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LOW - FLOW FREQUENCY AND FLOW DURATION OF TENNESSEE STREAMS

U. S. Geological Survey

OPEN-FILE REPORT 78-807

Prepared in cooperation with the
Tennessee Department of Conservation
Division of Water Resources

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

LOW-FLOW FREQUENCY AND FLOW DURATION OF TENNESSEE STREAMS

by Robert L. Gold

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Prepared in cooperation with the
TENNESSEE DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

Nashville, Tennessee

1981

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

DOYLE G. FREDERICK, Acting Director

For additional information write to:

U.S. GEOLOGICAL SURVEY
A-413 FEDERAL BUILDING
U.S. COURTHOUSE
NASHVILLE, TENNESSEE 37203

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LOW-FLOW FREQUENCY AND FLOW DURATION OF TENNESSEE STREAMS

By Robert L. Gold

ABSTRACT

Low-flow frequency and duration data are presented to define variations of the low flow of streams both in time and place. Analysis has been made of 204 continuous record stations, both regulated and unregulated and 651 partial-record stations operated either by the U.S. Geological Survey or Tennessee Valley Authority through the 1975 water year.

Flow duration and frequency data have been tabulated for the continuous record sites using the digital computer and graphical methods. Frequency data only is presented for partial-record sites computed in most cases by comparing several discharge measurements at the site with concurrent daily mean flow for an appropriate gaging station.

Flow duration data can be used to define a flow duration curve, with the slope at points on that curve used to establish the dependability of the stream to sustain a particular flow. Low-flow frequency data are presented to predict the probability that a specified flow or lesser flow will recur through time.

INTRODUCTION

More than any other section of the country, the Southeastern United States has been experiencing growth in population and the activities associated with such growth. Industrial and agricultural endeavors have had to expand to keep pace. Transportation systems have been modernized and the cities of the region have witnessed capital improvements and modernization. Tennessee, finding itself immersed in these changes, is reaping the benefits and facing the problems for such expansion.

One large problem is that of the increased utilization of the State's water resources. As shown by Kernodle and Wilson (1973), for the period of 1963-1970, while the population of the State increased by approximately 7 percent, withdrawals of water for all uses increased by 38.3 percent.

The increased demand for water has not, for the most part, caused significant problems. Tennessee has been blessed by thousands of streams, large quantities of ground water throughout most of the State, and has benefited by years of surface-water development by the U.S. Army Corps of Engineers and the Tennessee Valley Authority. However, events have occurred that indicate the water situation is not entirely satisfactory and that attention should be focused on managing our abundant resources.

The first of such events in recent times was a series of drought years in the early fifties that brought a realization by the people of the State that their water resources were not inexhaustible. Later came the disasterous floods in the early seventies creating increased concern about flood control. These events point out the major sources of water problems in Tennessee - the extreme conditions of low flow and flood, and their variations in time and place.

The problems associated with variations in the low flow of streams has its greatest affect on those activities dealing with water-supply, waste-water treatment, irrigation, water storage, and the drafting of water use regulations.

As a means to define variations, the parameters, low-flow frequency and flow duration have been developed.

Previous investigations

Previously published information includes (1) low-flow frequency and flow-duration values at continuous-record gaging stations through 1956 (Eaton, 1958), (2) flow-duration tables for continuous-record stations through 1960 (Wood and Johnson, 1965), and (3) low-flow frequency data for unregulated continuous-record stations through 1967 (May, Wood, and Rima, 1970). This report updates some of the information in these earlier reports and furnishes much information not previously published through the 1975 water year. Values contained within this report may differ from previously published values due to revised analysis that has been made at the sites.

Purpose and scope

Data in this report are provided as an aid to designers, planners, and managers in the field of water resources who are concerned with the amount and variability of the low-flow of streams in Tennessee.

This report contains low-flow frequency and duration values for all continuous record stations, regulated and unregulated, for which the U.S. Geological Survey has sufficient data. In addition, a tabulation of low-flow frequency figures has been provided at low-flow partial-record stations operated by the Survey and the Tennessee Valley Authority (TVA) for which correlations have been made.

Tables for 204 continuous record sites and 651 partial-record sites that are contained in this report are based on data collected through the 1975 water year. It should be noted that these values represent conditions that have applied to the basins in the past. The values presented herein may be subject to change due to factors such as urban development, man-made diversions, deforestation and other changes in the physical characteristics of the basin.

Cooperation and acknowledgments

The data in this report were compiled and analyzed as a part of the surface-water program being conducted in the State by the U.S. Geological Survey in cooperation with the Tennessee Department of Conservation, Division of Water Resources.

The Tennessee Valley Authority made data available and technically assisted in the compilation of this report.

Special note should be made of J. Jonas and D. A. Poole for their assistance in compilation of data and production of the location map for this report.

METHOD OF ANALYSIS

Flow-duration at continuous-record stations

The flow duration curve is a cumulative frequency curve of daily discharges showing the percent of time that specified discharges were equaled or exceeded during a given period. Tables in this report give data from which the flow duration curve can be plotted.

Flow duration figures were calculated for continuous record stations with more than 5 years of record. The figures were computed for the period of record of the stated gage. Adjustments were not made to any other base period. The procedure followed was to use only complete years of record, which may or may not be consecutive, but for years where physical conditions in the basin, such as diversions, storage, or other types of manmade regulations were essentially the same.

The duration figures were computed with the aid of a digital computer from stored mean daily discharges at the gaging stations. Table 1 shows an example of the computer printout for Roaring River near Hilham, Tenn. Computation of the percentage (PERCT) at each class interval was accomplished by first selecting values for the groups labeled in the figure as "CLASS" and "VALUE." These two constituents are used to define a class interval. A class interval defines a range of discharges selected to divide the full range of discharge recorded at a station into about 35 groups. The "VALUE" in cubic feet per second shown in table 1 represents the lower limit of each class interval. The mean daily discharges recorded at the station are then tabulated for the interval in which they fall. This defines the number of days that a particular class of discharges occurred. Computation of the percentages is then performed by summing, beginning with the largest class interval, all the days that are equal or exceeding that class interval. The sum is then divided by the total number of days contained in the record (the first value under the heading ACCUM).

Table 1.-- Flow-duration summary for Roaring River near Hilham, Tenn.

STATION NUMBER 03418000

DURATION TABLE OF DAILY VALUES FOR YEAR ENDING SEPTEMBER 30

DISCHARGE, IN CUBIC FEET PER SECOND
MEAN
ROARING RIVER NEAR HILHAM, TENN.

CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT	CLASS	VALUE	TOTAL	ACCUM	PERCT
0	0.00	0	15706	100.0	12	34.0	949	8652	55.1	24	600	111	396	2.5
1	2.30	47	15706	100.0	13	43.0	871	7703	49.0	25	760	93	285	1.8
2	3.10	74	15659	99.7	14	54.0	988	6832	43.5	26	960	63	192	1.2
3	3.90	220	15585	99.2	15	69.0	950	5844	37.2	27	1200	48	129	.8
4	4.90	460	15365	97.8	16	87.0	850	4894	31.2	28	1600	32	81	.5
5	6.30	753	14905	94.9	17	110.0	841	4044	25.7	29	2000	19	49	.3
6	8.00	740	14152	90.1	18	140.0	768	3203	20.4	30	2500	13	30	.1
7	10.00	865	13412	85.4	19	180.0	702	2435	15.5	31	3200	12	17	.1
8	13.00	827	12547	79.9	20	230.0	521	1733	11.0	32	4000	3	5	
9	16.00	1161	11720	74.6	21	290.0	381	1212	7.7	33	5100	1	2	
10	21.00	891	10559	67.2	22	370.0	259	831	5.3	34	6500	1	1	
11	26.00	1016	9668	61.6	23	470.0	176	572	3.6					

Once a table such as table 1 has been computed, class values were plotted against the corresponding PERCT on a log-probability graph and a smooth curve drawn to average the points. Figure 1 shows the flow duration curve plotted from the data of table 1 excluding the extremes. Discharges were taken from the plotted curve at selected percentages; these are the values tabulated in this report.

Low-flow frequency at continuous-record stations

Low-flow characteristics are defined by points on a frequency curve of annual values of the lowest average flow for a given number of consecutive days. The lower part of a frequency curve of 3-day low-flow for the French Broad River below Douglas Dam is shown in figure 2. The 3-day, 20-year low flow, referred to as a low-flow characteristic, is about 630 ft^3/s from the graph. The annual 3-day low-flow will be less than the 3-day, 20-year low flow at intervals averaging 20 years in length, or the probability is 1/20 (5%) that an annual 3-day low-flow will be less than the 3-day, 20-year low-flow in any one year.

Annual minimum flows for periods of 1, 3, 7, 14, 30, 60, 120 and 183 days were obtained by computer from daily discharges. The climatic year beginning April 1 is used to allow for complete period of low-flow occurring during the summer and fall months to be considered in the same year.

A printout of the minimum average values as calculated by the digital computer is shown in figure 3. The computer also ranks the low-flow values in ascending order from the lowest value, ranked as 1, to the greatest value for the period of record (for use in graphical frequency analysis).

The frequency curve is obtained from the annual minimum low-flows either mathematically (fig. 4) or graphically.

The mathematical process was used in the vast majority of analyses in this report. The procedure is based on the log-Pearson Type III distribution, as described in the U.S. Water Resources Council Bulletin 17 (1976). Figure 4 shows a printout that resulted from the log-Pearson Type III analysis of the annual 3-day low flows for the Roaring River near Hilham, Tenn. In the printout the input values are the annual low flows, and the recurrence interval and the parameter value are the coordinates of the frequency curve. A computer plot of the frequency curve is in figure 5.

If the calculated station data contained zero values or outliers, the graphical method described by Riggs (1972) was used. The procedure employs the previously described rankings (fig. 3) calculated for each period of days by the computer. Recurrence intervals are computed for each annual low flow utilizing the formula:

$$R.I. = \frac{n+1}{m}$$

where R.I. is the recurrence interval, in years; n the number of years of record; and m the order of magnitude (rank).

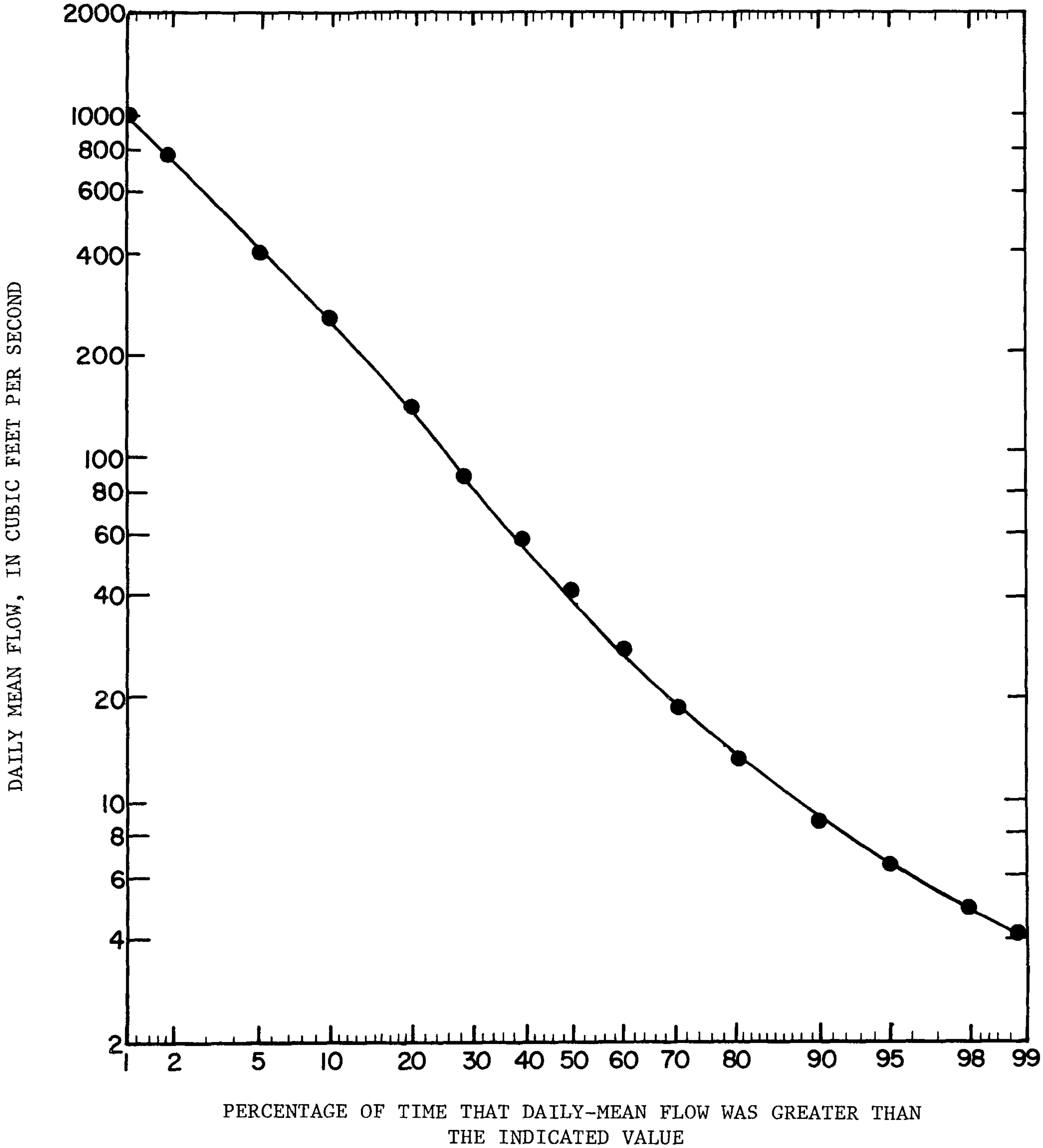


Figure 1.-Flow-duration curve for Roaring River near Hilham, Tenn., 1932-1975

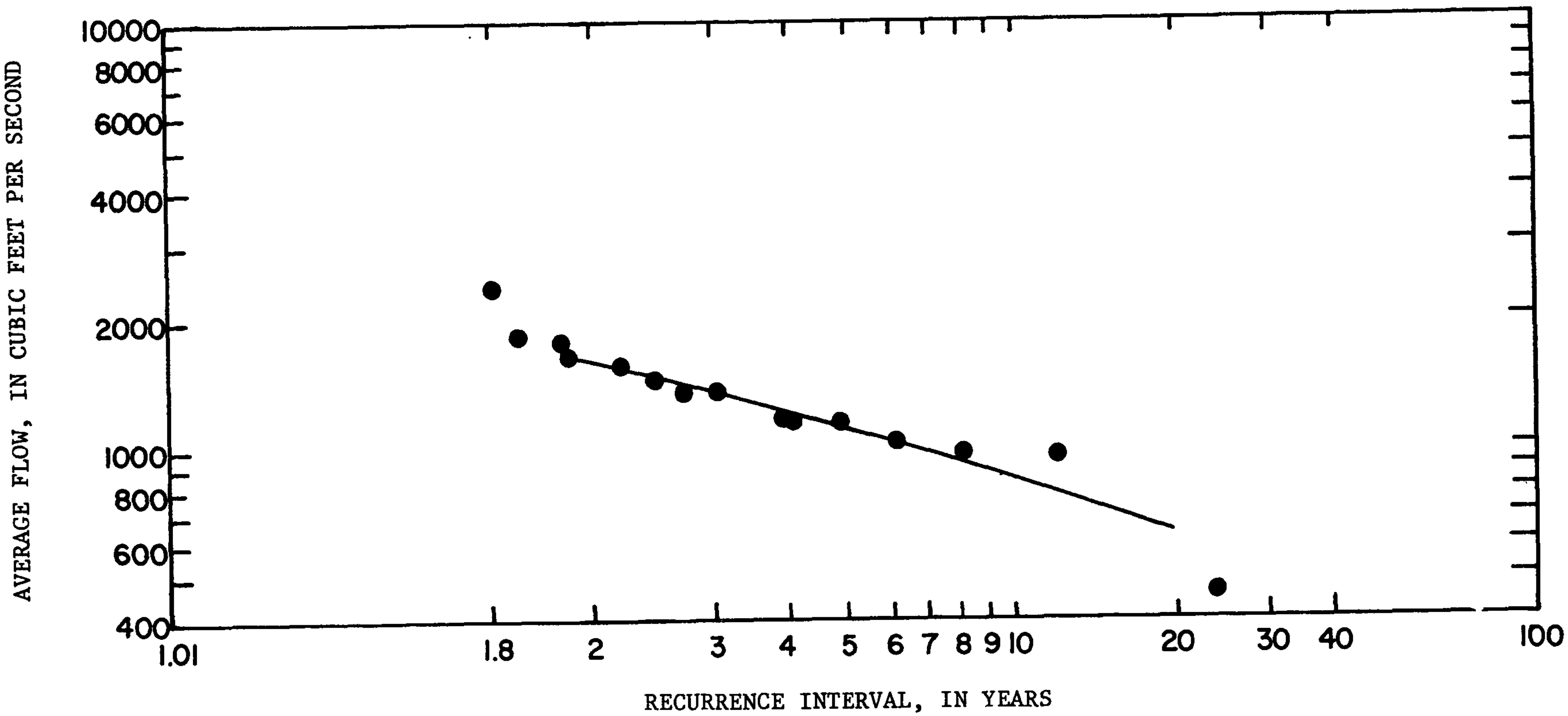


Figure 2.--Three-day low-flow frequency curve for French Broad River below Douglas Dam, Tenn.,1918-43, determined by graphical method.

STATION NUMBER 03418000

LOWEST MEAN VALUE AND RANKING FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31
DISCHARGE, IN CUBIC FEET PER SECOND
MEAN
ROARING RIVER NEAR HILHAM, TENN.

YEAR	1	3	7	14	30	60	90	120	183	ANNUAL
1933	5.00 16	6.80 29	7.20 29	7.70 28	9.20 25	14.00 28	15.00 25	20.00 26	29.00 27	115.00 26
1934	8.20 35	9.30 36	10.00 37	11.00 38	13.00 37	14.00 29	20.00 33	27.00 34	52.00 36	111.00 24
1935	7.00 31	7.80 31	8.60 32	11.00 39	15.00 39	21.00 38	25.00 38	25.00 31	26.00 22	94.00 14
1936	4.00 6	5.50 15	6.20 21	6.50 21	7.40 17	9.30 20	14.00 22	19.00 25	27.00 23	102.00 15
1937	2.50 2	2.60 2	2.60 2	2.80 2	2.90 1	3.50 1	4.00 1	5.70 2	8.30 2	134.00 35
1938	4.80 13	6.00 26	6.80 27	8.30 29	12.00 34	16.00 34	17.00 26	18.00 23	23.00 20	87.00 13
1939	10.00 41	11.00 40	12.00 40	13.00 40	15.00 40	22.00 39	32.00 41	42.00 43	54.00 37	129.00 33
1940	4.10 7	5.70 18	5.90 17	6.40 17	7.70 22	8.30 15	11.00 18	11.00 11	17.00 11	84.00 10
1941	3.60 4	4.90 9	5.60 14	6.40 18	7.20 15	8.50 18	9.60 15	12.00 16	18.00 12	59.00 3
1942	5.00 14	5.10 12	5.50 13	5.70 9	6.70 11	7.50 10	9.80 16	16.00 21	25.00 21	73.00 6
1943	9.50 38	9.60 38	10.00 38	10.00 34	12.00 35	15.00 32	23.00 35	33.00 39	32.00 30	114.00 25
1944	5.50 22	5.90 22	6.00 18	6.00 14	6.50 10	8.40 16	9.00 11	9.50 9	12.00 8	104.00 18
1945	5.20 17	5.90 23	6.50 26	7.20 25	9.30 26	14.00 30	18.00 29	26.00 32	42.00 33	126.00 31
1946	5.20 18	5.60 16	6.10 19	6.40 19	6.90 13	7.50 11	9.20 12	11.00 12	30.00 28	128.00 32
1947	4.40 10	4.50 7	5.00 7	5.30 7	6.40 8	7.10 8	7.60 7	9.10 6	16.00 9	73.00 7
1948	5.70 26	5.70 19	5.80 15	6.20 15	6.50 9	7.40 9	7.90 8	11.00 13	20.00 17	84.00 11
1949	5.20 19	5.20 13	5.40 11	5.80 12	6.10 6	7.00 7	9.30 13	18.00 22	18.00 13	110.00 23
1950	9.10 37	9.30 37	9.80 35	10.00 35	13.00 36	20.00 37	28.00 39	32.00 37	60.00 40	159.00 40
1951	10.00 39	11.00 41	12.00 41	14.00 41	16.00 41	26.00 42	33.00 42	40.00 41	69.00 41	147.00 39
1952	5.40 20	5.50 14	5.50 12	5.70 10	7.60 18	8.00 13	9.40 14	11.00 14	19.00 14	146.00 38
1953	3.90 5	4.00 4	4.10 4	4.30 4	4.50 4	5.00 3	6.10 4	6.90 4	9.60 4	70.00 5
1954	3.10 3	3.20 3	3.20 3	3.30 3	3.50 3	4.00 2	4.50 2	5.40 1	7.90 1	75.00 8
1955	2.40 1	2.40 1	2.40 1	2.50 1	2.90 2	5.70 5	6.90 5	7.20 5	9.60 5	118.00 29
1956	4.80 11	4.90 10	5.20 10	5.80 11	7.20 16	10.00 21	14.00 23	14.00 18	20.00 15	117.00 27
1957	5.50 21	5.60 17	5.80 16	6.00 13	6.30 7	6.60 6	7.40 6	10.00 10	12.00 6	134.00 36
1958	5.00 15	5.00 11	5.10 8	5.60 8	7.60 19	11.00 22	18.00 30	22.00 28	32.00 29	102.00 16
1959	5.60 23	6.00 24	6.30 22	6.70 24	9.50 27	17.00 35	21.00 34	24.00 30	27.00 24	104.00 19
1960	4.30 9	4.40 6	4.70 6	5.20 6	7.70 23	12.00 25	14.00 24	14.00 19	21.00 18	108.00 20
1961	14.00 42	14.00 42	15.00 42	18.00 42	23.00 43	28.00 43	28.00 40	30.00 35	56.00 38	102.00 17
1962	6.30 28	6.30 27	6.40 25	6.60 22	6.80 12	8.10 14	10.00 17	13.00 17	35.00 32	167.00 41
1963	5.70 27	5.80 20	6.10 20	6.60 23	7.60 20	8.40 17	13.00 21	15.00 20	22.00 19	130.00 34
1964	5.60 24	6.00 25	6.30 23	6.40 16	7.00 14	7.80 12	8.60 9	9.30 7	20.00 16	53.00 1
1965	4.80 12	4.80 8	5.20 9	6.50 20	9.00 24	23.00 40	24.00 36	33.00 38	43.00 34	110.00 21
1966	6.40 29	6.80 28	7.00 28	7.30 26	7.70 21	8.90 19	8.90 10	9.50 8	12.00 7	57.00 2
1967	7.00 30	7.30 30	7.60 30	8.50 30	10.00 28	14.00 31	17.00 27	19.00 24	28.00 25	86.00 12
1968	16.00 43	16.00 43	17.00 43	18.00 43	21.00 42	23.00 41	33.00 43	41.00 42	75.00 42	118.00 28
1969	4.10 8	4.20 5	4.40 5	4.70 5	5.30 5	5.60 4	5.80 3	6.50 3	9.10 3	61.00 4
1970	8.70 36	8.80 35	8.90 33	9.80 32	11.00 31	12.00 26	17.00 28	22.00 29	29.00 26	110.00 22
1971	5.60 25	5.80 21	6.40 24	7.40 27	10.00 29	11.00 23	12.00 19	12.00 15	17.00 10	83.00 9
1972	10.00 40	10.00 39	11.00 39	11.00 36	12.00 32	16.00 33	19.00 31	26.00 33	58.00 39	126.00 30
1973	7.80 33	7.90 32	9.10 34	10.00 33	12.00 33	14.00 27	19.00 32	31.00 36	34.00 31	142.00 37
1974	7.70 32	8.00 33	8.40 31	9.40 31	11.00 30	12.00 24	13.00 20	21.00 27	87.00 43	205.00 43
1975	8.00 34	8.60 34	10.00 36	11.00 37	14.00 38	20.00 36	24.00 37	35.00 40	52.00 35	195.00 42

Figure 3.-- Computer printout of minimum-average values for Roaring River near Hilham, Tenn.

ROARING RIVER NEAR HILHAM, TENN. STATION 03418000

1933-1975, 12 MON PERIOD ENDING MARCH 31

3 DAY LOW VALUE

INPUT DATA (ZERO VALUES OMITTED)

6.800	9.300	7.800	5.500	2.600	6.000	11.000	5.700	4.900	5.100
9.600	5.900	5.900	5.600	4.500	5.700	5.200	9.300	11.000	5.500
4.000	3.200	2.400	4.900	5.600	5.000	6.000	4.400	14.000	6.300
5.800	6.000	4.800	6.800	7.300	16.000	4.200	8.800	5.800	10.000
7.900	8.000	8.600							

MEAN = 6.714

VARIANCE = 7.694

STANDARD DEVIATION = 2.774

SKEWNESS = 1.362

STANDARD ERROR OF SKEWNESS = 0.361

SERIAL CORRELATION COEFFICIENT = 0.045

COEFFICIENT OF VARIATION = 0.413

MEAN LOGS = 0.794

VARIANCE LOGS = 0.029

STANDARD DEVIATION LOGS = 0.170

SKEWNESS LOGS = 0.022

STANDARD ERROR OF SKEWNESS LOGS = 0.361

SERIAL CORRELATION COEFFICIENT LOGS = 0.180

COEFFICIENT OF VARIATION LOGS = 0.214

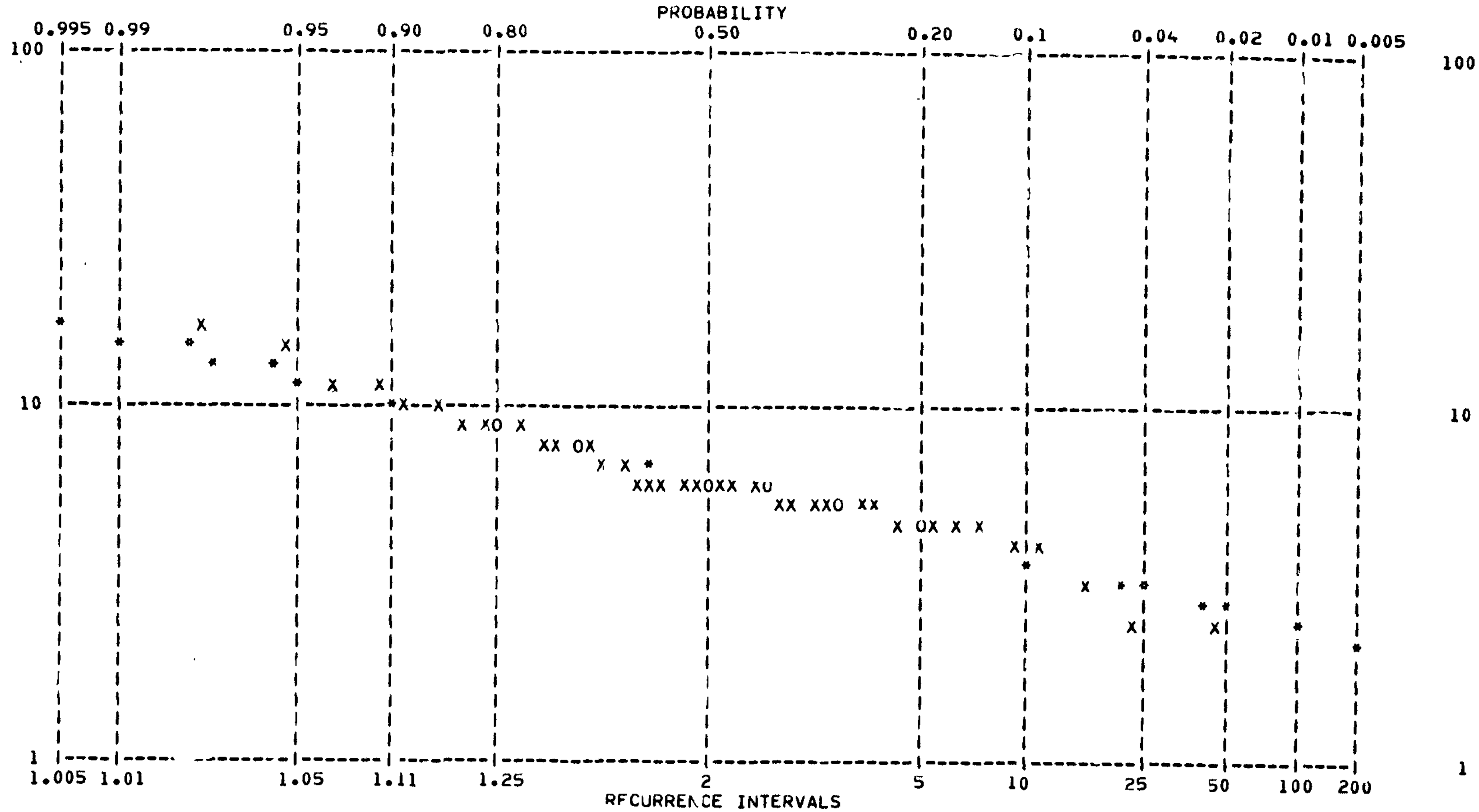
NON EXCEED PROB	RECURRENCE INTERVAL	PARAMETER VALUE
0.0100	100.00	2.518
0.0200	50.00	2.797
0.0500	20.00	3.276
0.1000	10.00	3.772
0.2000	5.00	4.475
0.5000	2.00	6.217
0.8000	1.25	8.654
0.9000	1.11	10.295
0.9600	1.04	12.397
0.9800	1.02	13.983
0.9900	1.01	15.586

Figure 4.--Statistical values from log-Pearson Type III mathematical analysis of Roaring River near Hilham, Tenn.

ROARING RIVER NEAR HILHAM, TENN. N = 43 STATION 03418000

1933-1975. 12 MON PERIOD ENDING MARCH 31

3 DAY LOW VALUE



THE FOLLOWING SYMBOLS MAY APPEAR IN THE PLOT
X - AN INPUT DATA VALUE
* - A CALCULATED VALUE
O - A CALCULATED VALUE AND ONE DATA VALUE AT SAME POSITION

Figure 5.--Computer printout showing curve from mathematical computation of low-flow frequency for Roaring River near Hilham, Tenn.

Points representing recurrence interval and discharge are then plotted on log-probability paper and a curve is drawn through the plotted points. An example for a 3-day frequency curve for French Broad River below Douglas Dam, Tenn. is shown in figure 2.

Sites where the period of record was less than ten years and the flow was unregulated were analyzed in the same way as partial-record sites by correlating flows with other continuous record stations of longer period. Only periods of 1, 3, and 7 days are presented in the "Magnitude and Frequency" tables.

Estimating low-flow frequency at partial-record sites

Low-flow frequency data calculated for continuous record stations are by far the most accurate data that may be computed at a site. However, the need exists for low-flow frequency data at sites other than those for which long-term continuous-record are compiled.

A low-flow partial record site is one at which several base-flow discharge measurements have been made for the purpose of defining the low-flow frequency characteristics.

Low-flow frequency characteristics at a partial record site are estimated by relating the measured flows to concurrent flows at a continuous-record index site where the low-flow frequency curve has been defined. The selection of an index site which must be a perennial stream is based primarily on close proximity to the site to be computed, similarity of geologic setting, and closeness in the size of the respective drainage areas. A typical relation between partial record and index sites is shown in figure 6. The 3-day, 20-year low flow of Powell River, 73 ft^3/sec, corresponds to 0.3 ft^3/s on Russell Creek.

Some discharges at some partial record sites may be zero. At these sites computation of low-flow frequency was accomplished by assigning a value of zero for the 3-day, 20-year low-flow. As Riggs (oral commun., 1974) stated, the observation of zero flow is enough to determine the unsuitability of a site for dependable water supply. The 3-day, 20-year low-flow has traditionally been used in the State of Tennessee as the design parameter for water dependent projects, thus a value of zero assigned to such a frequency is sufficient to indicate such a fact to the users of data in this report. However, if documentation was found that the zero flow observed was due to unnatural conditions such as one time man-made diversion, or occurred only once in a period greater than 20 years, a correlation curve, previously described, is used to determine low-flow frequency.

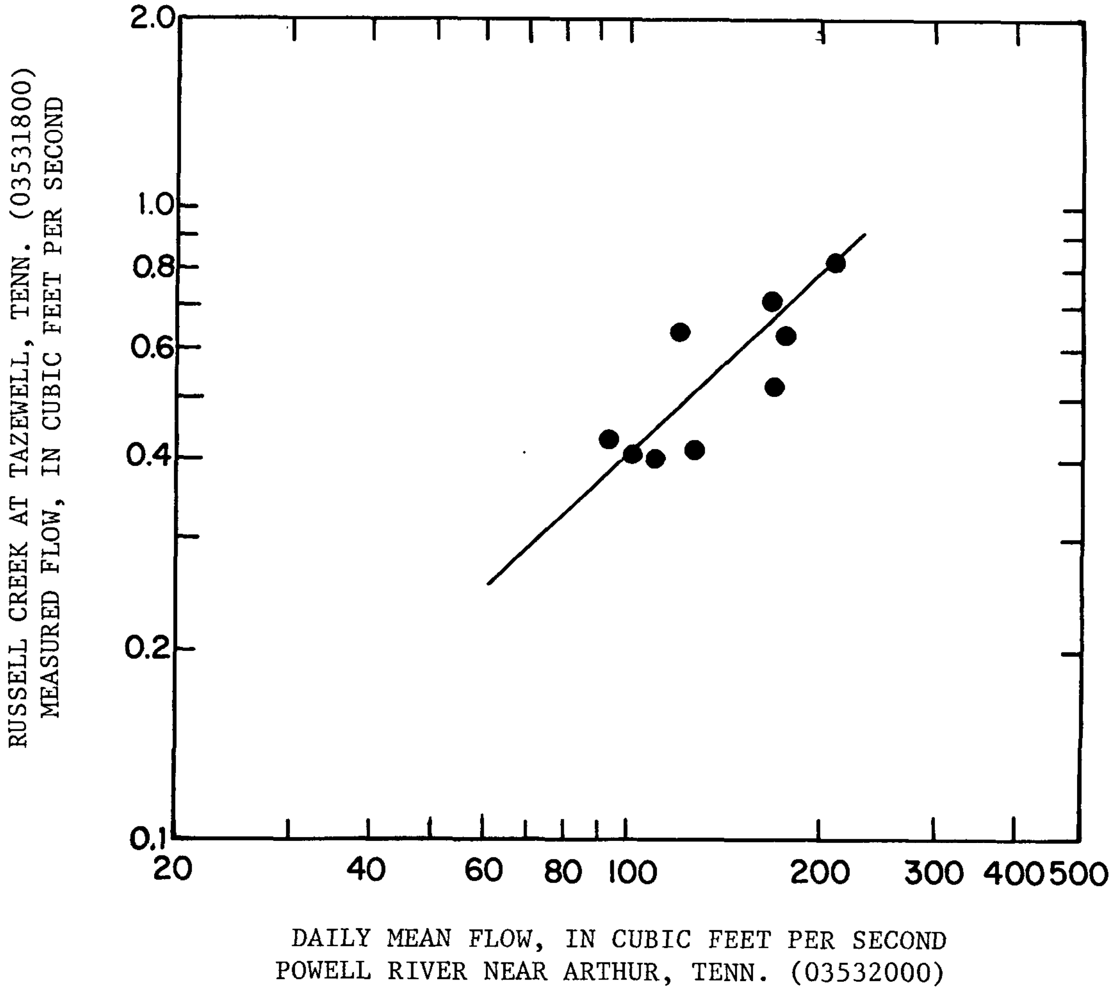


Figure 6.-Correlation between index site, Powell River near Arthur, Tenn. and partial-record station, Russell Creek at Tazewell, Tenn.

Estimating low-flow frequency at ungaged sites

There is a demonstrated need to determine low-flow characteristics at sites in Tennessee where little or no discharge information is available. To date, no totally satisfactory method has been devised, but it is worth mention to list the current techniques used.

The first is the determination of low-flow statistics at a site where insufficient discharge information has been collected to define a correlation with an index site. The ratio of the observed discharge at the site to the concurrent discharge at the index site is multiplied by a low-flow statistical value of the index site providing an estimate at the site in question. While subject to possibly large, unknown error, this technique does relate the observed base flow values between the two sites.

The second is a technique involving the use of drainage areas to relate two sites. The ratio of drainage areas of the ungaged site to that of the index site is multiplied by the low-flow statistical value at the index site to estimate a value at the ungaged site. This technique assumes that discharge from the aquifer system above the ungaged site is at the same rate per square mile based on surface drainage area as is the discharge above the index site. Such a relationship may not in fact exist and thus the estimated value would be subject to considerable error. This is due in part to the fact that surface drainage area does not always represent the aquifer's area of drainage. Additionally, other basin characteristics may influence the relationship between the two sites.

The technique of using drainage area ratios is the same as using a unit flow (cfs/mi^2) from a nearby gaged site multiplied by the drainage area of the ungaged site to estimate a flow value for the ungaged site. This technique can be expanded to include unit flow values for several index sites (gaged sites) within the surrounding vicinity. These values plotted on a map may reveal a pattern which then can be used to estimate the unit flow for the ungaged site. As far as possible, the basins selected for the index sites should have similar physiographic, geologic, and climatic characteristics to that of the ungaged site.

Lastly, basin characteristics such as drainage area, basin slope, forest cover, and altitude have been used to determine a relationship with low-flow characteristics. The basin characteristics are regressed statistically against low-flow characteristics determined at specific sites. The regression technique allows for the isolation of specific basin characteristics that may determine low-flow values. The result of the analysis is an equation that provides for insertion of a specific set of basin values to determine a corresponding low-flow value at the ungaged site. The regression technique at this time has not provided satisfactory values for Tennessee. However, with additional research, relations may be found suitable for certain areas of the State.

PRESENTATION OF RESULTS

Reliability of results

Data presented in this report are subject to error due to such things as physical, time, and human factors. These factors tend to affect the statistical analysis at a stream site.

One physical factor affecting the data may be regulation. Regulation has been defined as the artificial manipulation of a flow of a stream. This could be caused by the effects of dams, irrigation systems, or water-supply withdrawals for towns and industry.

In any case, regulation of the natural flow of a stream would cause modification of the sites low-flow frequency and duration figures. The use of such figures for regulated streams to predict future flows would be valid only if the cycle of regulation in the future is the same as it was in the past.

Continuous record sites subject to regulation have been noted in the "Remarks" paragraph included with the site data. Regulation at partial-record stations is minor and consists mostly of diversion of small amounts of inflow.

The period of record that has been analyzed at a site may have significant effects on the low-flow data calculated. First of all, a longer period of record would provide a better estimate of the low-flow characteristics. As a "rule of thumb", a low flow value calculated for a particular recurrence interval (for example 20 years) should be based on a record on not less than half that time (10 years), unless extended by correlation with a site of longer record.

Secondly, the relative time frame of a particular period of record affects the calculated low-flow characteristics. For example, analysis made of 10 years of record occurring during an extremely dry cycle of climatic conditions would differ considerably for the same site from analysis made if the 10 years were for a relatively wet period.

At partial record sites the number of discharge measurements available for correlation would have considerable effect on the accuracy of the resulting relation. Additionally the period of record length as previously described at the index site could bias the relation. For example, if a site were correlated against two different index sites of differing periods of record, the resulting low-flow characteristics calculated could also differ.

Low-flow analysis is very much a subjective operation. Review of the digital computer results is made to assure "reasonableness" of the figures. These figures may be adjusted if deemed suitable. By the same token analysis of partial-record or ungaged sites is dependent on the judgement and knowledge of the person doing the analysis. These data are then subject to revision as further flow data are collected or as increased knowledge of hydrologic relationships is obtained.

Low-flow characteristics presented in this report have in many cases been shown to three significant figures. This is not necessarily representative of the accuracy of such figures. These figures for continuous record sites have been generated by computer to this precision and are transferred to the accompanying tables. Indicating to the reader which figures warrant such accuracy is an arbitrary task and thus it was not chosen to do so. Data for partial record sites have been recorded in some cases to three significant figures to provide a difference between values for different magnitudes and frequencies. This has been done to allow the reader to discern the trend of the correlation line in the analysis and not the degree of accuracy.

Downstream order numbers

The arrangement of measurement sites for which data are presented in this report is by the downstream order number system used for annual publications by the Survey since 1958. The sites are listed in a downstream direction along the main stem, and all sites on each tributary entering above a main-stem station are listed before that station. If a tributary enters between two main-stem stations, it is listed between them. In assigning station numbers, no distinction is made between continuous record gaging stations and partial-record stations, so that the station number indicates the proper downstream sequence of the station, regardless of type. Gaps are left in the numbers to allow for new stations that may be established, therefore the station numbers are not always consecutive.

Locating individual site information

The user of this report can find data for a specific stream by using the indexes or site location map contained herein.

The index has been divided into two parts. The first is a listing of continuous record gages arranged first alphabetically then alphabetically by county with the corresponding page number for each site. The second is an index for the partial record sites also arranged alphabetically then alphabetically by county. Once a partial record site has been located in the index the corresponding downstream number can be used to find the station data in table 2.

The map on plate 1 visually displays for the report user the locations of the sites for which 3-day,20-year low-flows are available. The location numbers contained in the map can be used to refer to specific tabulations in the report. It should be noted that major drainage basins have been delineated in the map as an aid in future investigations of regional low-flow relations.

Continuous-record stations

Data for each continuous record site includes a station description and tables listing low-flow duration and frequency. If a stream has a period of both natural flow and regulated flow, two tabulations are presented to reflect the different periods.

The station description gives the downstream order number, location, drainage area, period of record analyzed, and general remarks. The Location paragraph gives both the latitude and longitude of the site along with a narrative describing the station location in relation to nearby landmarks. The Drainage area is that area, measured in a horizontal plane in square miles, which is enclosed by a topographic divide. Direct surface runoff from precipitation normally would drain by gravity into the stream above the station. Groundwater divides normally correspond to the surface water divides. The locations and drainage areas, are obtained from the most accurate maps available. The Remarks paragraph includes information pertaining to conditions which affect the natural flow at a gaging station, and other pertinent data.

The data contained in the tables on the magnitude and frequency of low flow and duration of flow are explained in preceding sections of this report.

Partial-record stations and miscellaneous sites

The data in table 2 are grouped in the following five river basins (fig 7): Mobile River basin, Green River basin, Cumberland River basin, Tennessee River basin, and Lower Mississippi River basin.

On each page of table 2, the data are arranged in nine columns, whose heading and content are:

Column 1, REF. NO., gives to each site a reference number whose location, with other data are shown on plate 1.

Column 2, STATION NO., gives the station number which is also the downstream order number for each site.

Column 3, STATION NAME, gives the site name referred to a nearby town.

Column 4, DRAINAGE AREA, gives the drainage area, in square miles, at the site if determined.

Column 5, LOCATION, gives both the latitude and longitude of the site along with a narrative describing the station location in relation to nearby landmarks.

Columns 6-9, 1, 3 or 7 DAY MEAN LOW FLOW, with 10 or 20 YEAR RECURRENCE, interval for each heading if determined. If no value has been calculated three asterisks will appear.

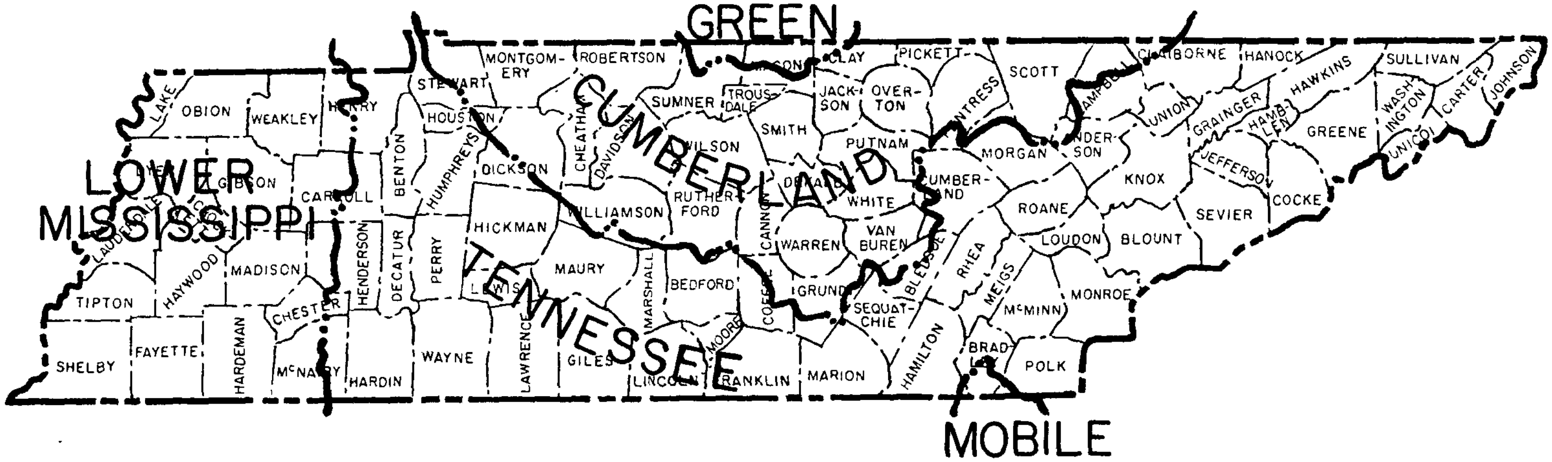


Figure 7.-- Map showing location of major river basins in Tennessee.

Data for continuous-record stations

03408000 - NEW RIVER NEAR NEW RIVER, TN

LOCATION.-- Lat 36°23'03", long 84°31'43", Scott County at county highway bridge 1.1 miles east of town of New River, 1.6 miles upstream from Brimstone Creek, and at mile 11.9.

DRAINAGE AREA.-- 314 mi^2.

PERIOD OF RECORD.-- December 1922 to December 1934

REMARKS:

FLOW DURATION

FLOW IN CUBIC FEET PER SECOND, WHICH WAS EQUALED OR EXCEEDED FOR PERCENTAGE OF TIME INDICATED.

99.5	99.1	99	98	95	90
1.30	1.58	1.65	2.20	4.60	9.20

80	70	60	50	40	30
26.0	62.0	126	219	345	500

20	10	5	2	1	0.5
790	1400	2400	4400	6800	9300

MAGNITUDE AND FREQUENCY

LOWEST AVERAGE FLOW IN CUBIC FEET PER SECOND, FOR INDICATED RECURRENCE INTERVAL IN YEARS.

PERIOD (CONSECUTIVE DAYS)	2	5	10	20	50
1	2.03	0.68	0.40	0.25	
3	2.45	0.81	0.45	0.28	
7	2.76	1.16	0.79	0.59	
14	3.72	1.75	1.28	1.03	
30	6.56	2.92	2.06	1.60	
60	16.6	6.24	3.94	2.76	
120	66.7	33.4	23.7	17.9	
183	134	70.6	51.0	39.2	

03408500 - NEW RIVER AT NEW RIVER, TN

LOCATION.-- Lat 36°23'08", long 84°33'17", Scott County, on left bank at town of New River, 700 ft downstream from Phillips Creek, 1000 ft downstream from bridge on U.S. Highway 27, 1.7 miles downstream from Brimstone Creek, and at mile 8.6.

DRAINAGE AREA.-- 382 mi^2.

PERIOD OF RECORD.-- September 1934 to September 1975.

REMARKS:

FLOW DURATION

FLOW IN CUBIC FEET PER SECOND, WHICH WAS EQUALED OR EXCEEDED FOR PERCENTAGE OF TIME INDICATED.

99.5	99.1	99	98	95	90
0.50	0.71	0.79	1.59	5.30	14.1

80	70	60	50	40	30
36.7	71.0	129	233	391	595

20	10	5	2	1	0.5
940	1720	3030	5220	8210	11000

MAGNITUDE AND FREQUENCY

LOWEST AVERAGE FLOW IN CUBIC FEET PER SECOND, FOR INDICATED RECURRENCE INTERVAL IN YEARS.

PERIOD (CONSECUTIVE DAYS)	2	5	10	20	50
1	3.13	0.75	0.33	0.16	0.07
3	3.44	0.82	0.36	0.18	0.07
7	4.25	0.99	0.42	0.20	0.08
14	5.89	1.38	0.58	0.27	0.11
30	11.6	2.98	1.32	0.63	0.26
60	23.7	7.04	3.44	1.83	0.86
120	64.3	25.5	14.8	9.08	5.06
183	130	62.8	41.9	29.6	19.7

03409500 - CLEAR FORK NEAR ROBBINS, TN

LOCATION.--Lat 36°23'18", long 84°37'49", Scott County, on right bank 300 ft downstream from Burnt Mill Bridge, 3.3 miles northwest of Robbins, and at mile 3.7

DRAINAGE AREA.--272 mi^2.

PERIOD OF RECORD.-- October 1930 to September 1971.

REMARKS:

FLOW DURATION

FLOW IN CUBIC FEET PER SECOND, WHICH WAS EQUALED OR EXCEEDED FOR PERCENTAGE OF TIME INDICATED.

99.5	99.1	99	98	95	90
1.88	2.49	2.57	3.50	5.75	9.90

80	70	60	50	40	30
23.2	42.3	79.0	142	242	384

20	10	5	2	1	0.5
613	1120	1820	3190	4770	6790

MAGNITUDE AND FREQUENCY

LOWEST AVERAGE FLOW IN CUBIC FEET PER SECOND, FOR INDICATED RECURRENCE INTERVAL IN YEARS.

PERIOD (CONSECUTIVE DAYS)	2	5	10	20	50
1	4.27	1.83	1.09	0.69	0.39
3	4.38	1.91	1.17	0.76	0.45
7	4.74	2.16	1.40	0.96	0.63
14	5.73	2.71	1.82	1.29	0.88
30	8.76	4.29	2.96	2.19	1.56
60	14.9	7.57	5.39	4.10	3.04
120	35.8	17.3	11.7	8.43	5.78
183	72.6	38.0	26.7	19.8	14.0

03414500 - EAST FORK OBEY RIVER NEAR JAMESTOWN, TN

LOCATION.-- Lat 36°24'58", long 85°01'35", Fentress County, on right bank 200 ft upstream from bridge on State Highway 52, 0.5 miles upstream from Poplar Cove Creek, 5.3 miles west of Jamestown, and 12.8 miles upstream from confluence with West Fork.

DRAINAGE AREA.-- 202 mi^2.

PERIOD OF RECORD.--March 1943 to September 1975.

REMARKS:

FLOW DURATION

FLOW IN CUBIC FEET PER SECOND, WHICH WAS EQUALED OR EXCEEDED FOR PERCENTAGE OF TIME INDICATED.

99.5	99.1	99	98	95	90
4.50	5.29	5.42	6.58	9.37	13.8

80	70	60	50	40	30
24.4	42.4	81.1	149	248	372

20	10	5	2	1	0.5
549	949	1600	2750	3970	5550

MAGNITUDE AND FREQUENCY

LOWEST AVERAGE FLOW IN CUBIC FEET PER SECOND, FOR INDICATED RECURRENCE INTERVAL IN YEARS.

PERIOD (CONSECUTIVE DAYS)	2	5	10	20	50
1	8.26	5.40	4.40	3.76	3.18
3	8.42	5.52	4.53	3.89	3.32
7	8.99	5.87	4.80	4.11	3.49
14	10.1	6.39	5.13	4.32	3.60
30	12.5	7.72	6.24	5.34	4.57
60	18.7	10.1	7.68	6.28	5.12
120	35.7	17.6	12.4	9.46	7.05
183	68.9	34.2	23.6	17.4	12.3

03415000 - WEST FORK OBEY RIVER NEAR ALPINE, TN

LOCATION.-- Lat 36°23'49", long 85°10'28", Overton County, on upstream end of left pier of bridge on State Highway 52, 0.3 mile upstream from Nettlecarrier Creek, 2.4 miles east of Alpine, and 7.8 miles upstream from confluence with East Fork.

DRAINAGE AREA.-- 114 mi^2 (includes 34 mi^2 without surface drainage).

PERIOD OF RECORD.-- January 1943 to September 1971.

REMARKS:

FLOW DURATION

FLOW IN CUBIC FEET PER SECOND, WHICH WAS EQUALED OR EXCEEDED FOR PERCENTAGE OF TIME INDICATED.

99.5	99.1	99	98	95	90
3.34	3.49	3.52	3.93	4.95	6.39

80	70	60	50	40	30
10.3	16.5	27.4	49.0	80.8	133

20	10	5	2	1	0.5
209	365	610	1140	1690	2320

MAGNITUDE AND FREQUENCY

LOWEST AVERAGE FLOW IN CUBIC FEET PER SECOND, FOR INDICATED RECURRENCE INTERVAL IN YEARS.

PERIOD (CONSECUTIVE DAYS)	2	5	10	20	50
1	4.22	3.20	2.86	2.66	2.48
3	4.33	3.28	2.94	2.73	2.55
7	4.53	3.43	3.08	2.88	2.70
14	5.07	3.80	3.39	3.13	2.90
30	6.07	4.58	4.17	3.50	3.35
60	8.48	5.62	4.73	4.19	3.73
120	14.3	8.61	6.86	5.80	4.89
183	23.9	13.3	10.0	8.05	6.35

03415500 - OBEY RIVER NEAR BYRDSTOWN, TN

LOCATION.--Lat 36°32'09", long 85°10'13", Pickett County, at former bridge on State Highway 42, 0.4 mile downstream from present bridge, 1.8 miles upstream from Big Eagle Creek, and 3.2 miles southwest of Byrdstown.

DRAINAGE AREA.--445 mi^2.

PERIOD OF RECORD.--April 1919 to September 1943.

REMARKS: Site now inundated by Dale Hollow Reservoir.

FLOW DURATION

FLOW IN CUBIC FEET PER SECOND, WHICH WAS EQUALED OR EXCEEDED FOR PERCENTAGE OF TIME INDICATED.

99.5	99.1	99	98	95	90
13.1	15.2	15.4	17.4	23.4	34.3

80	70	60	50	40	30
61.0	101	174	294	447	649

20	10	5	2	1	0.5
966	1680	2800	5100	7300	9910

MAGNITUDE AND FREQUENCY

LOWEST AVERAGE FLOW IN CUBIC FEET PER SECOND, FOR INDICATED RECURRENCE INTERVAL IN YEARS.

PERIOD (CONSECUTIVE DAYS)	2	5	10	20	50
1	18.5	12.2	9.88	8.32	6.88
3	21.4	14.7	12.1	10.3	8.66
7	23.6	16.5	13.7	11.8	10.0
14	26.7	18.3	15.1	12.9	10.8
30	32.8	21.1	17.1	14.6	12.3
60	46.3	28.5	22.6	18.8	15.4
120	103	51.8	35.4	25.5	17.3
183	180	95.0	64.3	45.2	29.4

03416000 - WOLF RIVER NEAR BYRDSTOWN, TN

LOCATION.--Lat 36°33'37", long 85°04'23", Pickett County, on right bank 0.3 mile upstream from bridge on county road, 0.5 mile upstream from Widow Creek, 1.6 miles north of Moodyville, 3.2 miles east of Byrdstown, and 5.4 miles upstream from Lick Creek.

DRAINAGE AREA.--106 mi².

PERIOD OF RECORD.-- July 1943 to September 1975.

REMARKS:

FLOW DURATION

FLOW IN CUBIC FEET PER SECOND, WHICH WAS EQUALED OR EXCEEDED FOR PERCENTAGE OF TIME INDICATED.

99.5	99.1	99	98	95	90
5.05	5.50	5.65	6.54	8.44	11.3

80	70	60	50	40	30
17.3	25.6	40.1	67.7	108	162

20	10	5	2	1	0.5
247	430	678	1260	1890	2510

MAGNITUDE AND FREQUENCY

LOWEST AVERAGE FLOW IN CUBIC FEET PER SECOND, FOR INDICATED RECURRENCE INTERVAL IN YEARS.

PERIOD (CONSECUTIVE DAYS)	2	5	10	20	50
1	7.22	4.74	3.77	3.09	2.46
3	7.51	5.09	4.12	3.45	2.81
7	7.92	5.85	5.07	4.54	4.03
14	8.75	6.56	5.73	5.16	4.63
30	10.7	7.77	6.66	5.91	5.20
60	13.4	9.39	7.93	6.94	6.02
120	21.0	12.9	10.2	8.46	6.94
183	36.7	21.0	15.9	12.6	9.85