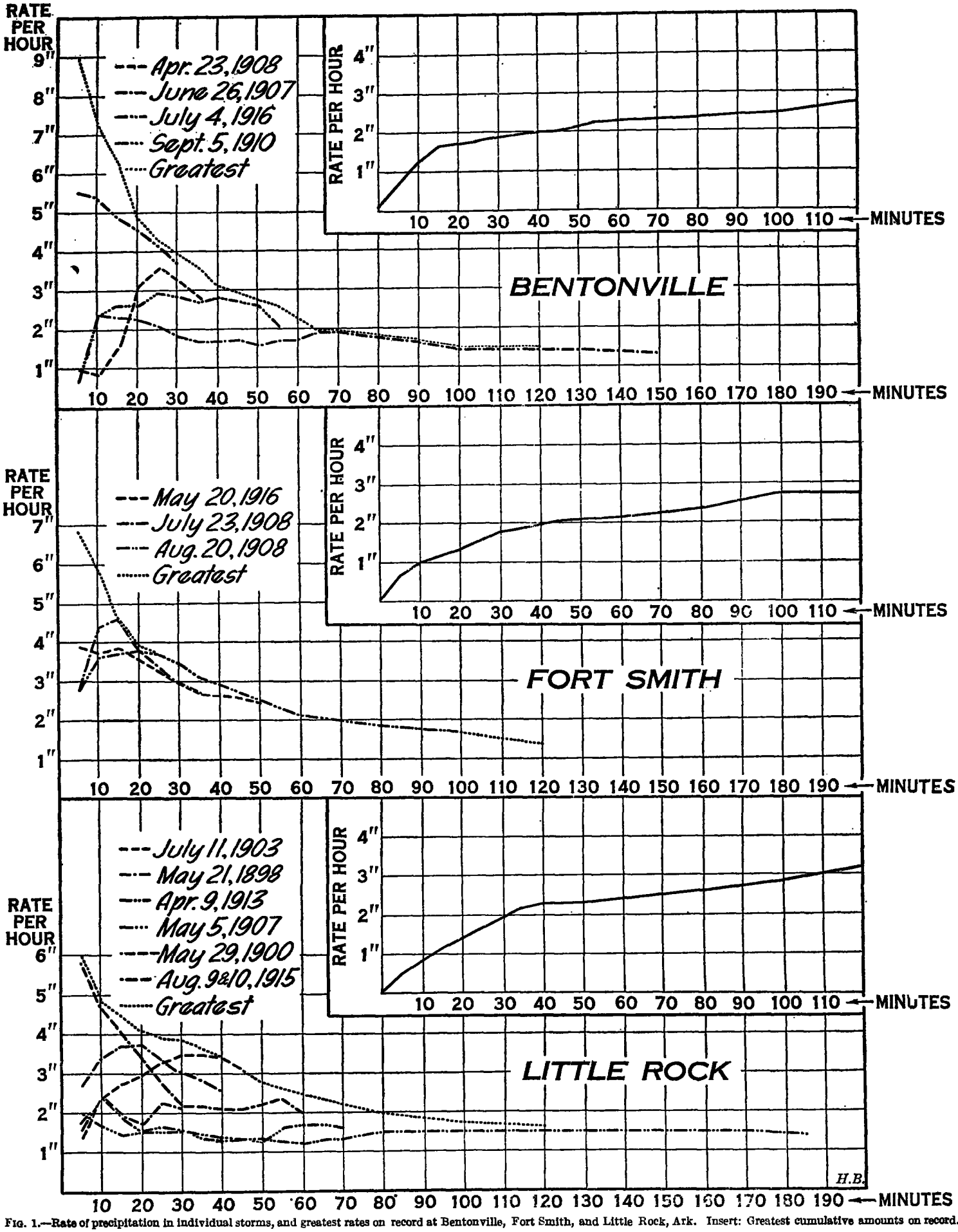

FIG. 1.—Rate of precipitation in individual storms, and greatest rates on record at Bentonville, Fort Smith, and Little Rock, Ark. Insert: Greatest cumulative amounts on record.

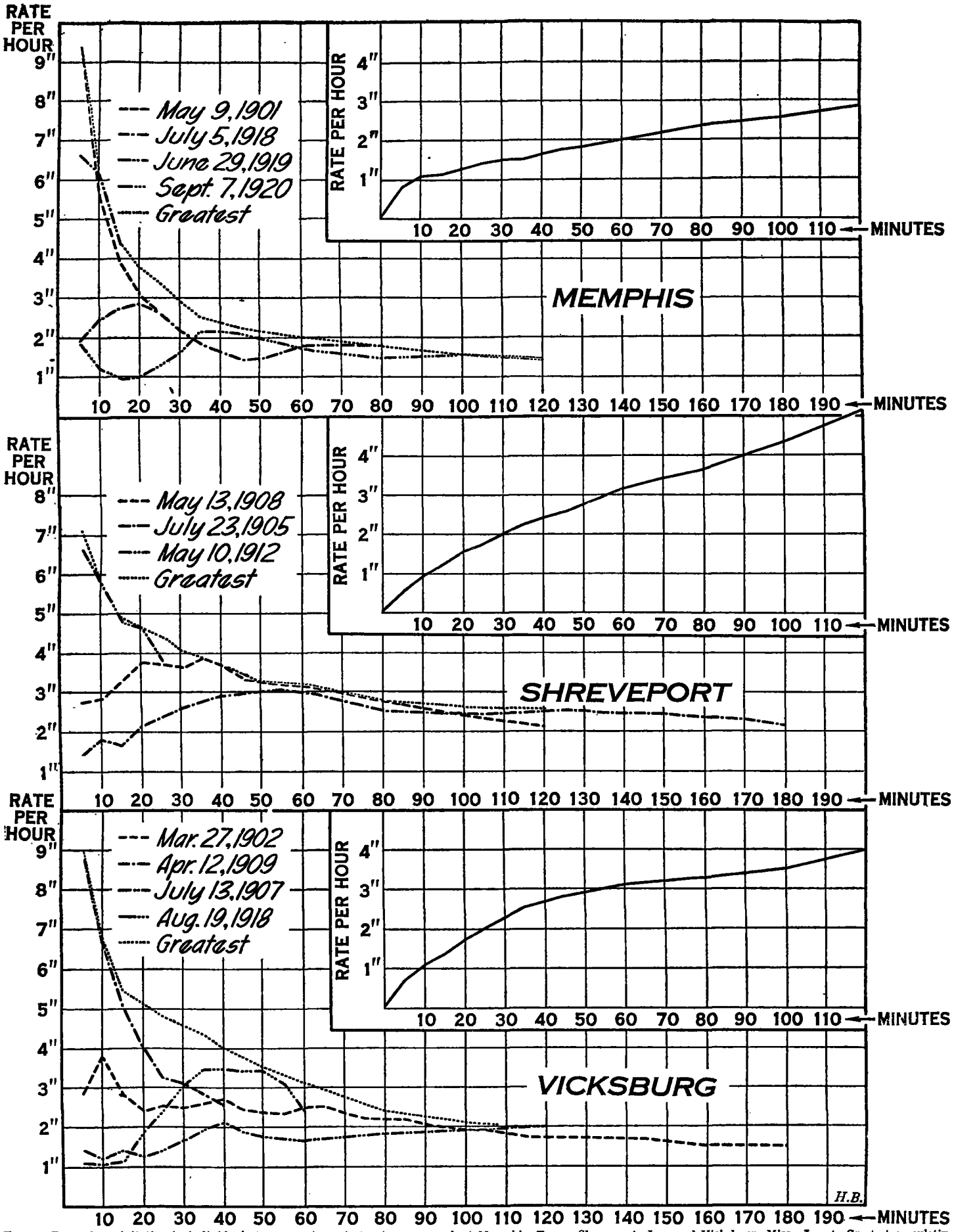

FIG. 2.—Rate of precipitation in individual storms, and greatest rates on record at Memphis, Tenn., Shreveport, La., and Vicksburg, Miss. Insert: Greatest cumulative amounts on record.

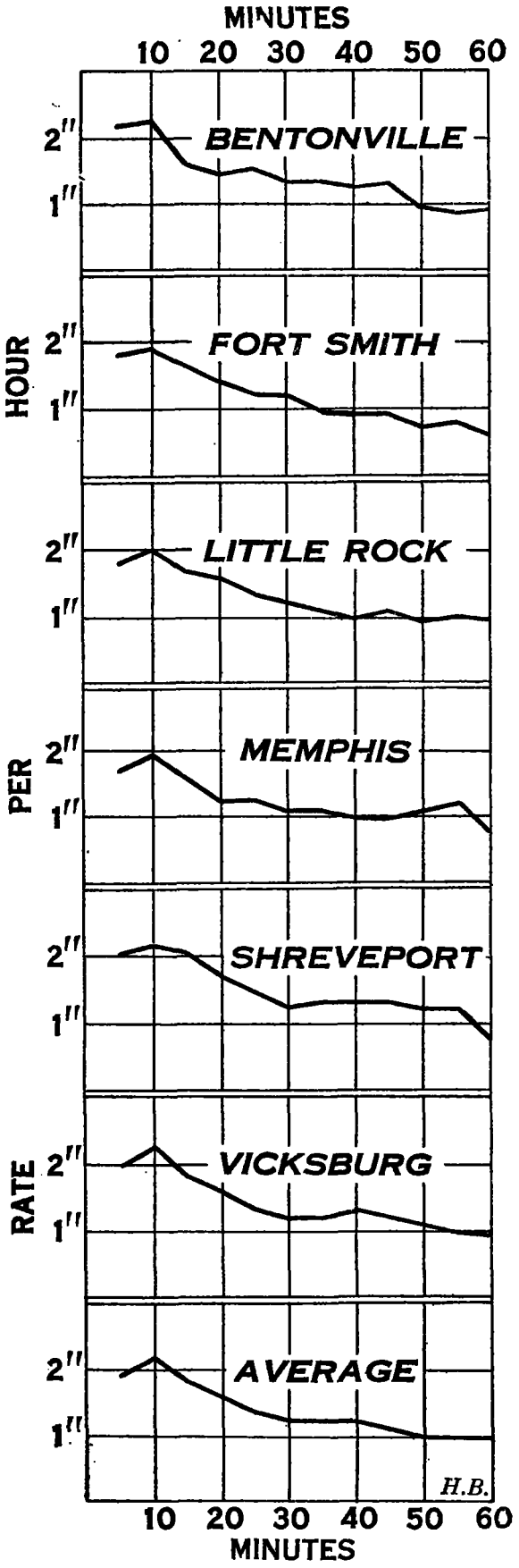

FIG. 3.—Average rate of precipitation per hour (consecutive five-minute periods) at various stations.

at any station in the past 24 years is 9.58 inches at Little Rock, April 8–9, 1913, the next highest being 9.30 inches at Memphis, March 16, 1919, Shreveport being third, with 8.45 inches. Each of the stations has furnished one of the greatest rates, but it will be noted that the greatest amounts northwest of the Ozarks have been but little over 5 inches. The rates for the longer periods increase from northwest to southeast except the 24-hour periods at Little Rock and Memphis.

The distribution of the number of occurrences is somewhat similar. The number of occurrences of high rates per hour for 5-minute and 10-minute periods is about as great at Bentonville as at any station, but for the lower rates the number increases toward the southeast.

Curves for the six stations were drawn on the same axes, showing the average number of occurrences per year for the different rates for the 10-minute periods, similar curves being drawn for the 30-minute, 60-minute, and the 24-hour periods. The data will be found in Table VI. The curves for Little Rock and Memphis usually are near each other and are near the center of the group of curves. The Vicksburg curve usually forms the upper limit and the Fort Smith curve the lower limit, except for the 24-hour periods where the one for Bentonville is lower. The Shreveport curve is usually near the one for Vicksburg and the curve for Bentonville near the one for Fort Smith except for the 5-minute periods.

On June 13, 1877, a 24-hour rainfall of 9.67 inches occurred at Memphis, which is not included in the tables. This was 42 years before the 9.30 inches which occurred at Memphis and two years before the record at Little Rock began.

At Arkadelphia, a substation 65 miles southwest of Little Rock, 12 inches of rainfall occurred on June 28, 1905. No other amounts of over 8 inches have been reported at substations in the State, one of the records beginning in 1840.

The unusual amount at Arkadelphia was quite local. One 6-inch rain and several 2-inch rains were reported in the State on that date, but at most stations less than an inch occurred. When the 9.58 inches occurred at Little Rock, heavy rainfall was general over the State, nine of the 59 substations reporting over 4 inches. Heavy rains were general over considerable surrounding territory when the 9.30 inches occurred at Memphis; Henderson, Tenn., reporting 8.61 inches and a number of stations in western Tennessee, northern Mississippi, and eastern Arkansas reporting from 6 to 10 inches for the two-day period.

One of the greatest three-day rains on record in Arkansas occurred on August 17–20, 1915, when a tropical storm crossed the State from southwest to northeast' causing 6 to 14 inch rains, the greatest being 14.80 inches at Hardy in a little more than two days. There were two areas of heavy rainfall separated by the Arkansas River. As the storm approached the southern Ozarks 8 to 10 inch rains occurred, but only 4 to 7 inch rains were reported near the Arkansas. Just north of the river the rains became heavy again, 14 stations in the northern portion of the State reporting over 8 inches in less than three days, five stations reporting over 10 inches. The rainfall in the northwest corner of the State was from 4 to 5 inches, in the southeast portion, from 1 to 2 inches.

The greatest monthly precipitation on record in the State is 23.50 inches at Howe in May, 1905; the second largest being 21.55 inches at Arkadelphia in June, 1905, which includes the 12 inches in 24 hours mentioned above.