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EXTENDING FLOOD-FREQUENCY GRAPHS BY COMPARISON WITH RAINFALL

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Flood discharge is the consequence of many contributing hydrologic events which may be presumed to occur fortuitously and independently, such that the probability of a given flood is the product of the probability of each independent contributing event. Of the many factors that lead to a flood, the two most prominent are (1) storm rainfall and (2) the "antecedent conditions" (e.g., conditions of the soil encountered by the rainstorm).

If adequate experience tables can be prepared for each of these factors, and physical relations between them determined, then they can be combined so as to construct a flood-frequency table of great length. For example, suppose there are twenty events of phenomenon A and twenty events of phenomenon B. Phenomena A and B are related so as to produce phenomenon C. Then each event A can be combined with each event B to produce 20 x 20 combinations, corresponding to 400 events of phenomenon C. The application has its greatest usefulness where sufficient rainfall records are available for a period significantly longer than the record of flood discharges.

A study of the application of this scheme to flood peaks was made using data for Sepulga River near McKenzie, Alabama. This stream drains a 470 square-mile area of the coastal plain of Alabama. It was chosen for this study because 24-hour rainfall and discharge data would be suitable and snow melt is not involved. The record began in October 1937, so that 13 years of flood record was available at the time this study was made. Rainfall records were available for a 46-year period.

Base data: The base data for this study included each storm with one or more inches of rainfall, for which data are listed in table 1. The first data column lists the total rainfall expressed in inches. The depth of rainfall is weighted average of that reported at Greenville, which is in the basin and Evergreen somewhat to the South. The duration in days is listed in the second column. The duration in days is the number of days in which 85 percent of the volume of the rain fell.

The equivalent 1-day rainfall, listed in column 3, was computed by application of a distribution graph (a variant of the unit hydrograph) to the daily rainfall during a storm period. The peak day so computed was divided by the maximum ratio of the distribution graph (in this case 0.29) in order to obtain an equivalent depth of rainfall such that if it fell in 24 hours it would produce a peak equal to that produced by the given rainstorm.

24-hour distribution graph and unit hydrograph, Sepulga River near McKenzie, Alabama:

Days following rain	Percent	Unit hydrograph (cfs)
0	8	1,000
1	25	3,150
2	29	3,700
3	20	2,500
4	10	1,250
5	5	625
6	3	380
Total	100	

The fourth column of table 1 lists the maximum daily discharges in cubic feet per second. The hydrographs of this stream are fairly flat and the maximum daily discharges average only about 10 percent less than the discharge at the flood crest.

The relationship between rainfall and the observed peaks is conditioned chiefly by antecedent conditions. There are various measures of antecedent conditions. One might perhaps take the ratio of the observed peak to the rainfall as an expression of the antecedent conditions. Thus a low ratio might be indicative of dry soil conditions, and a high ratio might be indicative of a sodden soil. A frequency distribution of these ratios might be prepared and used in combination with the rainfall-frequency distribution, so as to synthesize a flood-peak frequency distribution. The technique here is simple, but has the rather important disadvantage that the ratio is not independent of the magnitude of rainfall, or stated in another way, there is not a simple proportional relation between rainfall and runoff. The fact might be accorded proper consideration by treating rainfall depths in specific ranges. Thus the frequency of flood ratios for rainfall in the 2 to 3-inch range could be determined, similarly for rainfalls in the 3 to 4-inch range and so on. However, with increasing rainfall the available experience decreases, so that for storm rainfalls over 7 inches there may be only one or two events, wholly inadequate on which to base a frequency distribution. This difficulty can be surmounted by using a correlating parameter that is nearly independent of the depth of storm rainfall. One such parameter sometimes used in flood forecasting, is the antecedent base flow; the base or ground-water component of stream flow from rainfall prior to a given rainstorm.

Thus column 5 lists the antecedent base flow in cfs, determined by extending the initial base flow by means of a depletion curve to the day of the peak. Antecedent base flow and daily precipitation were correlated graphically with the observed maximum discharges. Over two hundred points were available to define the graph on figure 1. The standard error of estimate is 0.20 $\log_{10}$ units (roughly 50 percent), and the coefficient of correlation is 0.94. It is believed that the residual errors may be attributed in greater part to inadequate definition of rainfall than to deficiencies in the technique. Although there is a very marked seasonal variation in base flow, no seasonal effect was evident in the residual errors of the correlation. Apparently the antecedent base-flow index is without bias in this respect. Insofar as the rainfall-discharge graph is without bias, it appears suitable for the purposes of the study.

Synthesis of extended flood frequency graph: The following lists the maximum peak daily discharge in each water year 1938-50, together with the concurrent equivalent 1-day rainfall and antecedent base flow. There are 13 events in this table, and if the rainfall and antecedent base flow are mutually independent there are 169 possible combinations. The concurrence of the maximum rainfall (7.78 inches) and the maximum antecedent base flow (5,700 cfs) according to figure 1 would produce a peak daily discharge of about 36,000 cfs. Its recurrence interval is 169 years. A table of all 169 combinations shows 5 peaks of 30,000 cfs or more and 34 peaks of 20,000 cfs or more. These correspond to recurrence intervals respectively of 33 and 5 years. The median flood corresponding to 5 combinations or a 2-year annual flood is 10,000 cfs. These points are shown on figure 2 together with the observed annual flows.

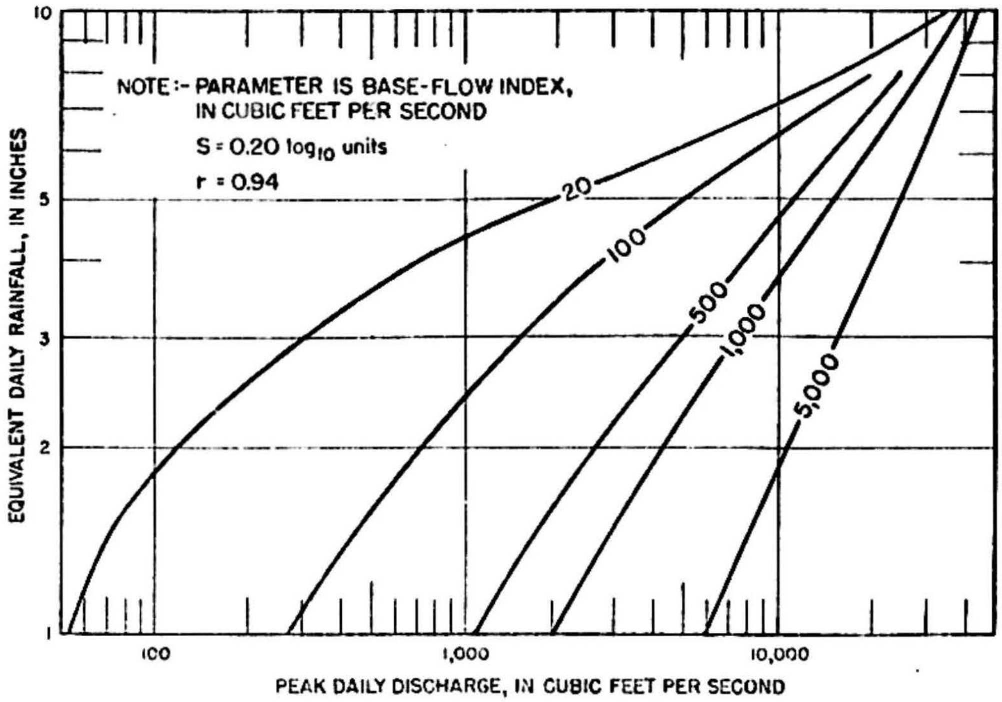

Figure 1.-- PEAK DISCHARGE OF SEPULGA RIVER IN TERMS OF RAINFALL AND BASE FLOW INDEX

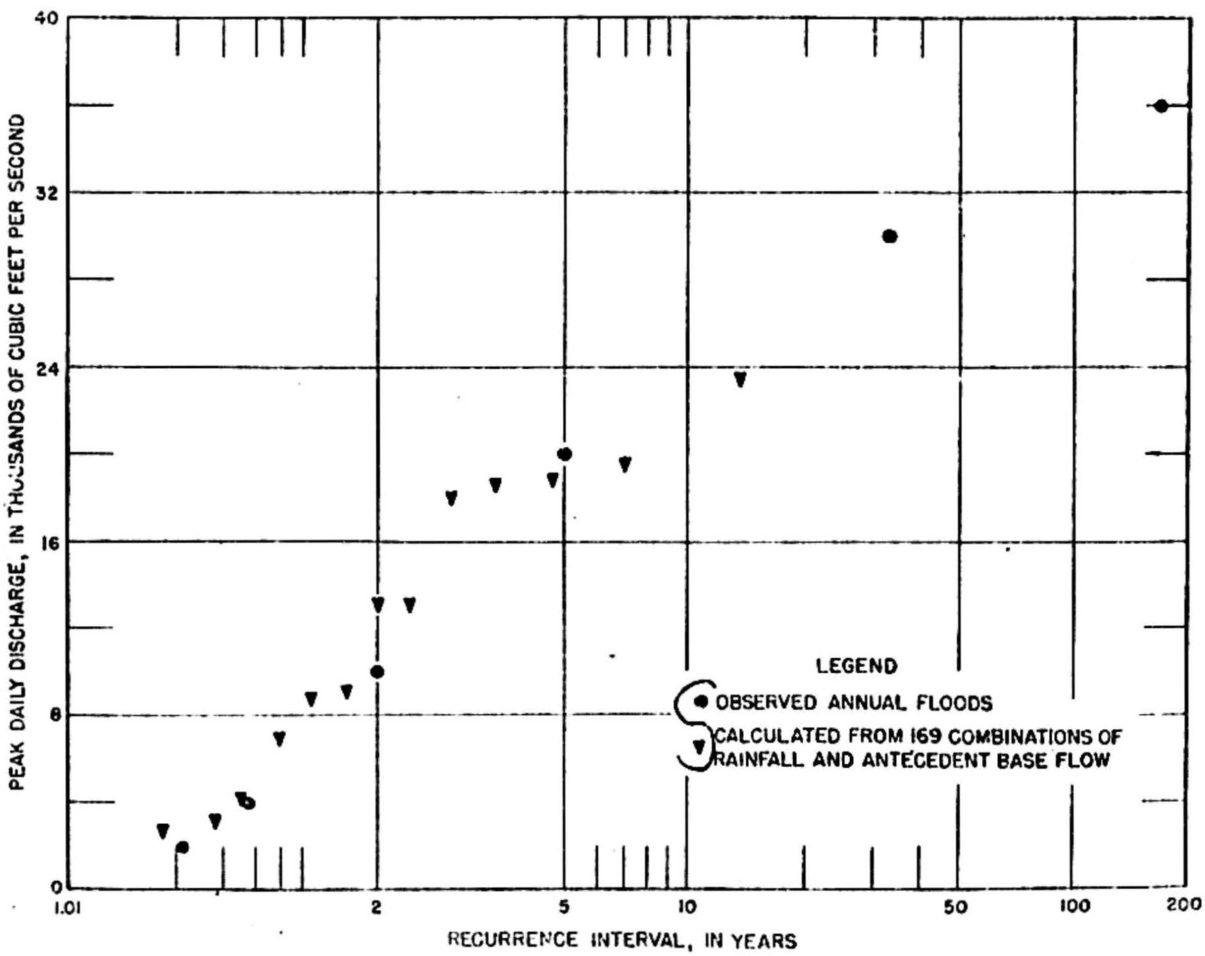

Figure 2.--ANNUAL FLOODS ON THE SEPULGA RIVER NEAR McKENZIE, ALA.; 1938-50

MAXIMUM WATER YEAR FLOODS

Water Year	Peak daily discharge (cfs)	Equivalent 1-day rainfall (inches)	Antecedent base flow (cfs)
1938	23,500	7.25	140
1939	13,000	7.05	30
1940	8,840	3.64	390
1941	4,030	2.16	370
1942	6,690	5.71	67
1943	18,000	5.55	1,500
1944	18,800	6.05	1,200
1945	2,860	2.33	540
1946	18,500	7.78	670
1947	9,000	2.95	1,580
1948	13,000	6.16	420
1949	19,800	6.37	5,700
1950	2,790	2.72	145

The procedure is especially useful as a hydrologic method of extrapolating a short flood record, or in assigning a recurrence interval to a major flood that may have occurred during a short period of record. However, another pertinent problem is to devise a method that is adapted to the use of a long-term precipitation record in combination with the short-term record of antecedent base flow, assuming that the latter is sufficiently representative of the stream. This application can be better carried out by means of separate frequency graphs of rainfall and antecedent base flow as follows:

The next step in the analysis was therefore to prepare frequency graphs of equivalent 1-day rainfall based on the period of discharge records and on the whole length of available rainfall records which in this example covers 45 years. See figure 3. The partial duration series method is used.

A frequency table of antecedent base flow is also prepared using the record presented in table 1. See figure 4. We are now ready to synthesize a frequency table of flood-peak discharges. For example, a 5,000 cfs flood peak may occur with the following different combinations:

Equivalent 1-day rainfall (inches)	Antecedent base flow (cfs)
7.0	8
6.0	25
5.0	100
4.0	250
3.5	350
3.0	500
2.0	1,300
1.0	4,000

If we deal first with the rainfall frequencies for the period 1938-50 that is contemporaneous with the stream-flow records, according to figure 2, a 7-inch equivalent 1-day rainfall occurs 0.2 times per year on the average. An antecedent base flow of 8 cfs is equalled or exceeded 100 percent of the time. Hence every 7-inch equivalent 1-day rainfall will produce a flood peak of 5,000 cfs or more.

The rainfall frequency graph (figure 3) shows that a 6-inch or more equivalent 1-day rainfall occurs 0.53 times per year on the average. However since 0.2 of these have been accounted for, there are 0.33 events per year in the 6-7 inch interval. Figure 4 shows that an antecedent base flow of 25 cfs or more occurs in 98 percent of the cases. Therefore, of the 0.33 times in a year that a rainfall in the 6-7 inch interval occurs, 0.99 x 0.33 will produce a flood peak of 5,000 cfs or more.

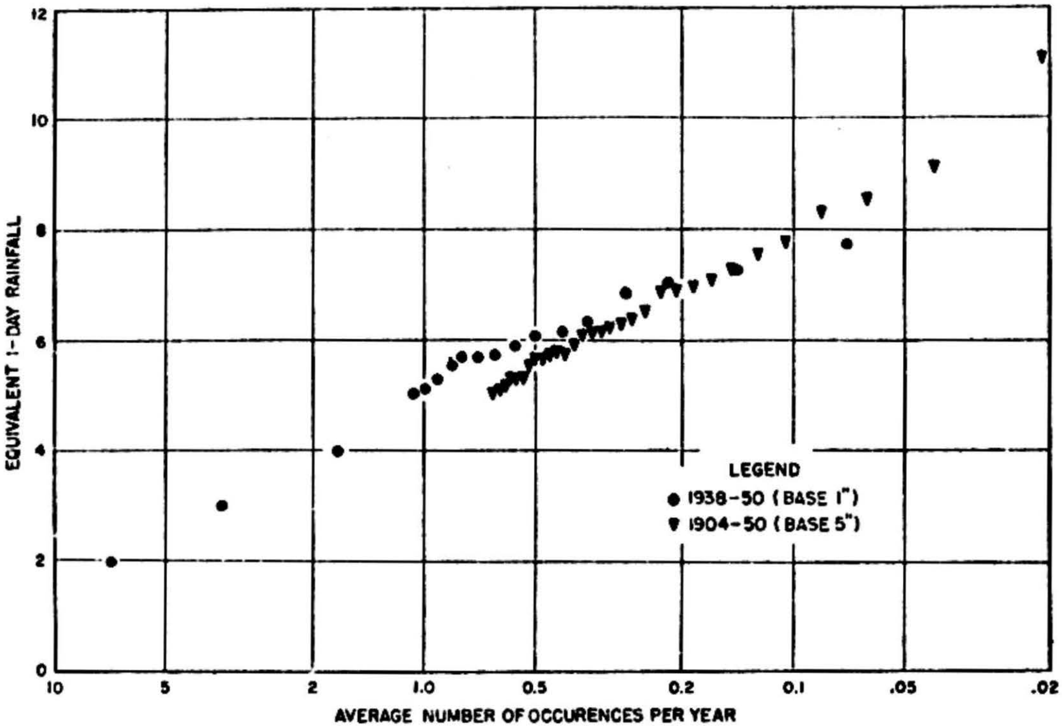

Figure 3.-- RAINFALL FREQUENCY GRAPHS (PARTIAL-DURATION SERIES)

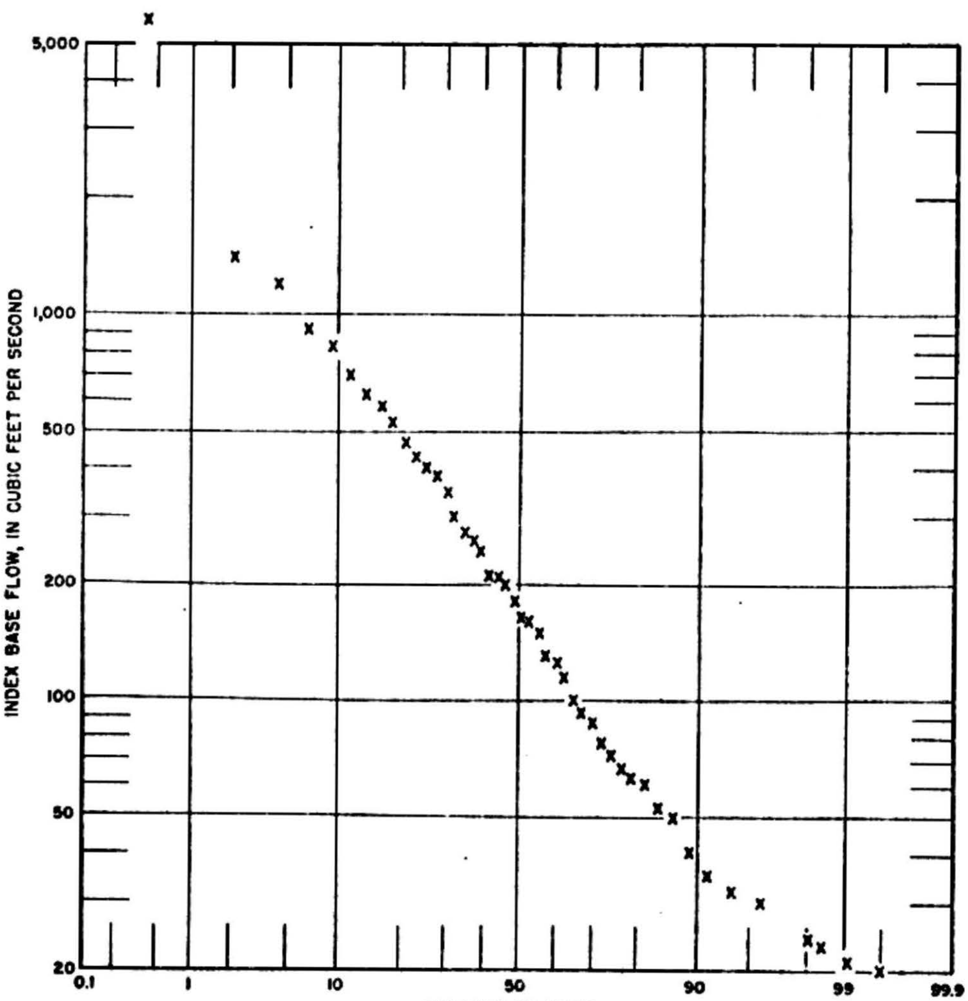

Figure 4.--FREQUENCY OF INDEX BASE FLOW

This computation is continued for each of the combinations. The complete tabulation is given below:

Equivalent 1-day rainfall		Antecedent base flow		Discharge frequency (no. per year)
(inches)	Average frequency (no. per year)	cfs	Average frequency (percent of cases)	
7.0	0.20	8	100	0.20
6.0	.53	25	98	.327
5.0	1.05	100	65	.420
4.0	1.8	250	39	.390
3.5	2.5	350	30	.238
3.0	3.5	500	20	.250
2.0	7.0	1300	3	.385
1.0	12.0	4000	0.1	.080
				2.290

It is thus computed that a peak discharge of 5,000 cfs occurs 2.29 times in a year on the average. The reciprocal of this frequency corresponds to a 0.435 year recurrence interval. This point is shown plotted as a circle on figure 5, where it agrees very well with flood experience. However, this point falls well within the main body of the graph. Major interest centers in the upper or extended portions of the graph.

The same procedure applied to a peak of 25,000 cfs, which is at the limit of definition of the rainfall-discharge relation on figure 1, leads to the following:

Equivalent 1-day rainfall		Antecedent base flow		Discharge frequency (no. per year)
(inches)	Average frequency (no. per year)	cfs	Average frequency (percent of cases)	
9.0	0.025*	30	96	0.0245
8.5	.036*	110	63	.0087
8.0	.05	450	22	.0059
7.5	.10	650	13	.0120
7.0	.20	1100	5	.0090
6.5	.33	1600	2	.0040
6.0	.53	2400	1	.0030
5.0	1.05	5000	0.5	.0039
				.0710

*Based on extrapolated graphs.

The calculations indicate a recurrence interval of $\frac{1}{0.0710} = 14$ years for a flood of 25,000 cfs. This point is also plotted on figure 5 falling generally on the trend indicated by the flood record. However, it will be noted that to construct the above table, it was necessary to extrapolate rainfall frequency above the 13-year experience. This portion of the table accounts for nearly 50 percent of the total calculated frequency of the 25,000 cfs flood. This point, (fig. 5) is just at the upper limit of flood experience, and serves to define this portion of the flood-frequency graph. The frequency of a higher flood, say a 50,000-cfs flood, could only be calculated provided liberal extrapolation were permitted not only on the rainfall-frequency graph, figure 3, but on the rainfall-discharge graph, figure 1, as well.

<u>Application to long-term rainfall record</u>: Our objective has been to verify the method of synthesizing a flood frequency graph from rainfall data. The need for extrapolating rainfall frequency can be

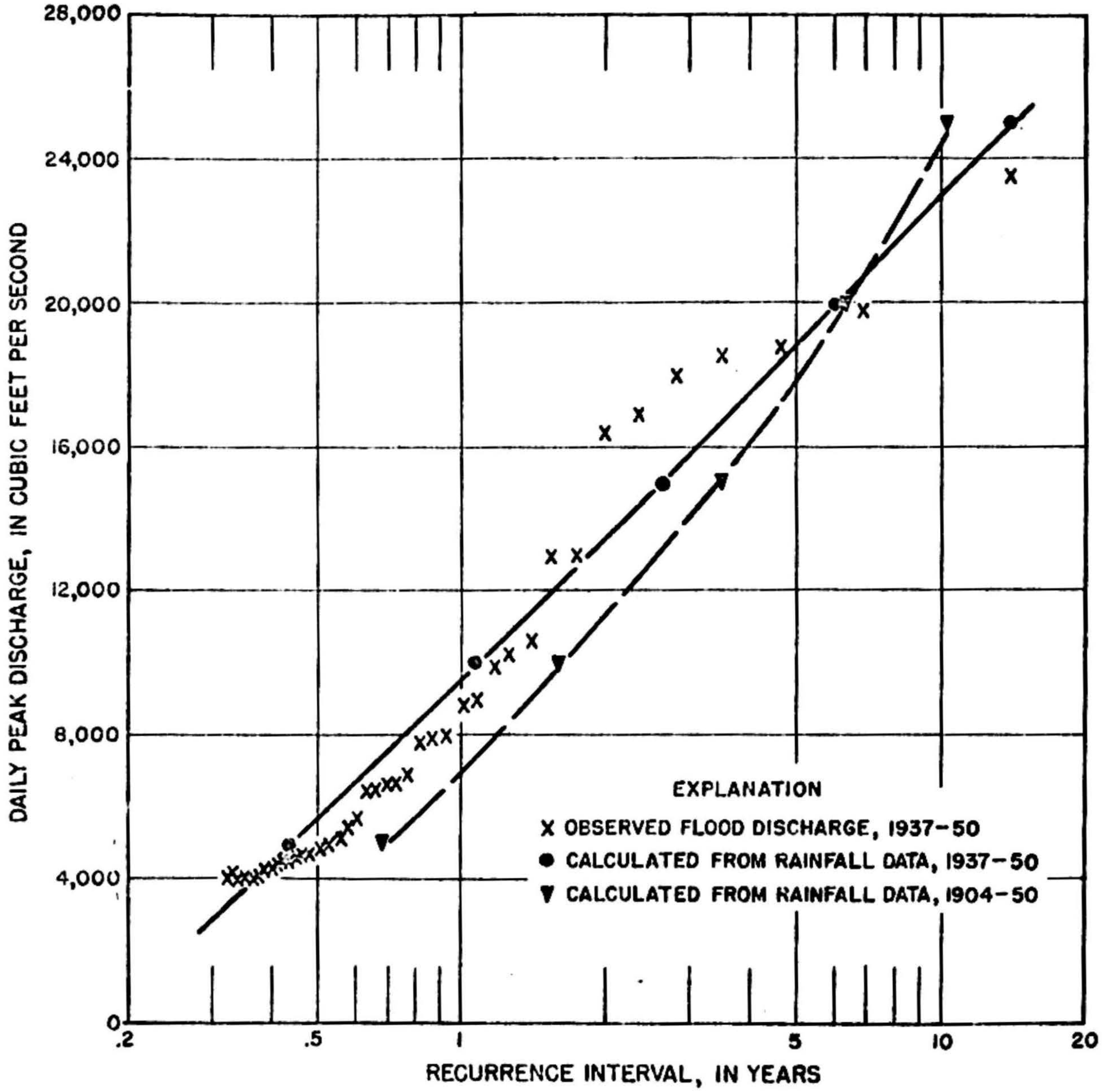

Figure 5.-- FLOOD FREQUENCIES OF SEPULGA RIVER NEAR McKENZIE, ALA.

lessened and a more representative rainfall graph obtained by use of longer period of rainfall records such as are available in this basin. Repetition of the same steps as before using, however, the rainfall graph for the period 1904-50, provides the points denoted by triangles on figure 5. No extrapolations are involved in this example up to the 25,000 cfs flood, the limit of the available experience to define the rainfall-discharge relationship. However, a rainfall-discharge graph can be extrapolated generally more safely than can a rainfall or a flood frequency graph. The rainfall-discharge graph expresses a physical relationship that is subject to somewhat definite controls. For example, the slopes of the upper ends of these graphs for Sepulga River can not exceed about 4,000 cfs per inch of rainfall, because that is the amount of peak daily discharge that can be produced even when all of the rainfall is converted into runoff.

The frequency of a 35,000 cfs flood, an event beyond actual flood experience, is calculated as follows:

Equivalent 1-day rainfall		Antecedent base flow		Discharge frequency (no. per year)
(inches)	Average frequency (no. per year)	cfs	Average frequency (percent of cases)	
10	0.02	20	99.5	0.02
9.5	.03	200	46	.0078
9.0	.05	1,100	10	.0056
8.5	.07	2,000	1.5	.0010
8.0	.09	3,300	1.0	.0002
7.5	.12	5,000	0.5	.0
7.0	.18	7,000	0.0	.0
				.0346
				29 years

Although no extrapolation of rainfall frequency is required, the calculation leans heavily on an extension of the rainfall-discharge relationship.

It may be observed that the calculated curve of peak discharge based on the long-term rainfall record on figure 5 crosses that defined by the available observed flood record 1937 to 1950. The relative positions of these series of points are quite similar to the relative positions of the graph of long-term rainfall frequency on figure 3 to that of the rainfall frequency observed during a period contemporaneous with the stream gaging. The percentage deviations between the rainfall graphs are not greatly different from that between the respective flood graphs at corresponding levels. To the extent that this is generally valid, and it should be for small deviations, a graph could be prepared between storm rainfall and flood peaks for corresponding recurrence intervals each based on a concurrent record. This graph, extended as necessary, could then be applied to the storm rainfalls of known recurrence interval during the long-term record to read off corresponding flood discharges. The slope of the extension must not exceed the limiting increment in peak discharge per inch of rainfall, 4,000 cfs in this example. Applicable within limits this method can reduce greatly the amount of work in using rainfall data to modify flood frequency graphs.

Correlation with nearby stream-flow record: When available, a nearby long-term flood record provides another and simpler method of extending a short-term record. The basin of Sepulga River is about 30 miles to the west of the Conecuh River above Andalusia where a streamflow record is available since 1904, except for a 9-year gap from 1920 to 1928. The correlation of flood peaks at the two stations during the 14-year period of contemporaneous records, although inadequate for estimation of the discharges for discrete flood peaks, is sufficient to define the general flood behavior over periods of several years as is considered in this problem. The relationship is such that peaks on Sepulga River at McKenzie are 70 percent of those at Andalusia. By this means the flood discharges at Andalusia were converted into equivalent discharges at McKenzie. The flood frequencies so computed are shown on figure 6 together with the flood frequencies computed from rainfall data. Even though the periods are not identical, the conformance is good.

Relative advantages of using rainfall or streamflow data: The relative advantage of rainfall or streamflow data for extending flood records, rests in part upon lengths of records available in each case. Rainfall data in general pre-date streamflow data. Figure 7 illustrates the situation in Alabama. The median length of record in each case is about 15 years, but for the longer periods the distribution is heavily loaded in favor of rainfall data. However, more than one rain gage station is generally needed for extending a flood record. Although rain gage records will always remain longer, the relative advantage will decrease in the future.

It is evident that the use of rainfall records in extending flood-frequency graphs should be particularly useful, where long-term, well-defined rainfall-frequency data are available, together with sufficient flood experience to define a rainfall-runoff relationship through a wide range. The chance occurence of an extraordinary flood in a short record, for example, might serve to define the rainfall-runoff relationship through a wide range. Rainfall data must be available for

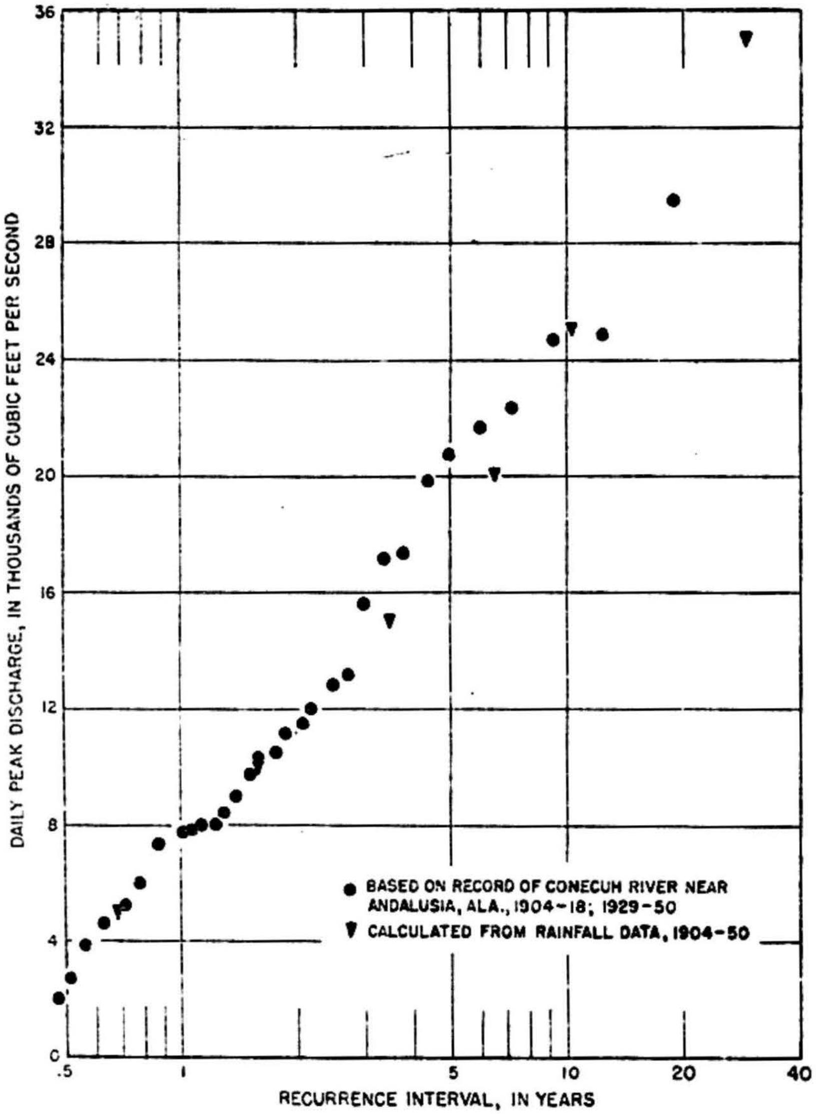

Figure 6.- COMPARISON OF LONG-TERM FLOOD FREQUENCIES OF SEPULGA RIVER COMPUTED FROM NEARBY GAGING STATION AND FROM RAINFALL DATA

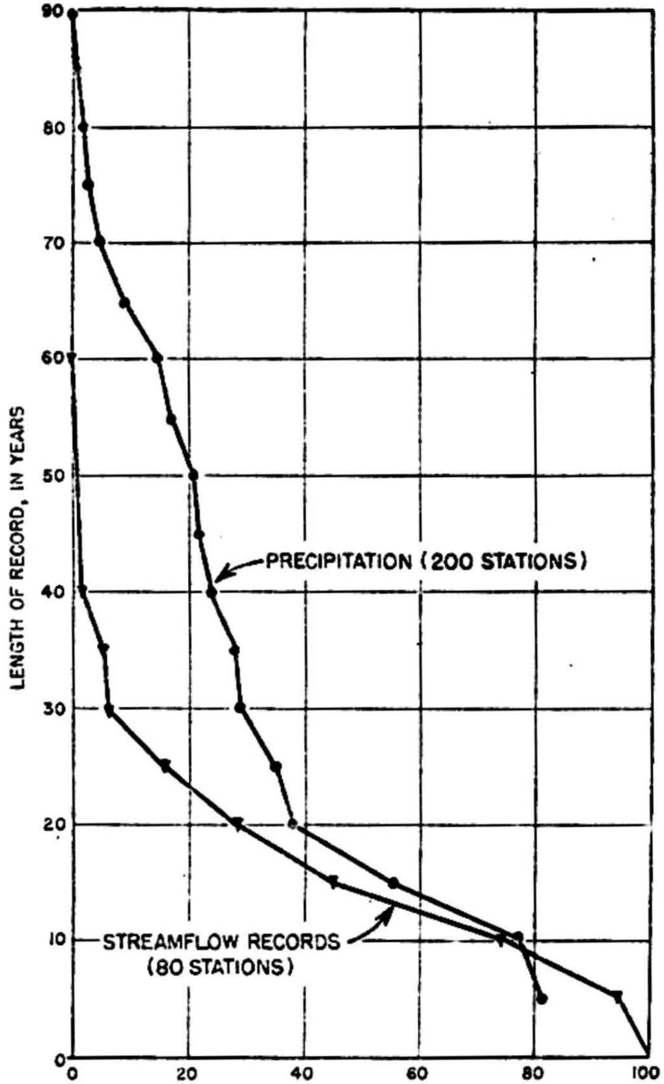

Figure 7.-- LENGTH OF PRECIPITATION AND STREAM-FLOW RECORDS IN ALABAMA, AS OF 1953

intervals not longer than the lag of the drainage basin. For basins in the 10 to 250 square-mile range this requires hourly rainfall data. Where the precipitation interval must be reduced to a short period (less than a day), the advantage of having long-term precipitation records will become sharply curtailed in many areas. Long-term recording gage records of rainfall are generally not plentiful.

The purpose of this study is to demonstrate the physical validity of the use of rainfall data to extend a flood frequency graph in those areas where stream-flow records are relatively short and daily discharges are of practical value. A need for short-period rainfall data or a great deal of snowfall will limit the usefulness of the procedure. Strengthening the stream-gaging network should also tend to lessen future needs for using rainfall data in this way.

Acknowledgments are due Mrs. E. W. Coffay and R. W. Carter for their assistance in the preparation of this report.

Table 1.- Storm rainfall and flood peaks on Sepulga River near McKenzie, Ala.

Date	Average rainfall (inches)	Duration (days)	Equiv. 1-day rainfall (inches)	Daily peak (cfs)	Antec. base flow (cfs)
1937					
Oct 1-5	1.28	3	1.09		
Oct 17-20	3.72	2	3.46	1,620	47
Nov. 11-12	5.32	2	4.95	4,630	62
Dec. 22-23	1.04	1	1.04	1,580	350
1938					
Feb. 19	1.53	1	1.53	1,440	165
Mar. 16-17	7.25	1	7.25	23,500	140
Apr. 6-8	5.67	2	5.27	6,950	285
Apr. 19-23	1.62	4	1.20	964	300
May 7-8	1.48	1	1.48	286	94
July 18-23	3.18	3	2.70	936	23
July 25-27	1.87	2	1.74	3,610	100
Aug 2-3	1.19	2	1.11	772	167
Aug. 7-9	2.37	3	2.01	6,670	210
Aug 28-30	1.90	2	1.77	129	36
Nov 19-20	1.84	1	1.84	94	19
Dec. 24-27	2.77	3	2.35	190	30
1939					
Jan 29-30	1.07	1	1.07	405	61
Feb. 14-15	1.11	1	1.11	692	180
Feb. 20-22	1.76	3	1.50	1,730	260
Feb 26-	6.75	3	5.74	10,100	580
Mar 30-31	2.72	1	2.72	4,030	250
May 20-	5.17	5	3.15	1,170	28
June 10-12	1.73	2	1.61	1,170	330
July 25-28	1.54	2	1.43	158	54
July 20-22	1.10	2	1.02	351	33
1939					
July 30-	2.01	3	1.71	308	53
Aug. 17-20	11.56	5	7.05	13,000	30
Sep. 25-27	1.97	2	1.83	372	77
Dec. 26-27	1.78	1	1.78	362	68
1940					
Jan 12-	1.87	3	1.59	2,110	96
Jan 23-4	1.33	2	1.24	461	246
Feb 5-7	2.28	2	2.12	2,110	168
Feb 17-19	3.93	2	3.65	8,840	390
Mar 12-15	1.79	2	1.66	2,190	380
Mar. 28-30	1.83	2	1.70	1,830	240
Apr. 5-8	4.24	2	3.94	4,390	425
May 1	2.33	1	2.33	2,840	208
May 28-30	1.84	2	1.71	2,240	160
June 12-18	3.90	3	3.63	4,030	120
June 25-26	1.34	2	1.25	447	270
June 29-30	1.88	2	1.75	861	271
July 4-7	6.17	8	2.65	4,630	310
Aug 3	1.16	1	1.16	518	200
Aug 10-11	1.58	1	1.58	637	150
Sep. 24-25	1.67	1	1.67	104	26
Nov. 10-12	1.84	2	1.71	104	32
Dec. 12-17	6.75	3	5.74	3,940	40
Dec. 22-29	1.74	5	1.06	1,780	260
1941					
Jan 14-17	2.88	3	2.45	3,480	200
Feb 14	1.09	1	1.09	1,220	370
1941					
Mar. 6-8	2.16	1	2.16	4,030	370
Apr. 1-4	1.48	2	1.38	1,390	310
July 3-8	4.88	3	4.10	574	35
July 14-18	2.29	2	2.13	220	90
July 27-29	1.62	2	1.51	661	110
Aug. 6-7	1.62	1	1.62	672	130
Aug. 9-12	2.71	2	2.52	1,300	210
Sep. 24-27	2.73	2	2.54	298	33
Dec. 3-5	3.05	2	2.84	313	35
Dec. 22-24	6.14	2	5.71	6,690	67
1942					
Jan. 1-4	2.66	3	2.26	4,210	570
Jan. 31	1.03	1	1.03	880	170
Feb 15-18	3.20	2	2.98	4,780	250
Feb 24	1.20	1	1.20	2,140	1,000
Mar 2-9	3.82	5	2.33	4,030	400
Mar. 21-22	2.98	1	2.98	5,160	730
Mar. 26-28	1.13	2	1.05	2,580	1,100
Apr. 10	3.07	1	3.07	5,160	325
May 13-16	2.67	2	2.48	1,780	88
Jun. 22-24	1.91	2	1.78	481	160
July 1-10	3.95	5	2.41	584	93
July 12-16	[illegible]	3	2.34	511	116
July 22-28	2.96	3	2.52	261	93
Aug 4-9	3.37	4	2.49	550	73
Aug 17-25	2.13	4	1.58	360	94
Sep. 26-27	3.56	1	3.56	763	38
Dec 28-29	2.11	1	2.11	1,000	110
1943					
Jan. 7-9	1.97	1	1.97	2,260	170
Jan 17-19	3.01	2	2.80	3,760	280
Jan. 26-9	1.33	2	1.24	1,620	640
Mar. 1-3	1.84	2	1.71	1,660	195
Mar. 5-6	2.32	1	2.32	4,850	570
Mar. 16-18	4.70	2	4.37	8,670	445
Mar. 20-22	5.97	2	5.55	18,000	1,500
May 10-12	2.10	2	1.95	553	78
May 24-26	3.74	3	3.18	1,400	62
June 18-27	4.03	5	2.46	332	53
July 12-16	2.37	3	2.01	1,940	87
Sep. 17-22	2.19	3	1.86	370	21
Nov. 7-8	6.86	1	6.86	6,580	25
Dec. 14-15	1.72	1	1.72	860	110
Dec. 25-29	3.25	2	3.02	2,530	160
1944					
Jan 3	1.35	1	1.35	1,770	590
Jan. 13-16	2.68	2	2.49	4,120	435
Feb. 14-25	6.14	6	3.44	2,010	320
Mar. 17-20	3.03	3	2.58	5,080	385
Mar 22-23	4.59	1	4.59	16,900	1,300
Mar. 27-30	6.51	2	6.05	18,800	1,200
Apr. 10-12	1.09	2	1.01	1,480	510
Apr. 15	1.25	1	1.25	2,210	830
Apr. 18-22	4.07	3	3.46	5,380	900
Apr. 24-27	6.00	3	5.10	16,400	1,400

Table 1 - Continued

Date	Average rainfall (inches)	Duration (days)	Equiv. 1-day rainfall (inches)	Daily peak (cfs)	Antec. base flow (cfs)
1944					
May 28-	2.49	3	2.12	340	140
Aug 13-15	1.95	1	1.95	692	65
Sep. 7-13	4.66	2	4.33	2,290	71
Sep. 29-30	1.36	2	1.26	290	118
Nov. 25-30	4.52	2	4.20	1,660	62
Dec. 7-8	1.69	1	1.69	1,810	210
Jan 22-23	1.36	1	1.36	1,560	270
May 21	1.48	1	1.48	995	200
Apr. 1-6	2.17	2	2.02	1,730	210
Apr. 17-18	1.57	2	1.46	1,280	120
Apr. 28-30	2.33	1	2.33	2,860	540
July 3-11	3.16	5	1.93	320	30
July 13-16	5.91	3	5.02	305	63
July 18-24	2.40	3	1.89	236	79
Aug. 3	5.27	4	3.90	1,930	51
Sep. 13-16	1.50	1	1.50	249	53
Sep. 20-21	1.14	2	1.06	108	78
Oct. 22-25	2.01	2	1.87	129	28
Nov. 21-22	3.09	2	2.87	1,300	400
Dec. 13-15	2.43	2	2.26	1,490	200
Dec. 24-	2.83	1	2.83	3,200	400
1946					
Jan 5-12	8.37	2	7.78	18,500	670
Jan. 15-17	1.27	2	1.18	3,120	930
Jan. 20	1.12	1	1.12	2,770	1,100
Feb. 18-19	1.78	1	1.78	3,540	540
Mar. 7-9	3.35	3	2.85	3,370	300
Mar. 14-16	2.93	2	2.72	4,490	740
Mar. 26-29	3.81	2	3.54	6,400	400
June 1-2	4.92	1	4.92	7,960	300
May 13-	6.50	4	5.50	10,600	160
June 26-	3.[illegible]	8	1.43	1,200	130
July 10-17	3.68	3	3.13	4,110	140
July 20-27	2.01	3	1.71	1,730	230
Aug 4-7	4.24	3	3.60	10,200	700
Sep. 15-17	2.02	2	1.88	960	97
Sep. 22-24	6.97	3	5.92	7,880	130
Oct. 11-12	0.86	1	.86	328	157
Nov. 16-18	1.07	2	1.00	525	150
Nov. 19-22	4.23	2	3.93	1,900	200
Nov. 25-29	1.43	2	1.33	1,690	760
Dec 30-	3.20	5	1.95	2,770	165
1947					
Jan 14-18	1.91	2	1.78	3,790	590
Jan. 19-20	1.28	2	1.19	2,770	1,300
Jan. 31	1.42	1	1.42	1,610	430
Mar. 5-8	3.62	3	3.08	5,460	210
Mar 14	1.78	1	1.78	3,540	1,600
Mar. 19-20	.90	1	.90	2,070	1,550
Mar. 30-31	1.57	1	1.57	2,200	410
Apr. 2	2.95	1	2.95	9,000	1,580
Apr. 14-16	2.78	3	2.36	4,110	1,000
May 1-2	1.76	2	1.64	1,570	400
May 15	.92	1	.92	1,000	203
May 20-22	2.21	1	2.21	1,940	183

Date	Average rainfall (inches)	Duration (days)	Equiv. 1-day rainfall (inches)	Daily peak (cfs)	Antec. base flow (cfs)
1947					
May 25-	1.65	2	1.53	2,590	910
May 29-	.97	1	.97	1,240	960
June 19-	1.36	1	1.36	794	90
June 24-	2.46	3	2.09	556	275
July 17-19	2.78	3	2.36	226	66
Aug 10-12	1.61	2	1.50	91	36
Aug 19	.47	1	.47	188	71
Sep. 9-12	1.20	2	1.20	81	20
Sep 19-20	.53	2	.49	78	39
Oct 28	.97	1	.97		
Nov 1-3	1.80	2	1.67	73	30
Nov. 6-8	1.20	1	1.20	99	35
Nov. 11-12	3.24	2	3.01	796	50
Nov. 14-16	1.30	1	1.30	870	250
Nov. 21-	1.48	3	1.26	924	260
Dec. 8-	6.67	6	3.74	4,260	102
1948					
Jan 12-	.96	1	.96	991	247
Jan 27-	2.08	3	1.77	2,390	525
Feb. 9-	2.15	4	1.59	2,550	505
Feb 21-	1.28	1	1.28	2,120	620
Mar. 2-7	8.33	4	6.16	12,[illegible]	420
Mar. 23	.86	1	.86	1,580	940
Mar. 31-	1.15	2	1.07	1,300	470
Apr. 9	.90	1	.90	1,030	465
May 5-7	1.07	2	1.00	210	95
June 14-	1.56	2	1.45	149	33
June 20	.56	1	.56	426	115
June 30-	1.27	1	1.27	242	54
July 9-10	2.86	2	2.66	119	41
July 13-17	3.23	3	2.75	422	97
July 29-	1.34	1	1.34	128	54
Aug 3-5	1.03	2	.96		
Sep 4-	1.87	2	1.74	72	24
Oct. 11-12	1.93	1	1.93	109	44
Nov. 5-7	3.32	2	3.09	509	32
Nov. 17-21	4.23	3	3.60	1,720	125
Nov. 22-24	4.19	3	3.56	8,800	700
Nov. 26-29	7.49	3	6.37	19,800	5,700
Dec. 6-9	.82	1	.82	1,980	800
Dec. 17-19	2.15	2	2.00	1,620	525
Dec. 29-30	1.42	1	1.42	2,300	620
1949					
Jan. 4-6	1.47	3	1.25	2,300	840
Jan. 30-31	1.00	2	.93	1,800	605
Feb 9-10	1.94	2	1.80	3,300	600
Feb 19-20	1.54	2	1.43	3,020	670
Feb. 27	1.01	1	1.01	1,940	590
Mar 14-	1.21	1	1.21	2,160	500
Mar 22-23	1.62	1	1.62	3,230	450
Mar 28-	.93	1	.93	1,620	740
Mar. 30-	1.78	1	1.78	4,480	1,400
Apr. 11-12	1.30	2	1.21	1,500	470
Apr. 21-23	.54	1	.54	890	295
Apr. 28-	5.46	3	4.64	5,720	245

Table 1- Continued

Date	Average rainfall (inches)	Duration (days)	Equiv. 1-day rainfall (inches)	Daily peak (cfs)	Antec. base flow (cfs)
1949					
May 24	1.66	1	1.66	445	81
May 29	1.08	2	1.00	436	165
June 9-	2.86	2	2.66	572	61
June 20-	2.03	3	1.73	256	126
July 1-4	2.40	2	2.23	628	72
July 11-12	.91	1	.91	1,160	122
July 14	1.47	1	1.47	1,940	840
July 16-19	3.15	2	2.93	5,080	1,200
Aug 1-5	1.27	2	1.18	2,550	150
Aug 16-	1.56	1	1.56	263	165
Aug 19-	1.15	2	1.07	530	207
Aug 30	.68	1	.68	620	112
Dec. 14-	2.40	2	2.23	386	71
1950					
Jan 4-7	1.11	2	1.03	187	73
Mar 3-8	2.57	4	1.90	1,380	86
Mar. 15-16	1.11	1	1.11	1,580	200
Mar. 28	.85	1	.85	990	250
Apr. 3-5	1.89	2	1.76	1,460	200
Apr. 18	1.24	1	1.24	920	163
May 28-	2.14	3	1.82	1,620	128
July 3-7	.58	2	.54	88	11
July 10-18	5.05	5	3.08	1,340	63
July 26-	2.93	2	2.72	2,790	145
Aug 25-	.62	2	.58	208	30
Aug 30	3.82	2	3.55	1,400	62
Sep. 7-9	1.39	1	1.39	445	122
Oct. 17-	1.01	2	.94	52	21
Dec. 2-4	1.24	1	1.24	133	43
Dec. 13-	1.45	2	1.35	162	51
Dec. 26-	1.22	1	1.22	138	66