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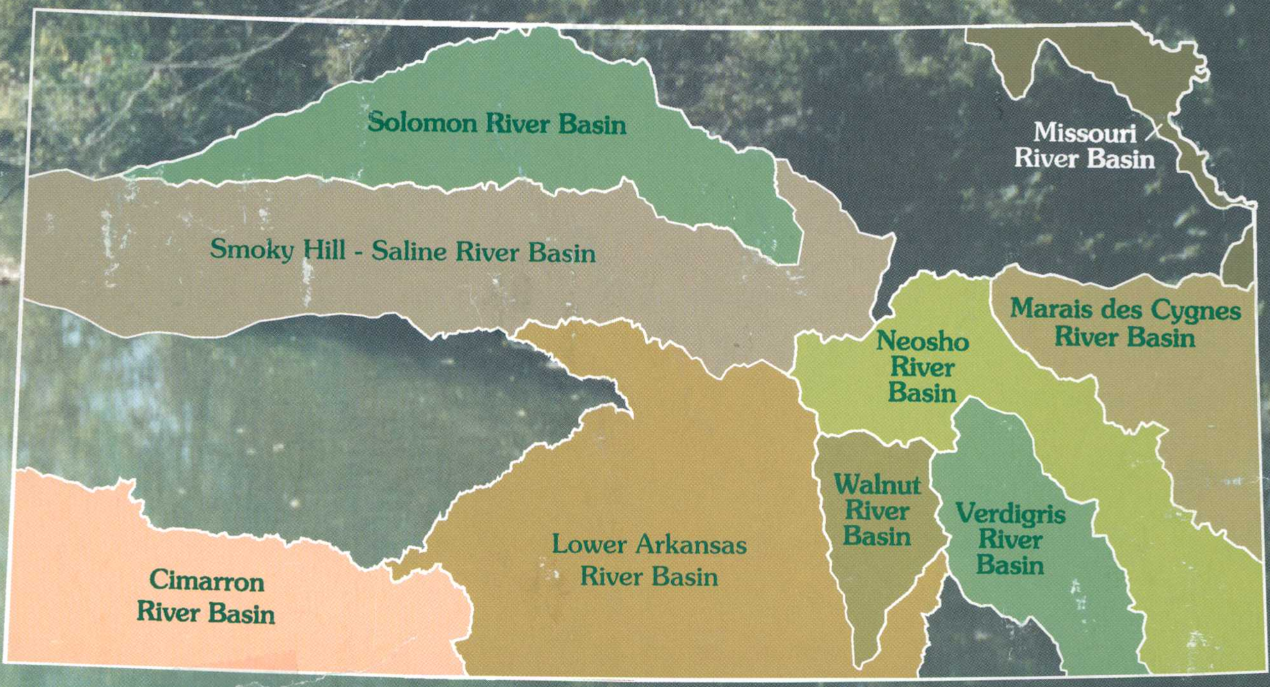
Estimated Flow-Duration Curves for Selected Ungaged Sites in Kansas

Water-Resources Investigations Report 01–4142



U.S. Department of the Interior
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Cover photograph

Chetopa Creek near Neodesha, Kansas, August 1999

(photograph taken by Seth Studley, U.S. Geological Survey, Lawrence, Kansas)

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By SETH E. STUDLEY

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KANSAS DEPARTMENT OF HEALTH AND ENVIRONMENT

Lawrence, Kansas
2001

U.S. Department of the Interior

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CONVERSION FACTORS, ABBREVIATIONS, AND DEFINITIONS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer
inch per square mile per year [$(in/mi^2)/yr$]	0.9807	centimeter per square kilometer per year
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Water year in U.S. Geological Survey reports is the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends; thus, the year ending September 30, 1998, is called the "1998 water year."

Estimated Flow-Duration Curves for Selected Ungaged Sites in Kansas

By Seth E. Studley

Abstract

Flow-duration curves for 1968–98 were estimated for 32 ungaged sites in the Missouri, Smoky Hill-Saline, Solomon, Marais des Cygnes, Walnut, Verdigris, and Neosho River Basins in Kansas. Also included from a previous report are estimated flow-duration curves for 16 ungaged sites in the Cimarron and lower Arkansas River Basins in Kansas. The method of estimation used six unique factors of flow duration: (1) mean streamflow and percentage duration of mean streamflow, (2) ratio of 1-percent-duration streamflow to mean streamflow, (3) ratio of 0.1-percent-duration streamflow to 1-percent-duration streamflow, (4) ratio of 50-percent-duration streamflow to mean streamflow, (5) percentage duration of appreciable streamflow (0.10 cubic foot per second), and (6) average slope of the flow-duration curve. These factors were previously developed from a regionalized study of flow-duration curves using streamflow data for 1921–76 from streamflow-gaging stations with drainage areas of 100 to 3,000 square miles.

The method was tested on a currently (2001) measured, continuous-record streamflow-gaging station on Salt Creek near Lyndon, Kansas, with a drainage area of 111 square miles and was found to adequately estimate the computed flow-duration curve for the station. The method also was tested on a currently (2001) measured, continuous-record, streamflow-gaging station on Soldier Creek near Circleville, Kansas, with a drainage area of 49.3 square miles. The results of the test on Soldier Creek near Circleville indicated that the method could adequately estimate flow-duration curves for sites with drainage areas of less than 100 square miles.

The low-flow parts of the estimated flow-duration curves were verified or revised using 137 base-flow discharge measurements made during 1999–2000 at the 32 ungaged sites that were correlated with base-flow measurements and flow-duration analyses performed at nearby, long-term, continuous-record, streamflow-gaging stations (index stations). The method did not adequately estimate the flow-duration curves for two sites in the western one-third of the State because of substantial changes in farming practices (terracing and intensive ground-water withdrawal) that were not accounted for in the two previous studies (Furness, 1959; Jordan, 1983). For these two sites, there was enough historic, continuous-streamflow record available to perform record-extension techniques correlated to their respective index stations for the development of the estimated flow-duration curves.

The estimated flow-duration curves at the ungaged sites can be used for projecting future flow frequencies for assessment of total maximum daily loads (TMDLs) or other water-quality constituents, water-availability studies, and for basin-characteristic studies.

INTRODUCTION

Section 303d of the 1977 Clean Water Act requires States to identify and list water bodies where State water-quality standards are not being met and to establish total maximum daily loads (TMDLs) for these waters (Kansas Department of Health and Environment, 1999a). A TMDL is a means for recommending controls needed to meet water-quality standards in a particular watershed. It specifies the amount a contaminant needs to be reduced to meet water-quality standards, allocates contaminant load reductions among contaminant sources in a watershed, and provides the basis for taking actions needed to restore a water body. A TMDL can identify the need for point-source and nonpoint-source controls (U.S. Environmental Protection Agency, 1998).

The State of Kansas has proposed the use of a stream's flow-duration curve to assess whether a stream's TMDL criterion is being exceeded (Kansas Department of Health and Environment, 1999b). Use of the duration curve yields a contaminant load that is based on the magnitude of the streamflow and also projects the expected annual duration of that load. Flow-duration curves for continuous-record, streamflow-gaging stations can be generated using the U.S. Geological Survey's (USGS) automated data-processing system (ADAPS), a component of the National Water Information System (NWIS). For ungaged sites (those without continuous record), a method for estimating the flow-duration curves is needed.

One method for estimating flow-duration curves is outlined in Furness (1959) and in Searcy (1959). Furness (1959) applied the method to sites with drainage areas between 100 and 3,000 mi^2. The drainage-area limits were imposed because of the lack of long-term data for sites with drainage areas less than 100 mi^2 and the lack of unregulated or natural streamflow data for sites with more than 3,000 mi^2. The current (2001) availability of data from several continuous-record, streamflow-gaging stations in Kansas with less than 100 mi^2 of drainage area allows for the testing of the Furness method for its applicability to smaller drainage basins. The estimated duration curve compared with the computed duration curve for the gaging station on Soldier Creek near Circleville (station 06889160, fig. 1) shows the accuracy of the Furness method for ungaged sites with drainage areas less than 100 mi^2.

Previous Studies

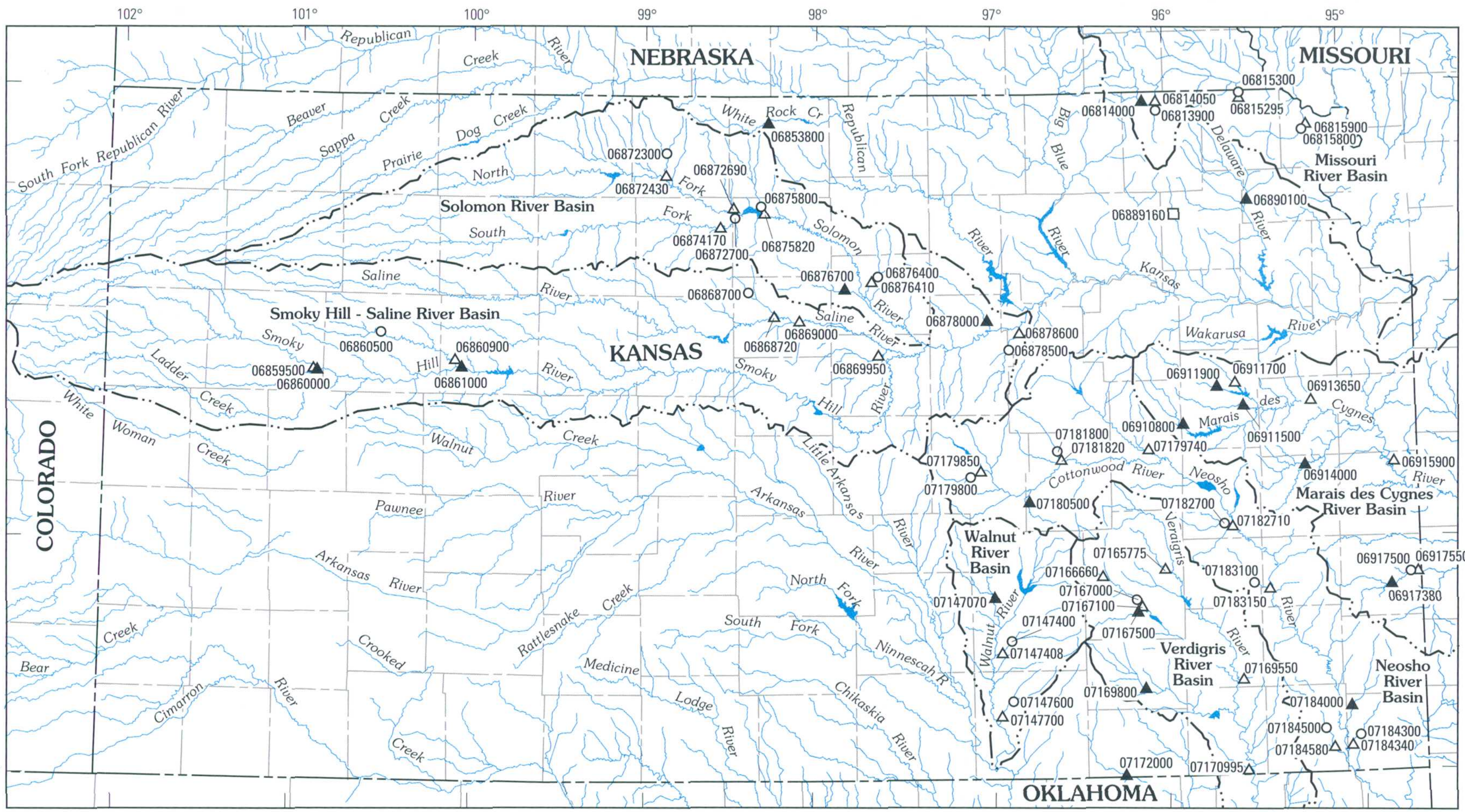
Furness (1959) developed a method for estimating flow-duration curves for ungaged sites that was based on regionalized flow-duration data from 122 continuous-record, streamflow-gaging stations with drainage areas of between 100 and 3,000 mi^2 for the period 1921–56. Maps were developed showing the distribution of the regionalized flow-duration data for mean streamflow, percentage duration of mean streamflow, ratio of 1-percent duration streamflow to mean streamflow for drainage area of 500 mi^2, ratio of 50-percent duration streamflow to mean streamflow for drainage area of 500 mi^2, percentage duration of 0.10 ft^3/s streamflow for drainage area of 500 mi^2, and variability index or average slope of the flow-duration curve for drainge area of 500 mi^2. Graphs were developed to relate the 500-mi^2 drainage-area flow-duration values to sites with between 100 and 3,000 mi^2 of drainage area. The average ratio of 1-percent flow–duration streamflow to 0.10-percent flow-duration streamflow (3.3) was used to estimate the 0.10-percent flow-duration streamflow at ungaged sites in Kansas. From these five estimated flow-duration points and the average slope of the flow-duration curve, it was found that a reasonable estimate of a flow-duration curve could be developed for ungaged sites in Kansas. It also was found that the low-flow parts of the flow-duration curves could be verified or improved by relating base-flow measurements at the ungaged site to base-flow measurements at a nearby, index streamflow-gaging station.

Jordan (1983) updated the maps developed by Furness by including additional years of streamflow data for the period 1957–76 and from additional streamflow-gaging stations. It was also determined that the average ratio of 1-percent flow-duration streamflow to 0.10-percent flow-duration streamflow was 5.7 for sites west of 99^o longitude in Kansas and 3.1 for sites east of 99^o longitude in Kansas.

This study is a continuation of a recent study by Studley (2000) that evaluated the application of the Furness method to 16 ungaged stream sites in the Cimarron and lower Arkansas River Basins in Kansas for the period 1968–98. The estimated flow-duration curves for these 16 sites are included in Appendix D in the back of this report. The results of the recent study indicated that the Furness method continues to be a useful tool for estimating flow-duration curves for ungaged sites and that the method could be used for sites with drainage areas of less than 100 mi^2.

Purpose and Scope

The study described in this report builds on the results and expands the scope of the previous study by



Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°

Basin delineation from Kansas Department of Health and Environment, 1999c

0 50 100 MILES

0 50 100 KILOMETERS

EXPLANATION

—··— Boundary of river basin

06874170 △ Ungaged site and number

06853800 ▲ Index station and number

06815300 ○ Historic base-flow-measurement site and number

06889160 □ Streamflow-gaging station and number used to test Furness method for estimating flow-duration curves

Figure 1. Location of selected ungaged sites, concurrently measured, continuous-record, streamflow-gaging stations (index stations), and historic base-flow-measurement sites Kansas used for estimation of flow-duration curves.

Studley (2000) to include seven additional river basins (Missouri, Smoky Hill-Saline, Solomon, Marais des Cygnes, Walnut, Verdigris, and Neosho) in Kansas. The Furness method was tested on a long-term, continuous-record, streamflow-gaging station, and estimated flow-duration curves were developed for 32 selected ungaged sites in the Missouri, Smoky Hill-Saline, Solomon, Marais des Cygnes, Walnut, Verdigris, and Neosho River Basins in Kansas.

This study was done in cooperation with the Kansas Department of Health and Environment (KDHE) to fulfill a part of the Kansas State Water Plan to help ensure a safe and clean water supply for Kansans. From a national perspective, the methods and results presented in this report could have wide applicability for water-supply and water-quality assessments for sites where little or no streamflow data have been collected. The estimated flow-duration curves can provide a basis for evaluating streamflow on ungaged streams for water-power studies, water-availability studies, basin-characteristic studies, stream-contamination studies, and water-quality studies.

The specific study objectives were to:

(1) Test and, if necessary, refine the Furness method by generation of an estimated flow-duration curve for a long-term, continuous-record, streamflow-gaging station and compare the estimated curve with the computed curve for that station.

(2) Evaluate existing historic streamflow information for 32 selected ungaged sites in Kansas for the verification and (or) refinement of the estimated flow-duration curve.

(3) Collect several base-flow measurements at 32 selected ungaged sites in Kansas and concurrently at respective nearby, long-term, continuous-record, streamflow-gaging stations (index stations).

(4) Construct estimated flow-duration curves for the 32 selected ungaged sites in Kansas using the Furness method and the base-flow measurements.

The streams that need estimated flow-duration curves were selected on the basis of the 1977 Clean Water Act's required 303d list developed by KDHE. USGS personnel selected the ungaged sites on those streams on the basis of stream accessibility, suitability of the site for streamflow measurement, and availability of historic streamflow data. In this report, ungaged sites are those sites that currently (2001) do not have continuous stage-recording equipment even though they may have some historical data available. Figure 1 shows the location of the 32 ungaged sites, 18 long-term, continuous-record, streamflow-gaging stations (index stations) used to correlate ungaged-site streamflows to flow-duration percentages, and 20 streamflow-measurement sites with historic base-flow measurements and (or) continuous-streamflow data available to refine or verify the estimated flow-duration curves. Table 1 lists the ungaged sites and the index stations used for estimation of flow-duration curves.

A period of record from 1968 through 1998 was used for this study of flow durations in the Missouri, Smoky Hill-Saline, Solomon, Marais des Cygnes, Walnut, Verdigris, and Neosho River Basins. This period was chosen because, in the years since Furness developed the method for estimating flow-duration curves, changes in farming practices, the number of lakes and ponds, population, and land use have caused substantial changes in some of the long-term flow-duration curves. By using 1968–98 streamflow records, the duration curves can be used to more nearly approximate the current streamflow conditions on the streams, from which planners can more accurately assess the availability of streamflow for future use. In addition, this period is long enough to include equal periods of both drought and flood conditions.

DESCRIPTION OF FURNESS METHOD

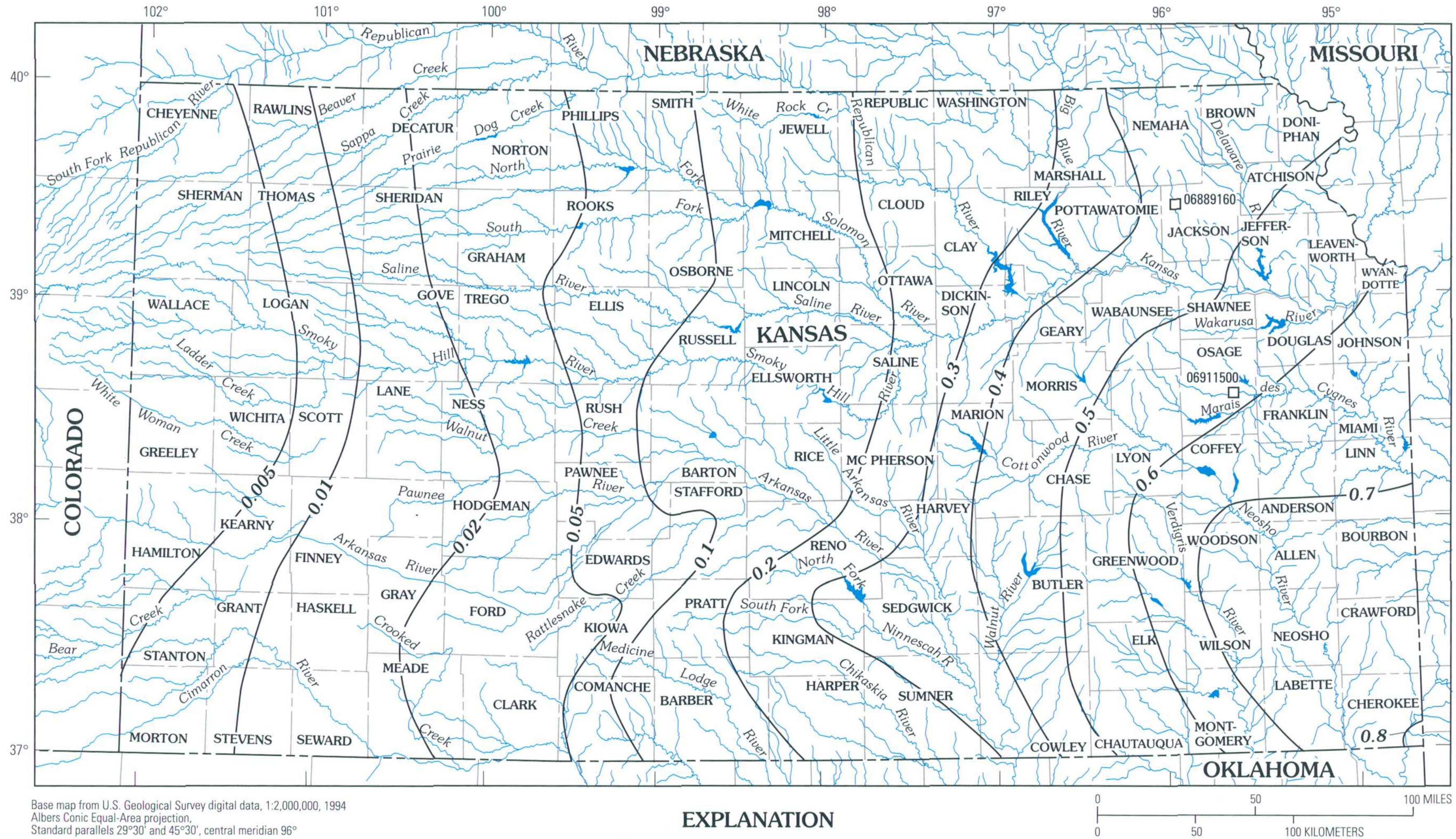
The method used in this study to estimate flow-duration curves (Furness, 1959, p. 186–211) uses maps, graphs, and computations to identify six unique factors of flow duration for ungaged sites. The factors are: (1) mean streamflow (fig. 2) and percentage duration of mean streamflow (fig. 3), (2) ratio of 1-percent-duration streamflow to mean streamflow (figs. 4 and 5), (3) ratio of 0.1-percent-duration streamflow to 1-percent-duration streamflow, (4) ratio of 50-percent-duration streamflow to mean streamflow (figs. 6 and 7), (5) percentage duration of appreciable (0.10 ft^3/s) streamflow (figs. 8 and 9), and (6) average slope of the flow-duration curve (variability index) (figs. 10 and 11). The maps, graphs, and computations in Furness (1959) were originally created using streamflow data for 1921–56. In 1983, the maps and computations were updated by Jordan (1983, p. 15–30) using an additional 20 years of data (1957–76) (in figure 2, data from 1965–80 were used

Table 1. Selected ungaged sites and their concurrently measured index stations in the Missouri, Smoky Hill-Saline, Solomon, Marais des Cygnes, Walnut, Verdigris, and Neosho River Basins in Kansas

Ungaged site			Index station	
Site number (fig. 1)	Site name	Drainage area (square miles)	Station number (fig. 1)	Station name
	Missouri River Basin			
06814050	South Fork Big Nemaha River near Bern	558	06814000	Turkey Creek near Seneca
06815295	Walnut Creek near Padonia	101	06890100	Delaware River near Muscotah
06815900	Wolf River at Sparks	239	do.	Do.
	Smoky Hill-Saline River Basin			
06859500	Ladder Creek below Chalk Creek near Scott City	1,432	06860000	Smoky Hill River at Elkader
06860900	Hackberry Creek near Trego Center	616	06861000	Smoky Hill River near Arnold
06868720	Spillman Creek near Lincoln	168	06876700	Salt Creek near Ada
06869000	Elkhorn Creek near Lincoln	68.1	do.	Do.
06869950	Mulberry Creek near Salina	261	do.	Do.
06878600	Lyon Creek near Wreford	267	06878000	Chapman Creek near Chapman
	Solomon River Basin			
06872430	Beaver Creek near Gaylord	178	06853800	White Rock Creek near Burr Oak
06872690	Oak Creek northwest of Cawker City	188	do.	Do.
06874170	Twin Creek near Corinth	87.6	06876700	Salt Creek near Ada
06875820	Limestone Creek at Glen Elder	211	06853800	White Rock Creek near Burr Oak
06876410	Pipe Creek at Minneapolis	146	do.	Do.
	Marais des Cygnes River Basin			
06911700	Hundred and Ten Mile Creek near Scranton	33.9	06911900	Dragoon Creek near Burlingame
06913650	Tauy Creek near Ottawa	79.5	06911500	Salt Creek near Lyndon
06915900	Middle Creek near La Cygne	62.8	06914000	Pottawatomie Creek near Garnett
06917550	Marmaton River near Kansas-Missouri State line	421	06917380	Marmaton River near Marmaton
	Walnut River Basin			
07147408	Little Walnut River southeast of Gordon	267	07147070	Whitewater River at Towanda
07147700	Timber Creek near Winfield	154	07172000	Caney River near Elgin
	Verdigris River Basin			
07165775	West Creek near Quincy	120	07167500	Otter Creek at Climax
07166660	West Branch Fall River near Eureka	96.5	do.	Do.
07167100	Fall River near Climax	327	do.	Do.
07169550	Chetopa Creek near Neodesha	54.4	06917380	Marmaton River near Marmaton
07170995	Onion Creek near Coffeyville	97.7	07169800	Elk River at Elk Falls

Table 1. Selected ungaged sites and their concurrently measured index stations in the Missouri, Smoky Hill-Saline, Solomon, Marais des Cygnes, Walnut, Verdigris, and Neosho River Basins in Kansas—Continued

Ungaged site			Index station	
Site number (fig. 1)	Site name	Drainage area (square miles)	Station number (fig. 1)	Station name
	Neosho River Basin			
07179740	Allen Creek near Emporia	117	06910800	Marais des Cygnes River near Reading
07179850	South Cottonwood River near Marion	113	07180500	Cedar Creek near Cedar Point
07181820	Diamond Creek on Highway 50 near Elmdale	152	do.	Do.
07182710	Big Creek 2 miles west of Le Roy	131	06914000	Pottawatomie Creek near Garnett
07183150	Owl Creek near Humboldt	203	06917380	Marmaton River near Marmaton
07184340	Cherry Creek near Chetopa	113	07184000	Lightning Creek near Mc Cune
07184580	Labette Creek near Chetopa	353	do.	Do.



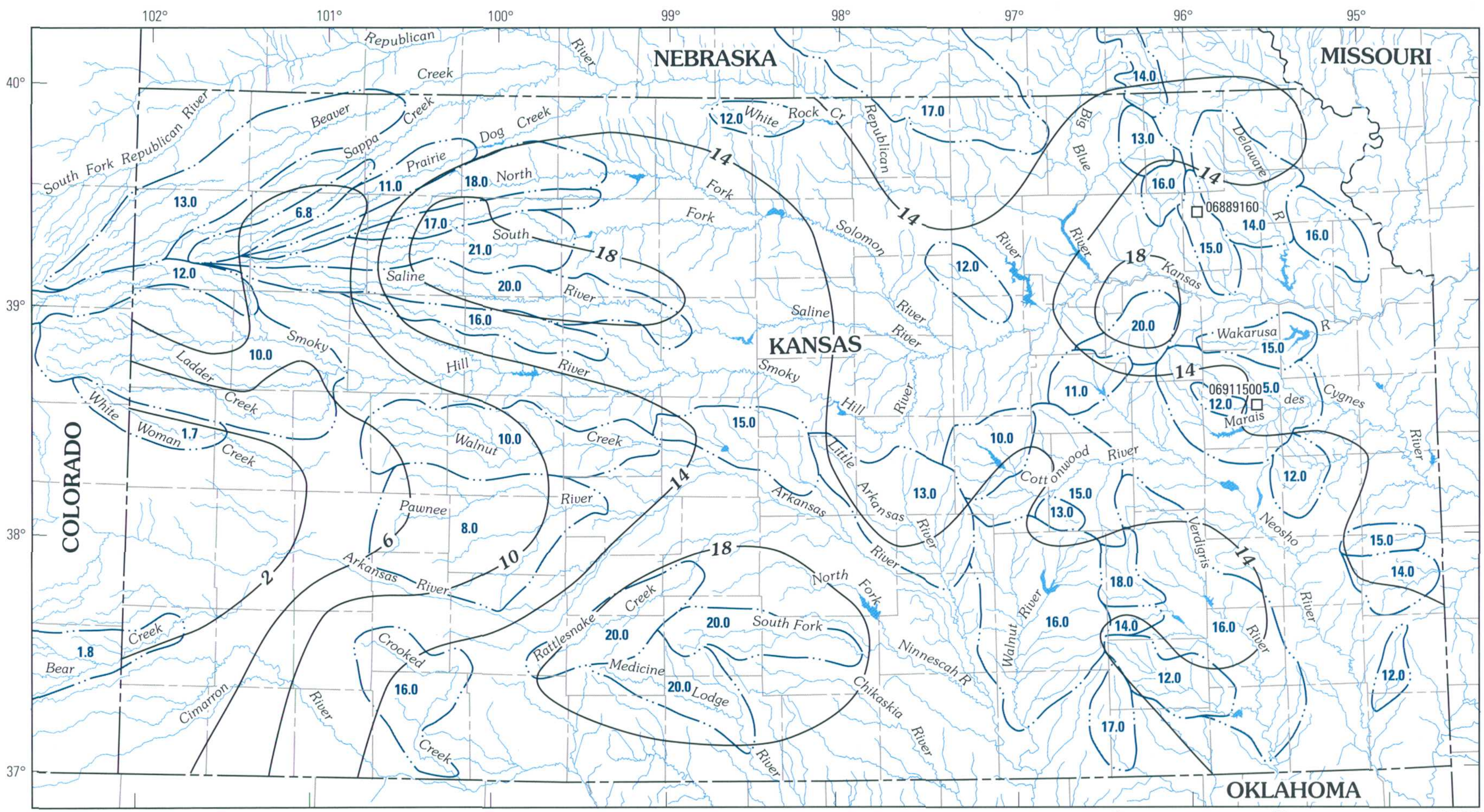
Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°

EXPLANATION

—*0.02*— Line of equal mean streamflow, in cubic feet per second per square mile—Interval varies

06889160□ Streamflow-gaging station and number used to test Furness method for estimating flow-duration curves

Figure 2. Geographic variation of mean streamflow in Kansas (from Jordan, 1983, fig. 7).



Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
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EXPLANATION

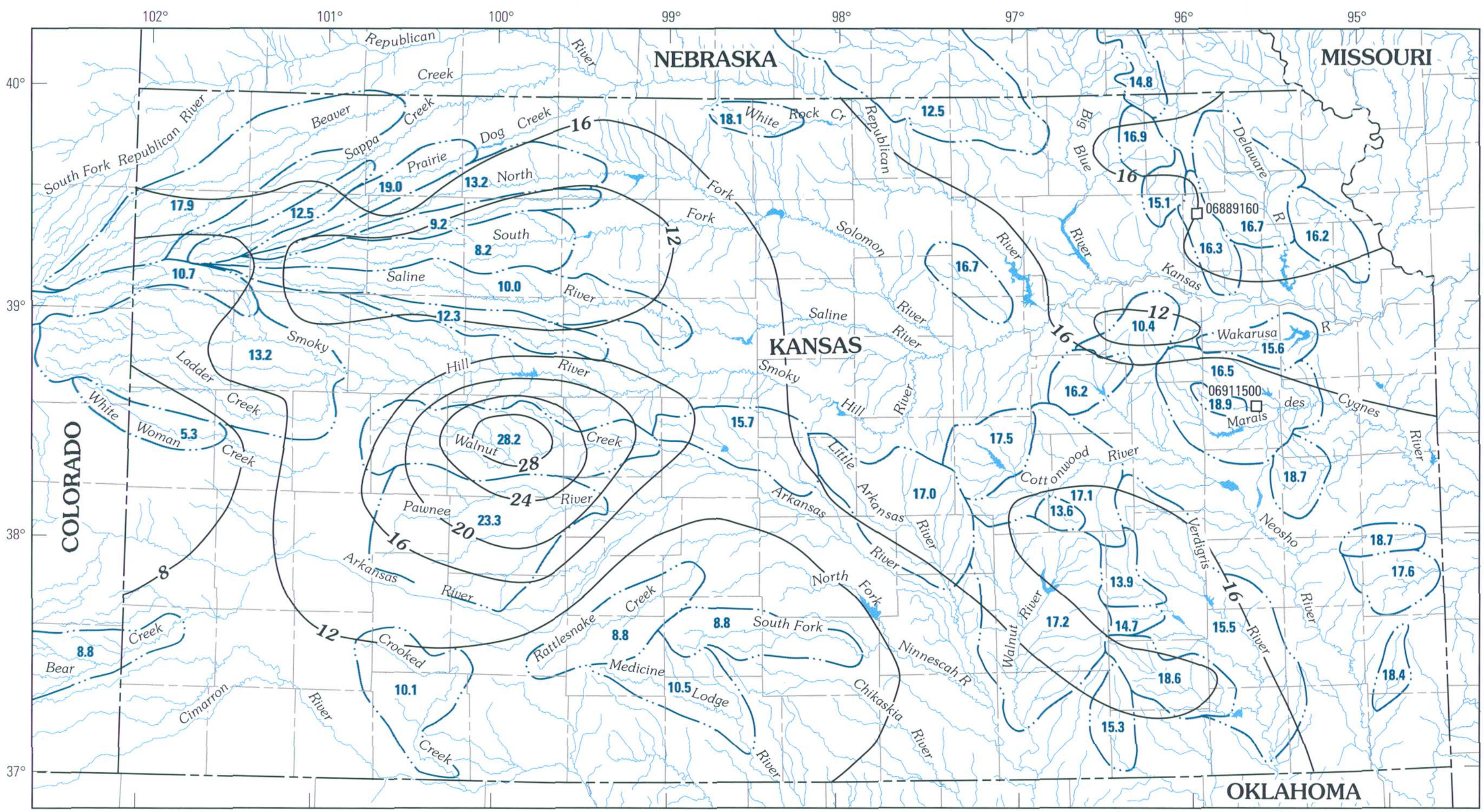
—10— Line of equal percentage duration—Interval 4 percent

—·· — Basin boundary

16.0 Percentage duration of mean flow for basin outlined

06889160□ Streamflow-gaging station and number used to test Furness method for estimating flow-duration curves

Figure 3. Percentage duration of mean streamflow in Kansas (from Jordan, 1983, fig. 8).



Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°

EXPLANATION

—*16*— **Line of equal ratio**—Interval 4 (nondimensional)

—·-— **Basin boundary**

10.5 **Ratio of 1-percent flow to mean flow, for basin outlined, as adjusted to 500 square-mile drainage area**

06889160□ **Streamflow-gaging station and number used to test Furness method for estimating flow-duration curves**

Figure 4. Ratios of 1-percent-duration streamflow to mean streamflow adjusted to drainage area of 500 square miles in Kansas (from Jordan, 1983, fig. 9).

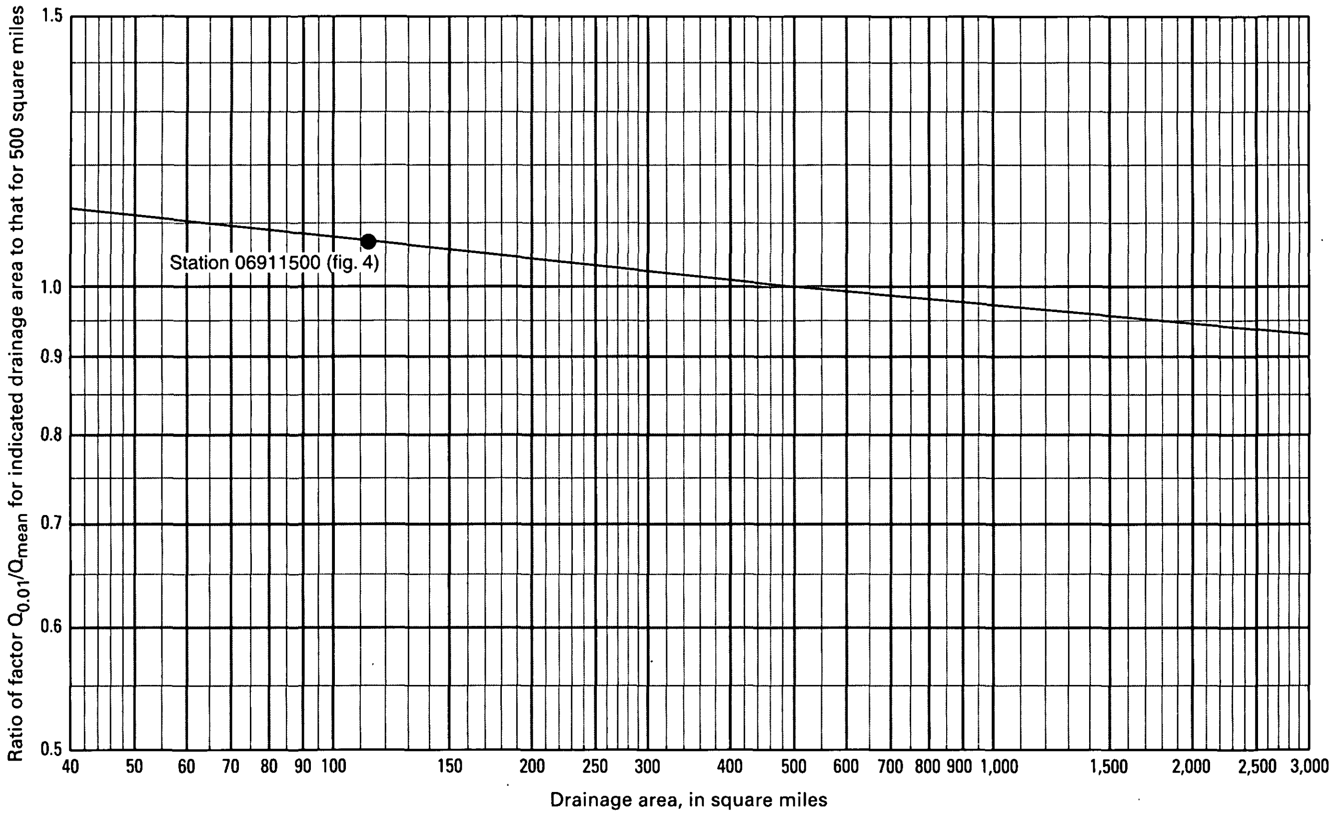


Figure 5. Relation between drainage area and ratio of 1-percent-duration streamflow ($Q_{0.01}$) to mean streamflow (Q_{mean}) (Furness, 1959, fig. 142).

for stations west of 99° longitude) and data from many additional streamflow-gaging stations.

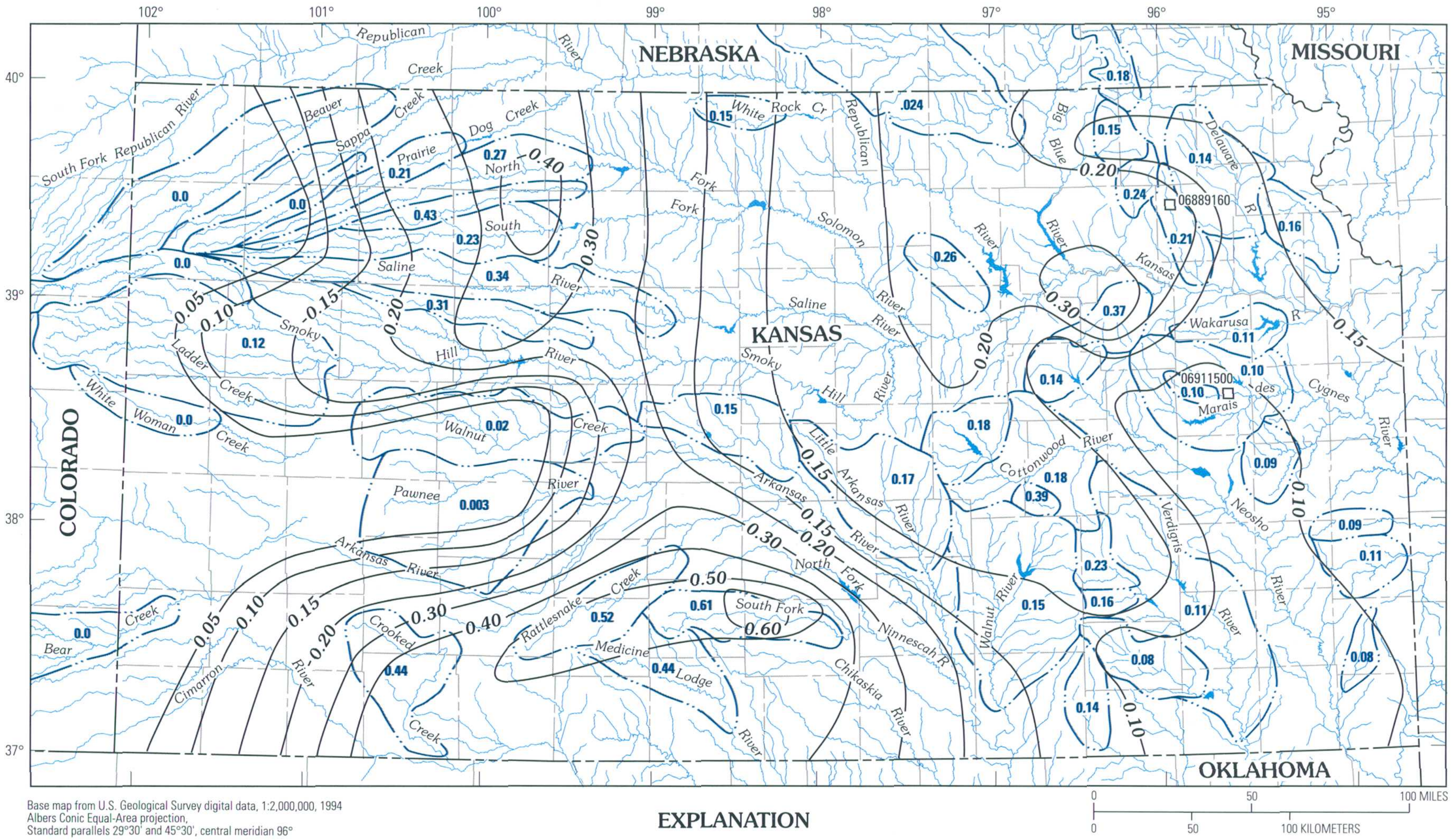
Estimation of the flow-duration curve for the long-term, continuous-record, streamflow-gaging station on Salt Creek near Lyndon, Kansas (station 06911500, fig. 1), provides a test of the Furness method. This station has operated continually since October 1940, has a drainage area of 111 mi^2, and is located in Osage County (fig. 2). The estimated flow-duration curve and the computed flow-duration curve for this station were compared (fig. 12) to test whether this method is an acceptable alternative to installation of a new streamflow-gaging station for long-term data collection in order to develop a flow-duration curve. The estimated factors were developed for figure 12 as follows:

Mean streamflow: From figure 2, the mean streamflow for Salt Creek near Lyndon (station 06911500, fig. 2) is 0.59 $(ft^3/s)/mi^2$ or 0.59 x 111 = 65.5 ft^3/s. From figure 3, the percentage duration for mean streamflow for Salt Creek near Lyndon (station 06911500, fig. 3) is 14 percent. The coordinates of mean streamflow are now defined and are plotted in figure 12 as 65.5 ft^3/s at 14-percent duration (point A).

1-percent-duration streamflow: From figure 4, the ratio of 1-percent-duration streamflow to mean streamflow for Salt Creek near Lyndon (station 06911500, fig. 4) is about 17. From figure 5, the adjustment from 500 to 111 mi^2 is 1.08. The ratio of 1-percent-duration streamflow to mean streamflow is 17 x 1.08 = 18.36. Therefore, the 1-percent-duration streamflow is 18.36 x 65.5 $ft^3/s \approx$ 1,200 ft^3/s. In figure 12, the 1-percent-duration point is plotted at 1,200 ft^3/s (point B).

0.1-percent-duration streamflow: Using the average ratio of 0.1-percent-duration streamflow to 1-percent-duration streamflow as calculated by Jordan (1983, p. 21), the value plotted in figure 12 for 0.1-percent duration is 1,200 x 3.1 = 3,720 ft^3/s (point C). If the Salt Creek near Lyndon station were located west of 99° longitude, the 1-percent-duration streamflow would be multiplied by 5.7, instead of 3.1, to obtain the 0.1-percent-duration streamflow.

50-percent-duration streamflow: Figure 6 indicates that the ratio of 50-percent-duration streamflow to mean streamflow for Salt Creek near Lyndon (station 06911500, fig. 6) is about 0.10, and figure 7 shows that the adjustment to 111 mi^2 is 0.75;



Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°

EXPLANATION

—*0.01*— **Line of equal ratio**—Interval 0.05 and 0.10 (nondimensional)

—·-·— **Basin boundary**

0.17 **Ratio of 50-percent flow to mean flow, for basin outlined, as adjusted to 500-square-mile drainage area**

06889160 □ **Streamflow-gaging station and number used to test Furness method for estimating flow-duration curves**

Figure 6. Ratios of 50-percent-duration streamflow to mean streamflow adjusted to drainage area of 500 square miles in Kansas (from Jordan, 1983, fig. 11).

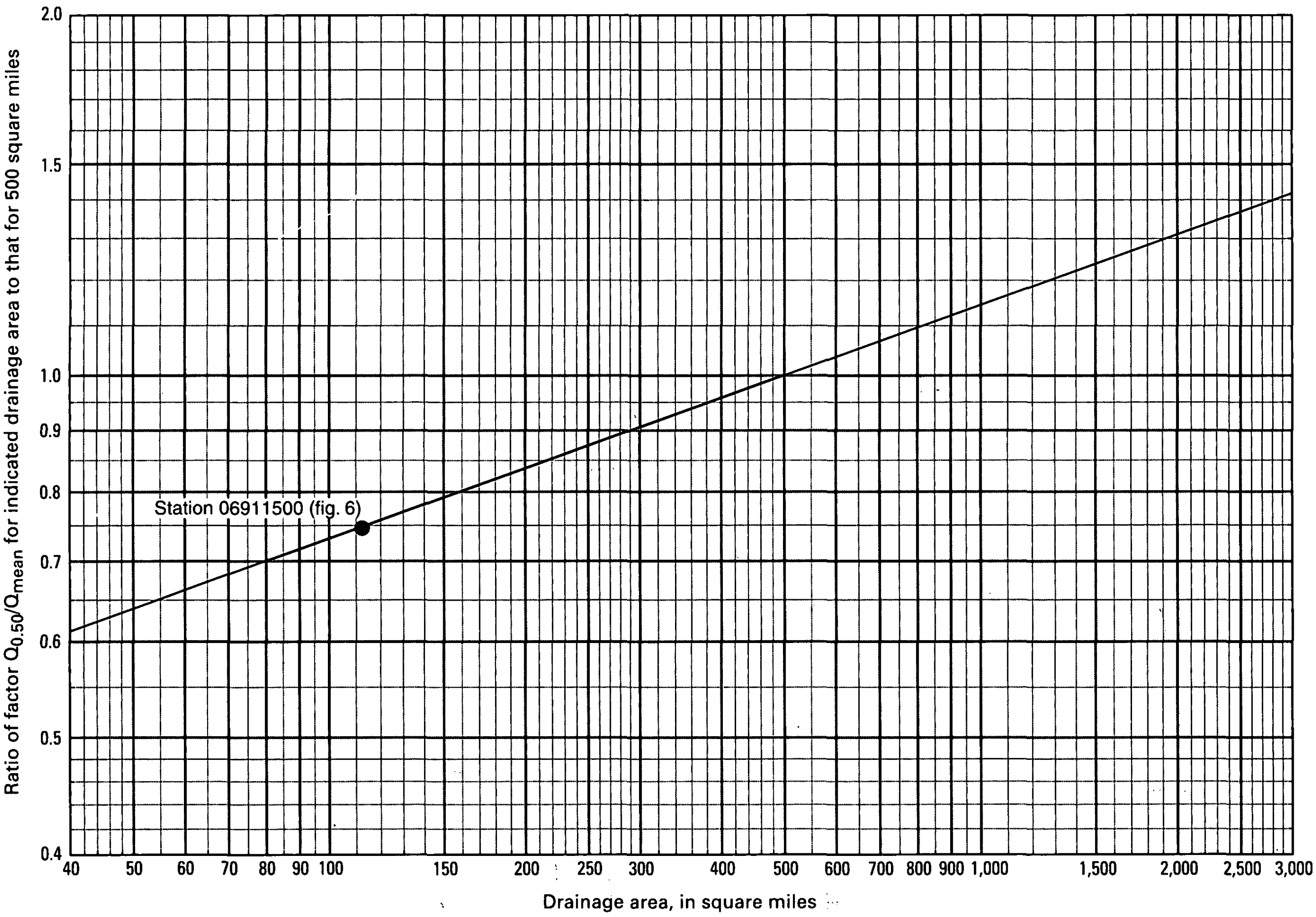


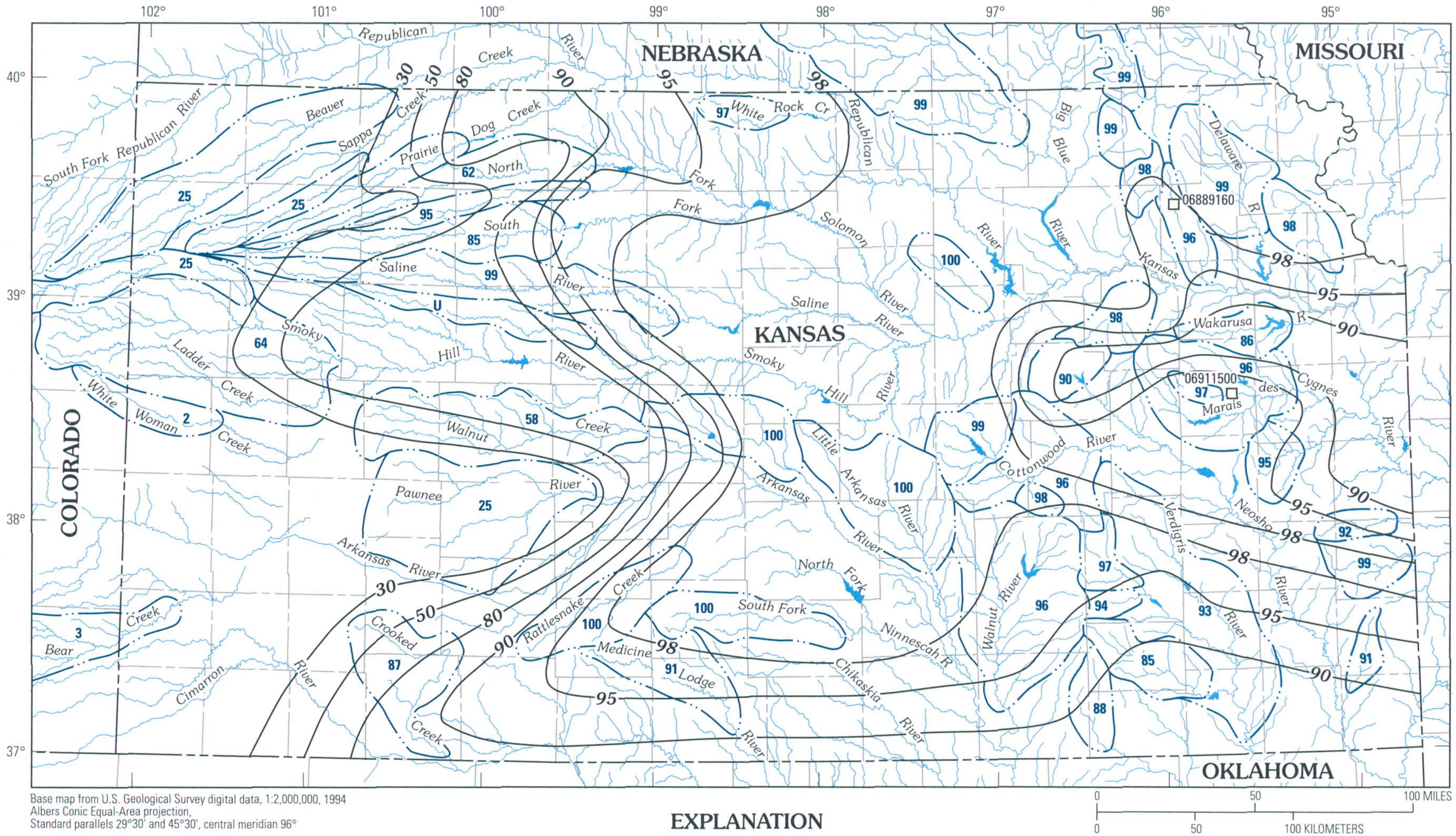
Figure 7. Relation between drainage area and ratio of 50-percent-duration streamflow ($Q_{0.50}$) to mean streamflow (Q_{mean}) (from Furness, 1959, fig. 144).

therefore, the 50-percent-duration streamflow is 0.10 x 0.75 x 65.5 = 4.91 ft^3/s as plotted in figure 12 (point D).

Duration percentage of appreciable flow: Furness (1959) defined appreciable flow as 0.10 ft^3/s. This value of streamflow was important because, for many years, this was the smallest non-zero streamflow value reported in most streamflow records. Figure 8 shows that the percentage duration of 0.10 ft^3/s adjusted to 500 mi^2 at Salt Creek near Lyndon (station 06911500, fig. 8) is about 97 percent. To find the duration of appreciable flow for 111 mi^2 in figure 9, a point representing 97-percent duration and a drainage area of 500 mi^2 was plotted. Following the diagonal line to 111 mi^2 of drainage area, the percentage duration of 0.10 ft^3/s was found to be about 90 percent. In figure 12, the point is plotted as 0.10 ft^3/s at 90-percent duration (point E). If an estimated duration curve is to be developed for a site where appreciable flow occurs more than 99 percent of the time, the value of the duration of appreciable flow is ignored, and the curve is developed using the other five factors.

Average slope of the duration curve: The average slope of the duration curve is a graphical approximation of the variability index, which is the standard deviation of the logarithms of the streamflows (Furness, 1959, p. 202–204, figs. 147 and 148). On a duration curve that fits the log-normal distribution exactly, the variability index is equal to the ratio of the streamflow at the 15.87-percent-duration point to the streamflow at the 50-percent-duration point. Because duration curves usually do not exactly fit the log-normal distribution, the average-slope line is drawn through an arbitrary point, and the slope is transferred to a position approximately defined by the previously estimated points.

Figure 10 provides an average slope of about 1.0 for a 500-mi^2 drainage area for Salt Creek near Lyndon (station 06911500, fig. 10). Figure 11 shows



EXPLANATION

—95— Line of equal percentage duration of appreciable flow for basins adjusted to 500-square-mile drainage area—Interval varies

—··— Basin boundary

0.17 Percentage duration of appreciable flow (0.10 cubic foot per second) adjusted to 500-square-mile drainage area, plotted near streamflow-gaging station for basin outlined—U, undefined

06889160 □ Streamflow-gaging station and number used to test Furness method for estimating flow-duration curves

Figure 8. Percentage duration of appreciable flow (0.10 cubic foot per second) adjusted to drainage area of 500 square miles in Kansas (from Jordan, 1983, fig. 13).

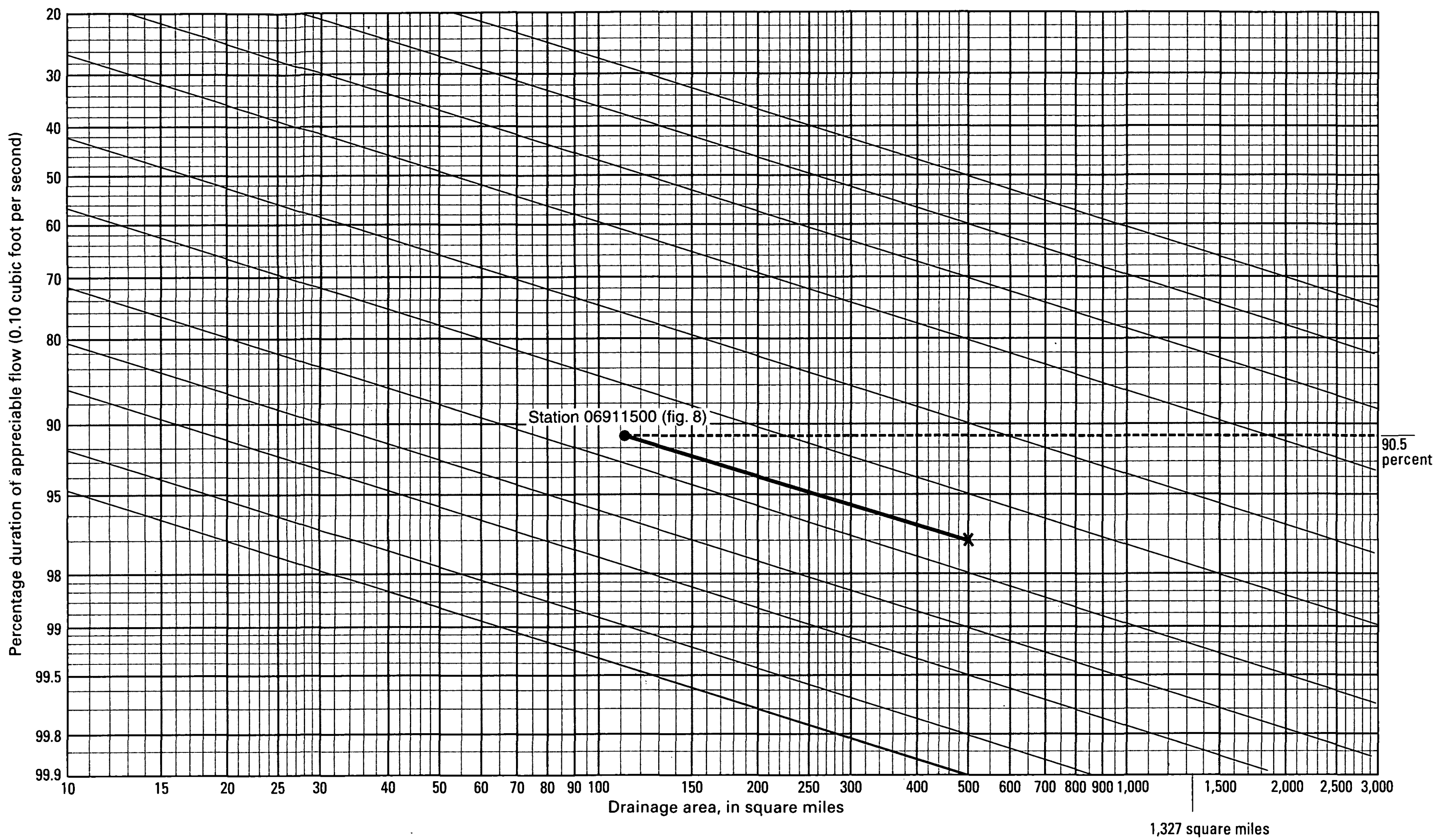
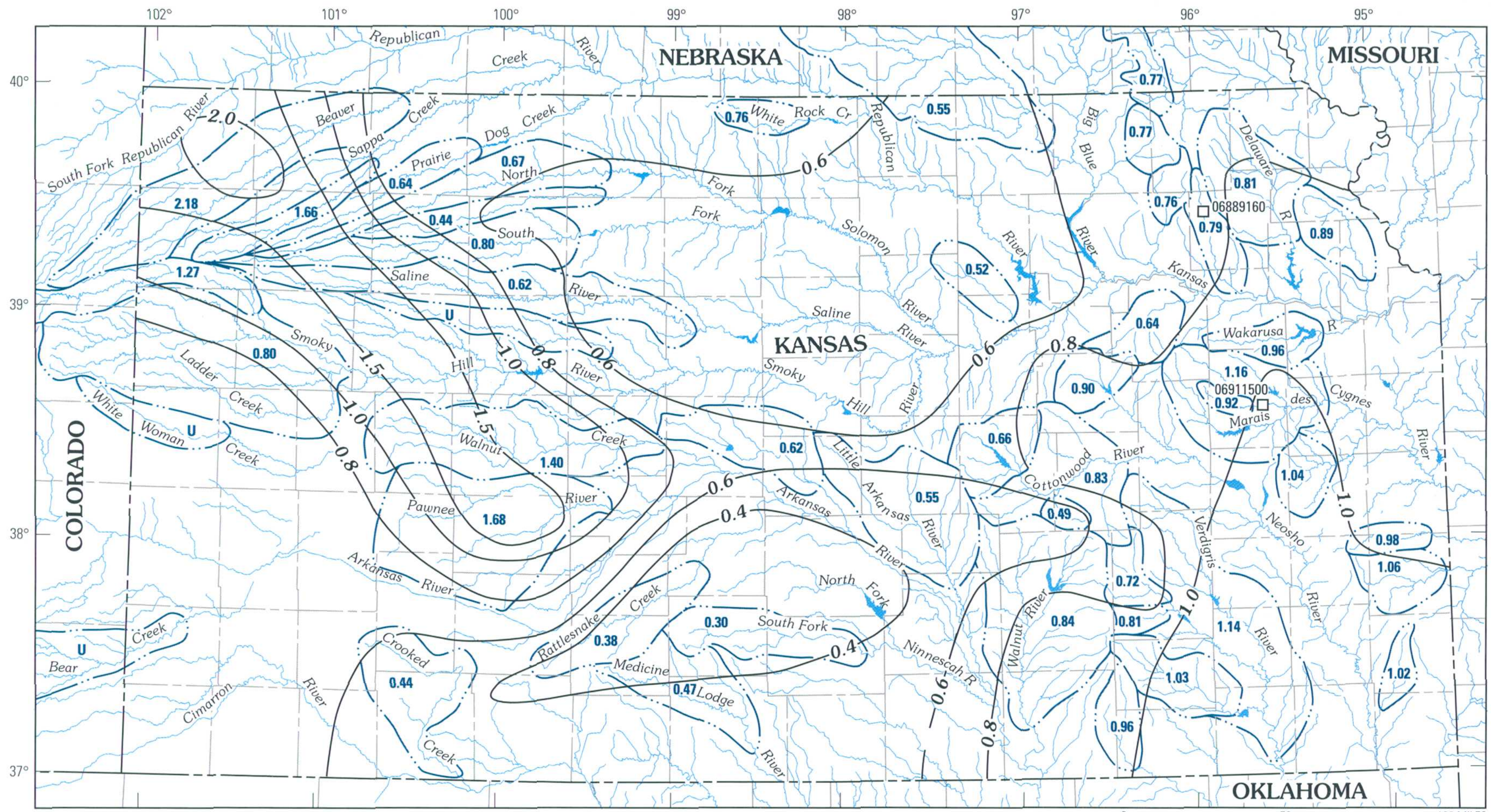


Figure 9. Relation between drainage area and percentage duration of appreciable flow (0.10 cubic foot per second0 (from Furness, 1959, fig. 145).



Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°

EXPLANATION

—0.6— **Line of equal average slope of duration curve**—Interval 0.2 and 0.5 logarithm unit

—·· — **Basin boundary**

0.44 **Average slope of duration curve for basin outlined, adjusted to 500-square-mile drainage area**—U, undefined

06889160□ **Streamflow-gaging station and number used to test Furness method for estimating flow-duration curves**

Figure 10. Average slopes of flow-duration curves adjusted to drainage area of 500 square miles in Kansas (from Jordan, 1983, fig. 15).

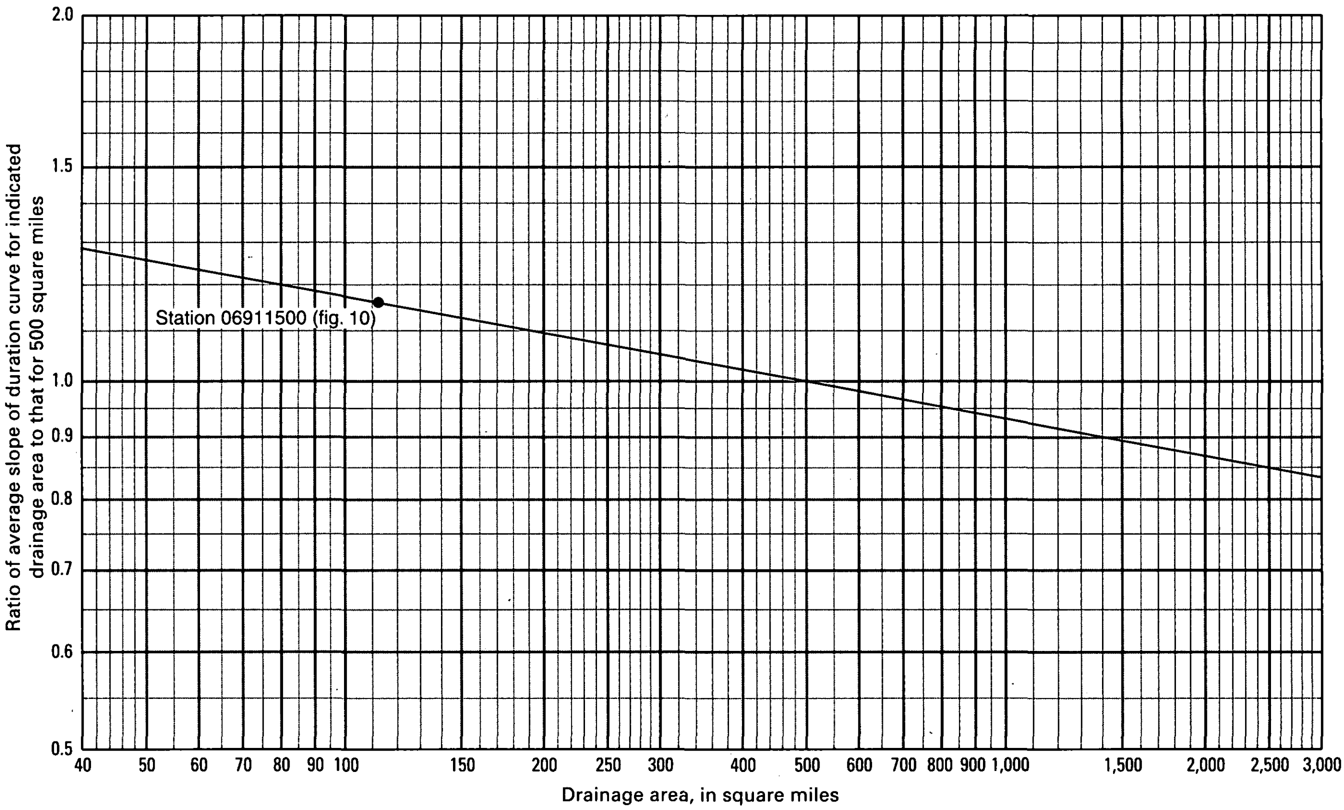


Figure 11. Relation between drainage area and average slope of flow-duration curve (from Furness, 1959, fig. 147).

an adjustment of 1.17 for 111 mi^2 of drainage area. Thus, the average slope for Salt Creek near Lyndon is 1.0 x 1.17 = 1.17. The average slope line is plotted in figure 12 by drawing a straight line between a point defined by 1.17 times the height of one log cycle, or about 15.5 ft^3/s plotted at 15.87-percent duration using the 1-to-10-ft^3/s cycle, and a point at 1.0 ft^3/s at 50-percent duration. If the duration percentage of appreciable flow is less than 95 percent, as in this case, then the average slope line defines the average slope of the estimated duration curve for 1/19 to 19/19 times the duration percentage of appreciable flow or from 4.74 to 90 percent. If the duration percentage of appreciable flow is greater than 95 percent, then the line of average slope defines the curve from 5 to 95 percent.

Using the six factors plotted in figure 12, duration-curve estimation was attempted for Salt Creek near Lyndon. A smooth curve was drawn through the five estimated points, keeping in mind the average slope and the duration range for which that slope applies. After the estimated duration curve was drawn, a line parallel to the average slope line was drawn to verify that the average slope of the estimated duration curve, between the limits of 4.74- and 90-percent duration, is close to the estimated slope from the map. The estimated duration curve for the station is shown as a dashed line in figure 12. The computed duration curve for the station for 1968–98 is shown as a solid line. Accuracy of the estimated duration curve may be improved with the use of base-flow measurements made at Salt Creek near Lyndon and correlating them with the durations of streamflow measurements at a nearby, index station such as Dragoon Creek near Burlingame (station 06911900, fig. 1).

A similar test performed for the long-term, continuous-record, streamflow-gaging station on Soldier Creek near Circleville, Kansas (station 06889160, fig. 1) shows that the Furness method can be used to estimate flow-duration curves for ungaged sites with drainage areas less than 100 mi^2. The estimated flow-duration curve for Soldier Creek near Circleville (station 06889160, fig. 1) and the computed 1968–98 flow-duration curve (fig. 13) compare well except at the low-flow end of the estimated curve. The low-flow part of the curve was improved significantly by using base-flow measurements made at the Circleville gaging station that were correlated with the flow-duration curve at a nearby gaging station on the Delaware River near Muscotah, Kansas (06890100, fig. 1).

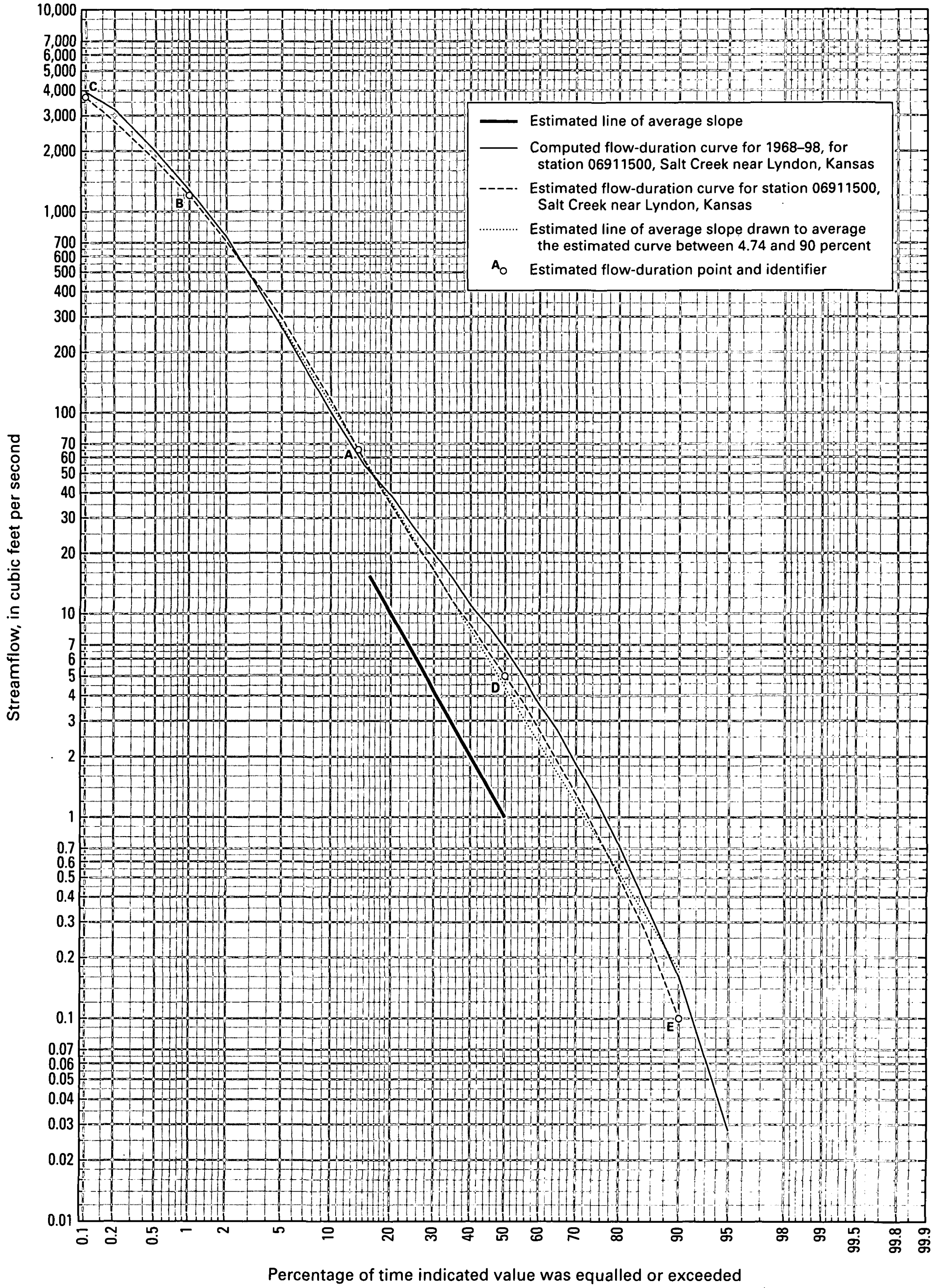


Figure 12. Comparison of estimated flow-duration curve with computed flow-duration curve for 1968–98 for Salt Creek near Lyndon (station 06911500, fig. 1).

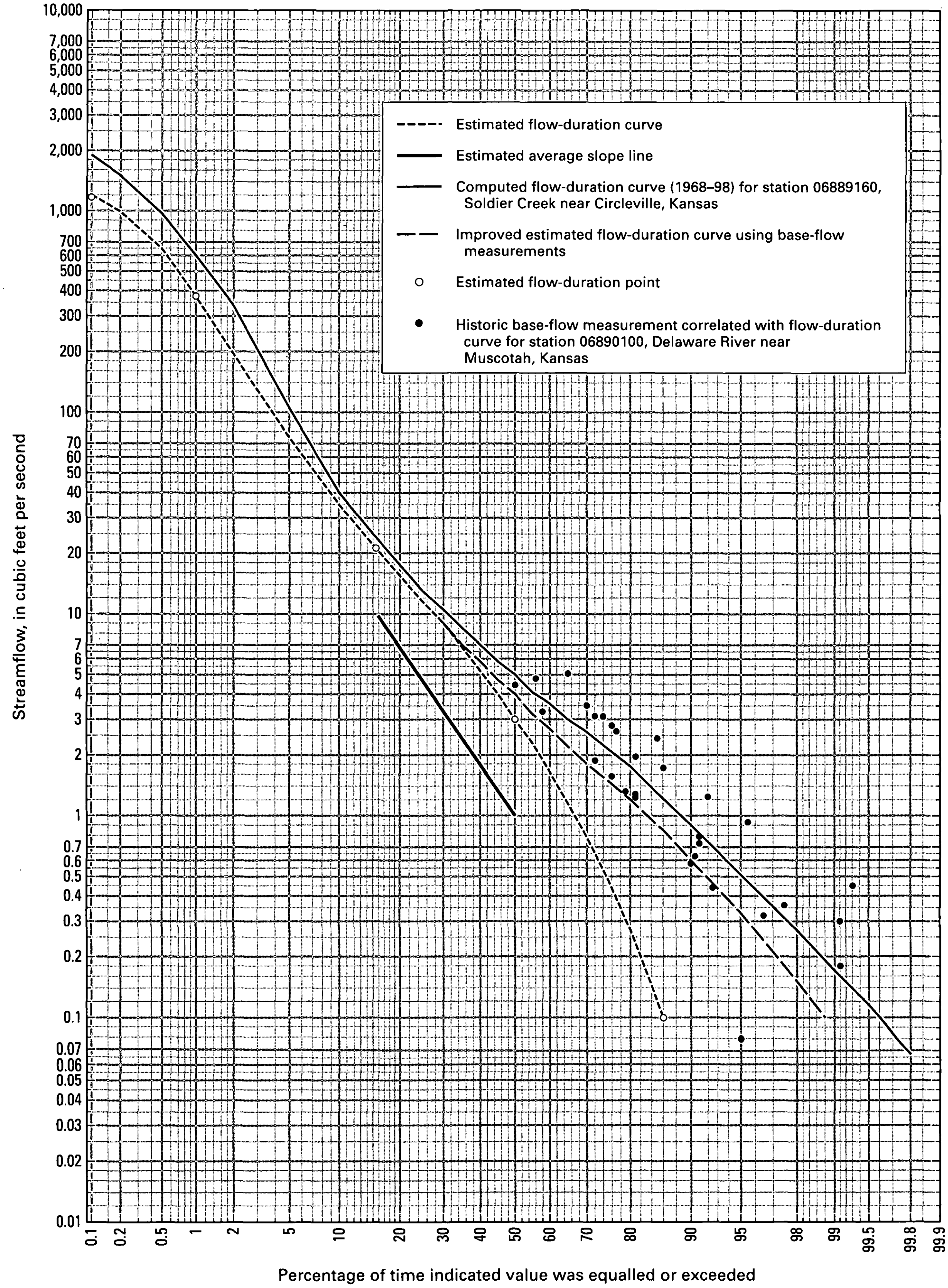


Figure 13. Comparison of estimated flow-duration curve with computed flow-duration curve for 1968–98 for Soldier Creek near Circleville (station 06889160, fig. 1).

Jordan (1983, p. 30) found that the accuracy of the estimated flow-duration curves was affected most by the variability of streamflow in the low-flow part of the estimated flow-duration curve. The errors were found to be +250 percent to -70 percent in the low-flow part of the estimated flow-duration curves. Although this amount of error seems significant, the magnitude of the streamflow is very small.

To illustrate the magnitude of streamflow involved, consider the estimated flow-duration curve tests for Salt Creek near Lyndon (fig. 12) and Soldier Creek near Circleville (fig. 13). At 90-percent duration, the estimated streamflow for Salt Creek near Lyndon is 0.1 ft^3/s, and for Soldier Creek near Circleville, it is 0.6 ft^3/s. The computed 90-percent duration streamflows are 0.18 and 0.9 ft^3/s, respectively. Thus the computed errors for the estimated flow-duration curves are 44 percent for Salt Creek near Lyndon and 33 percent for Soldier Creek near Circleville. Even though these seem like fairly large percentage errors, the difference in the streamflow is only 0.08 ft^3/s for Salt Creek near Lyndon and 0.3 ft^3/s for Soldier Creek near Circleville. If the error percentage were 250 percent, as Jordan (1983) found, the differences would be 0.27 ft^3/s for Salt Creek near Lyndon and 1.35 ft^3/s for Soldier Creek near Circleville and most likely would not change any management decisions made on the basis of the low-flow parts of the estimated flow-duration curves.

USE OF RECENT AND HISTORIC BASE-FLOW MEASUREMENTS

Because there are many factors that affect low-flow duration, that part of the flow-duration curve is usually the most difficult to accurately estimate. The maps and graphs used thus far reflect only the average regional low-flow trends, which in most cases are inadequate for uses that need more accurate data. A few appropriately timed base-flow measurements at an ungaged site will greatly improve the accuracy of the low-flow part of the estimated flow-duration curve. Only those measurements unaffected by surface runoff (base flow) and before the index station reaches zero flow are useful. The measurements can be correlated directly with a nearby, index station to determine the duration percentage. Historic base-flow measurements also may be used by correlating them to the daily streamflow duration percentage at a nearby index station.

Selection of Index Stations

It is important to choose an index station that is not affected by streamflow regulation or noticeably different climatic conditions for correlation to an ungaged site. The index station also should have a period of record that includes the period that is being estimated at the ungaged site. If there is no station close enough to the ungaged site meeting these criteria, a station with a shorter period of record can be used, and the data can be extended using methods outlined by Furness (1959) and Searcy (1959).

Another useful approach for choosing an index station is to use hydrologic landscapes. A fundamental hydrologic landscape unit is defined on the basis of land-surface form, geology, and climate. These fundamental hydrologic landscapes have a complete hydrologic system consisting of surface runoff, groundwater flow, and interaction with atmospheric water (Winter, 2001). Choosing an index station with hydrologic landscape properties similar to those for the ungaged site will help reduce errors in the estimated duration curve.

An example of how streamflow measurements at ungaged sites are used to improve or verify the estimated duration curve is shown in figure 14. The estimated curve that was developed in figure 12 shows a close approximation to the computed duration curve for 1968–98 for Salt Creek near Lyndon (station 06911500, fig. 1). A retrieval of data stored in NWIS for Salt Creek near Lyndon provided 26 measurements, dating back to 1987, with streamflow less than 5 ft^3/s, which is the estimated 50-percent-duration streamflow. These 26 measurements were made when the stream appeared to represent base-flow conditions (no apparent surface runoff). These 26 streamflow values were correlated with the mean daily streamflow values from Dragoon Creek near Burlingame (station 06911900, fig. 1). The duration percentages for each daily streamflow value then were taken from the 1968–98 duration curve for Dragoon Creek near Burlingame (station 06911900, fig. 1) and assigned to the same day's streamflow value for Salt Creek near Lyndon (station 06911500, fig. 1). The measurements were plotted in figure 14 at the correlated duration percentages acquired from Dragoon Creek near Burlingame (station 06911900, fig. 1). The measurements indicate that the estimated curve is acceptable, and no adjustments are necessary.

This test was performed on all of the index stations listed in table 1. Although the results are not

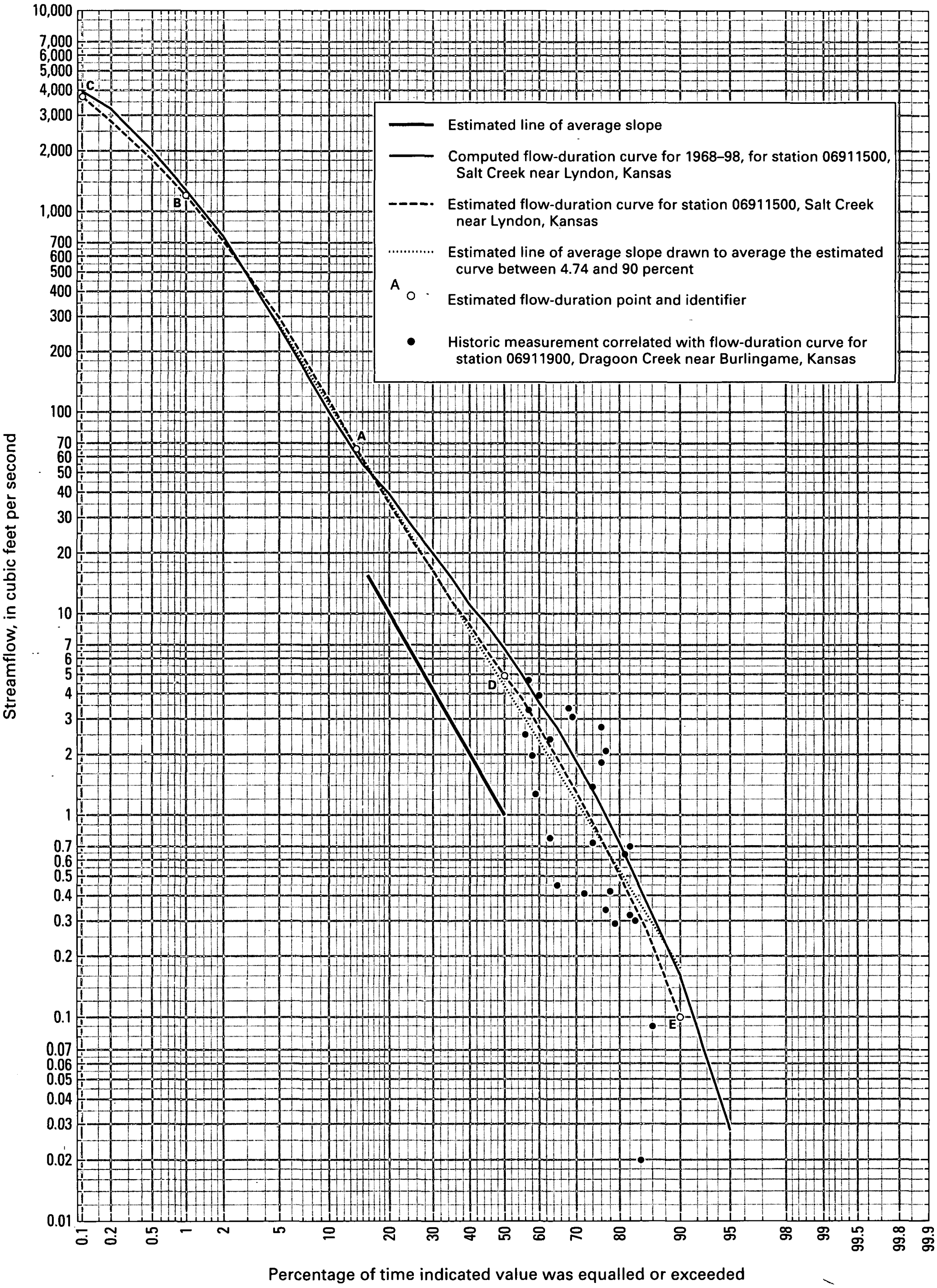


Figure 14. Verification of estimated flow-duration curve for Salt Creek near Lyndon (station 06911500, fig. 1) by use of historic base-flow measurements correlated with flow-duration data for Dragoon Creek near Burlingame (station 06911900, fig. 1).

shown in this report, they were similar to those for the Salt Creek near Lyndon station with two exceptions. The estimated flow-duration curves for index stations located in the western one-third of Kansas (Smoky Hill River at Elkader, station 06860000, and Smoky Hill River near Arnold, station 06861000, fig. 1) were quite different from the computed duration curves.

Many of the streams in the upper Arkansas, Cimarron, and Smoky Hill-Saline River Basins in western Kansas have experienced a decrease in streamflow during the past three decades. The shift to irrigated crop production has contributed to the lowering of the water table in the western part of the State and has reduced substantially the base-flow contributions to streams from shallow aquifers, thus changing the characteristics of the low-flow part of the duration curves in the area (Sophocleous and Wilson, 2000). The construction of terraces on dryland farms also has affected the flow-duration characteristics by decreasing surface runoff, thus affecting the high- to medium-flow parts of the duration curves. For these reasons, the Furness method of estimating duration curves alone does not adequately define the duration characteristics in the western one-third of Kansas for periods of record different from those used by Furness (1959) and Jordan (1983). Additional analysis and correlation with index stations are necessary to acquire a reasonable estimate of flow-duration characteristics.

Collection of Base-Flow Measurements

Base-flow measurements made at ungaged sites can be useful when refining an estimated flow-duration curve. These measurements should be made only when the ungaged site and the concurrently measured index station are not affected by runoff. Base-flow measurements eliminate inconsistencies that may be caused by variable rainfall-runoff rates. By monitoring the streamflow at the index station, specific flow-duration percentage streamflows can be identified so that a range of flow-duration percentage streamflows can be obtained to thoroughly define the estimated curve. It also is important to document observations of no streamflow at the ungaged site so that upper limits can be placed on the flow-duration percentages for the estimated flow-duration curve. If, for example, there is no streamflow at an ungaged site and the index station has a flow duration that same day of 85 percent, then it can be assumed that the estimated flow-duration curve for the ungaged site should not exceed 85-percent flow duration.

For this study, a total of 137 base-flow measurements were made during the 1999 and 2000 water years at the ungaged sites, an average of about four measurements per site. Only one measurement was made at several sites due to drought conditions during the summer of 2000. In most cases, a concurrent measurement was made at the index station. There were a few instances when this was not possible, and a computed hourly streamflow data value was retrieved from NWIS for the index station that then was used to determine the flow-duration percentage.

EXISTING STREAMFLOW INFORMATION AT UNGAGED SITES

The use of existing historic streamflow data for an ungaged site will improve the accuracy of the estimated flow-duration curve. Much of the streamflow data for the ungaged sites in this study were in the form of historic base-flow measurements made for previous studies. Some of the data were collected at exactly the same ungaged site, whereas other data were collected at a different site on the same stream. If the base-flow measurements are made on the same stream near the ungaged site to be estimated, the base-flow measurements can be related to the ungaged site by converting the base-flow measurements to streamflow per square mile of drainage area at the measurement site and then multiplying it by the drainage area of the desired ungaged site. The new streamflow value then is correlated with the streamflow at a nearby index station to assign its duration percentage.

Discontinued, continuous-record, streamflow-gaging stations that were operated at the currently (2001) ungaged sites provide some of the most useful data. The daily streamflow data from these discontinued stations can be used to calculate a flow-duration curve for the currently (2001) ungaged site. Although the calculated data will not necessarily represent the flow-duration curve for the desired period of record, the flow-duration data can be used for record extension by correlating it to the index station's flow-duration data and then adjustments can be made using base-flow measurements correlated to the index station. Twenty-two of the 32 selected ungaged sites for this study had historic streamflow data available for use in the estimation process. Thirteen of the ungaged sites had short periods of continuous streamflow data at or near the site.

Two of the sites located in the western part of the State (Ladder Creek below Chalk Creek near Scott City, station 06859500, and Hackberry Creek near Trego Center, station 06860900, fig. 1) had estimated flow-duration curves that did not appear to correlate well with the 1968–98 computed duration curves for their index stations. An analysis of the index station's flow-duration curves for periods prior to 1968 and after 1968 were significantly different; therefore, additional analysis was used to improve the estimation of the ungaged sites' flow-duration curves.

The record extension method described by Furness (1959, p. 23–25) and Searcy (1959, p. 12–17) was used to extend the existing historic data for the ungaged sites Ladder Creek below Chalk Creek near Scott City (station 06859500, fig. 1) and Hackberry Creek near Trego Center (station 06860900, fig. 1). The Ladder Creek below Chalk Creek near Scott City site (station 06859500, fig. 1) had 26 years of historic data from 1953 to 1978, and the Hackberry Creek near Trego Center site had 6 years of historic data from 1948 to 1953 from a nearby, discontinued station Hackberry Creek near Gove (station 06860500, fig. 1). The extension method worked well for Ladder Creek below Chalk Creek near Scott City (station 06859500, fig. 1) as indicated by the correlation with the index station Smoky Hill River at Elkader (station 06860000, fig. 1). The record extension method did not work as well for Hackberry Creek near Trego Center (station 06860900, fig. 1) because of the short period of historic streamflow data that was available. The estimated flow-duration curve computed using the record extension method, however, resulted in a more accurate estimate of flow-duration characteristics than the original estimated flow-duration curve using the Furness method.

CONSTRUCTION OF ESTIMATED FLOW-DURATION CURVES

The procedures for constructing the estimated flow-duration curves are those given in the section describing the Furness method. Five plotted points are used to draw a smooth curve, and then the average slope line is used to help refine the middle 90 percent of the flow-duration curve. If the percentage duration of appreciable flow is greater than 99 percent, then the point pertaining to appreciable flow is ignored, and the curve is drawn using the other four points and the average slope of the flow-duration curve from 5- to 95-percent duration. This procedure will yield a flow-duration curve that reflects the long-term flow duration for 1921–76.

The low-flow part of the flow-duration curve is the most difficult part of the curve to accurately estimate because there are many variables that affect the shape of that part of the flow-duration curve. Geology, geography, land use, changes in water use, and whether or not the stream flows perennially are some of the factors that affect the low-flow part of the flow-duration curve. If base-flow measurements have been made at a site in the past, they can be used to improve the low-flow part of the estimated flow-duration curve.

Because the period of record desired for a site is different from 1921–76, the flow-duration data from the index station used as the comparison site should be examined to quantify differences between the 1921–76 flow-duration curve and the 1968–98 flow-duration curve. The flow-duration curve for 1968–98 can be computed and compared to the estimated flow-duration curve for the index station to assess any changes that may be appropriate for the ungaged site's estimated flow-duration curve. If, for example, the computed 20-percent duration streamflow at the index station was 5 percent higher than the estimated 20-percent duration streamflow, then it would be appropriate to increase the estimated 20-percent duration streamflow for the ungaged site by 5 percent. In general, it was found through development of flow-duration curves for the eight index stations used for correlation in this study that the high-flow part of the flow-duration curves can be estimated closely using the maps and graphs provided. The low-flow part of the flow-duration curves generally were poorly estimated using the maps and graphs provided; however, the low-flow part of the flow-duration curves were greatly improved by the use of base-flow measurements.

The estimated flow-duration curves for the 32 selected ungaged sites are presented in Appendix A. In most cases, the low-flow parts of the flow-duration curves have been modified from the originally estimated flow-duration curve on the basis of base-flow measurements. Appendix B provides the site descriptions for the 32 ungaged sites and historic base-flow measurement sites. Appendix C provides a listing of the 137 base-flow measurements made at the 32 ungaged sites during 1999–2000. Appendix D provides estimated flow-duration curves for ungaged sites in the Cimarron and lower Arkansas River Basins in Kansas from a previous report by Studley (2000).

The estimated flow-duration curves are drawn as streamflow per square mile of drainage area so that they may be used for other ungaged sites on the same stream that are near the estimated site. To use the estimated flow-duration curve at another ungaged site, multiply the streamflow-per-square-mile value of the estimated flow-duration curve by the drainage area of the desired site to obtain the discharge for the site. Care should be taken not to use the estimated flow-duration curves at sites too far away because other factors may affect the flow-duration curve at the estimated site that may not affect the flow duration at other locations. It is more accurate to estimate a flow-duration curve for the intended site rather than trying to use the estimated flow-duration curve for a different site on the same stream.

RESULTS OF ESTIMATION METHODS

The Furness method of estimating flow-duration curves provided generally good results. The estimated flow-duration points that were developed from the maps and graphs provided a good start toward developing the estimated flow-duration curves. The preliminary flow-duration curves then were verified or improved using historic streamflow data and recent (1999–2000), base-flow measurements correlated to the nearby index station's flow-duration curve for 1968–98. This process worked well where there were no large differences between the 1921–76 flow-duration data compared to the 1968–98 flow-duration data.

Areas that do have large differences in the flow-duration data between the two periods generally are located in the western one-third of the State. The large differences generally are attributable to substantial changes in farming practices during the last three decades. This is an area of the State that has very low mean annual runoff rates [0.1 to 0.5 $(in/mi^2)/yr$] compared with the eastern part of the State [1.0 to 10.0 $(in/mi^2)/yr$] and is situated above the High Plains aquifer.

Terracing of farmland was implemented in the 1960s in an attempt to hold rainfall runoff for increased crop production. This practice significantly reduced the streamflow values in the upper or high-flow parts of the flow-duration curves. Also, intensive use of ground water for crop irrigation beginning in the 1960s has decreased the ground-water contribution to streamflow in the area. This has resulted in the reduction of streamflow values in the low-flow parts of the flow-duration curves. It also is important to note that the changes in the values of the flow-duration curves occurred even though climatic data showed a slight increase in average annual precipitation during 1968–98 compared with 1921–76.

As a result of these changes, it was found that the Furness method for estimating flow-duration curves did not work well in the western part of the State for the 1968–98 period. Therefore, it was necessary to use another method to estimate the flow-duration curves for two of the sites in this report. Ladder Creek below Chalk Creek near Scott City, station 06859500, and Hackberry Creek near Trego Center, station 06860900, are both located in the western one-third of the State, and their duration curves were estimated using a record-extension method that is described in detail by Searcy (1959, p. 12–17). The record-extension method is applicable only when there is an adequate period of historical, continuous-record, streamflow data available for the computation of a flow-duration curve. If there are little or no continuous streamflow data available for the ungaged site, an analysis of the differences between the computed flow-duration curve and an estimated flow-duration curve for the index station can provide information that can be used along with base-flow measurements to adjust the estimated flow-duration curve for the ungaged site.

SUMMARY AND CONCLUSIONS

Flow-duration curves were estimated for 32 ungaged sites in the Missouri, Smoky Hill-Saline, Solomon, Marais des Cygnes, Walnut, Verdigris, and Neosho River Basins in Kansas for 1968 through 1998 on the basis of regionalized, long-term streamflow data as well as base-flow measurements. The method for estimating flow-duration curves used six unique factors of flow duration that can be applied to ungaged sites. The six factors are (1) mean streamflow and percentage duration of mean streamflow, (2) ratio of 1-percent-duration streamflow to mean streamflow, (3) ratio of 0.1-percent-duration streamflow to 1-percent-duration streamflow, (4) ratio of 50-percent-duration streamflow to mean streamflow, (5) percentage duration of appreciable streamflow (0.10 ft^3/s), and (6) average slope of the flow-duration curve.

The six flow-duration factors for each ungaged site were determined using maps, graphs, and computations that were developed by Furness in 1959 and then updated by Jordan in 1983. These factors then were used as a guide to draw a smooth, estimated flow-duration curve for the ungaged site. The method was tested on a currently (2001) measured, continuous-record, streamflow-gaging station with a drainage area of 111 mi^2 on Salt Creek near Lyndon, Kansas, and was found to adequately estimate the computed flow-duration curve for the station. The method also was tested on a currently (2001) measured, continuous-record, streamflow-gaging station with a drainage area of 49.3 mi^2 on Soldier Creek near Circleville, Kansas, and was found to adequately estimate the computed flow-duration curve for the station. This test indicated that the Furness method could be applied to sites with drainage areas of less than 100 mi^2.

The low-flow parts of the estimated flow-duration curves generally are the most difficult part of the curve to accurately estimate because of the many factors that affect low flow at individual streamflow sites. The low-flow parts of the estimated flow-duration curves in this report were verified or improved substantially on the basis of historic streamflow data collected at or near the ungaged site (if available) and several recent (1999–2000) base-flow streamflow measurements made concurrently with nearby index stations. The correlation of the ungaged site's streamflow measurement with the index station's flow-duration percentage provides the data needed to verify or improve the low-flow part of the estimated flow-duration curve. The base-flow measurements need to be supplemented with an analysis of the differences between the estimated and computed flow-duration curves for index stations in the western part of the State to better define the medium to high-flow part of the estimated duration curve for the ungaged site because the Furness method does not adequately define recent flow-duration conditions there.

In addition to estimating duration curves for ungaged sites throughout the State, this report and the previous report (Studley, 2000) also provide an indication of the adequacy of the USGS current (2001) streamflow network in Kansas for the definition of natural flow characteristics for smaller, unregulated streams. It was found that there are gaps in available current (2001) streamflow data for areas in the extreme western part of the State. Additional continuous-record, streamflow-gaging stations in the western part of the State can provide much-needed streamflow data for planning and decisions related to agriculture, industry, city water supplies, highway bridge design, riverine and riparian habitat, and flood-hazard identification. Any gaps in the areal coverage of long-term records of streamflow can mean a gap in the essential understanding and management of water resources.

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APPENDIXES

Appendix A. Estimated flow-duration curves and tables for 32 ungaged sites in the Missouri, Smoky Hill-Saline, Solomon, Marais des Cygnes, Walnut, Verdigris, and Neosho River Basins in Kansas.

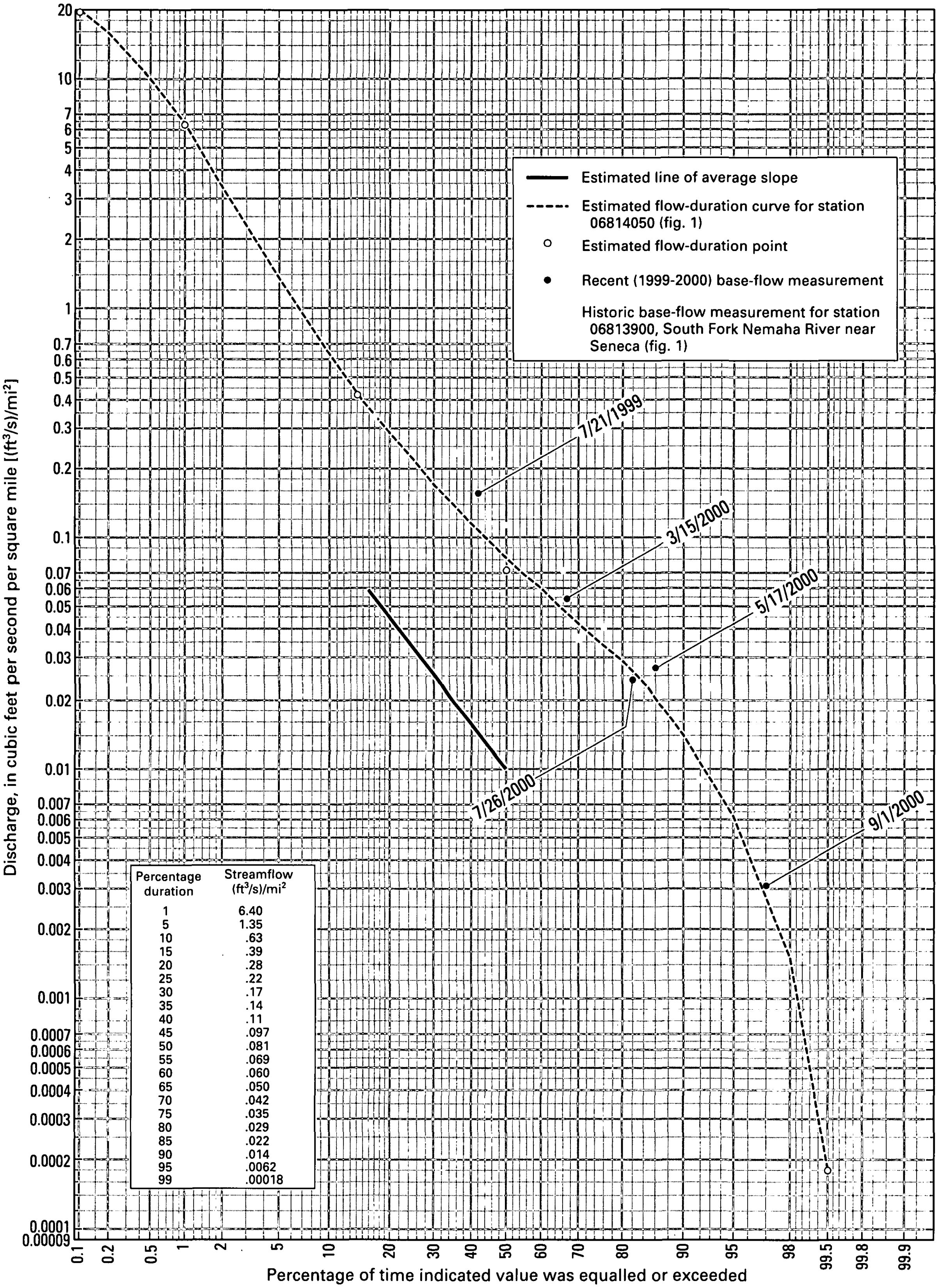


Figure 15. Estimated flow-duration curve for 1968–98 for site 06814050, South Fork Big Nemaha River near Bern. Location of site shown in figure 1.

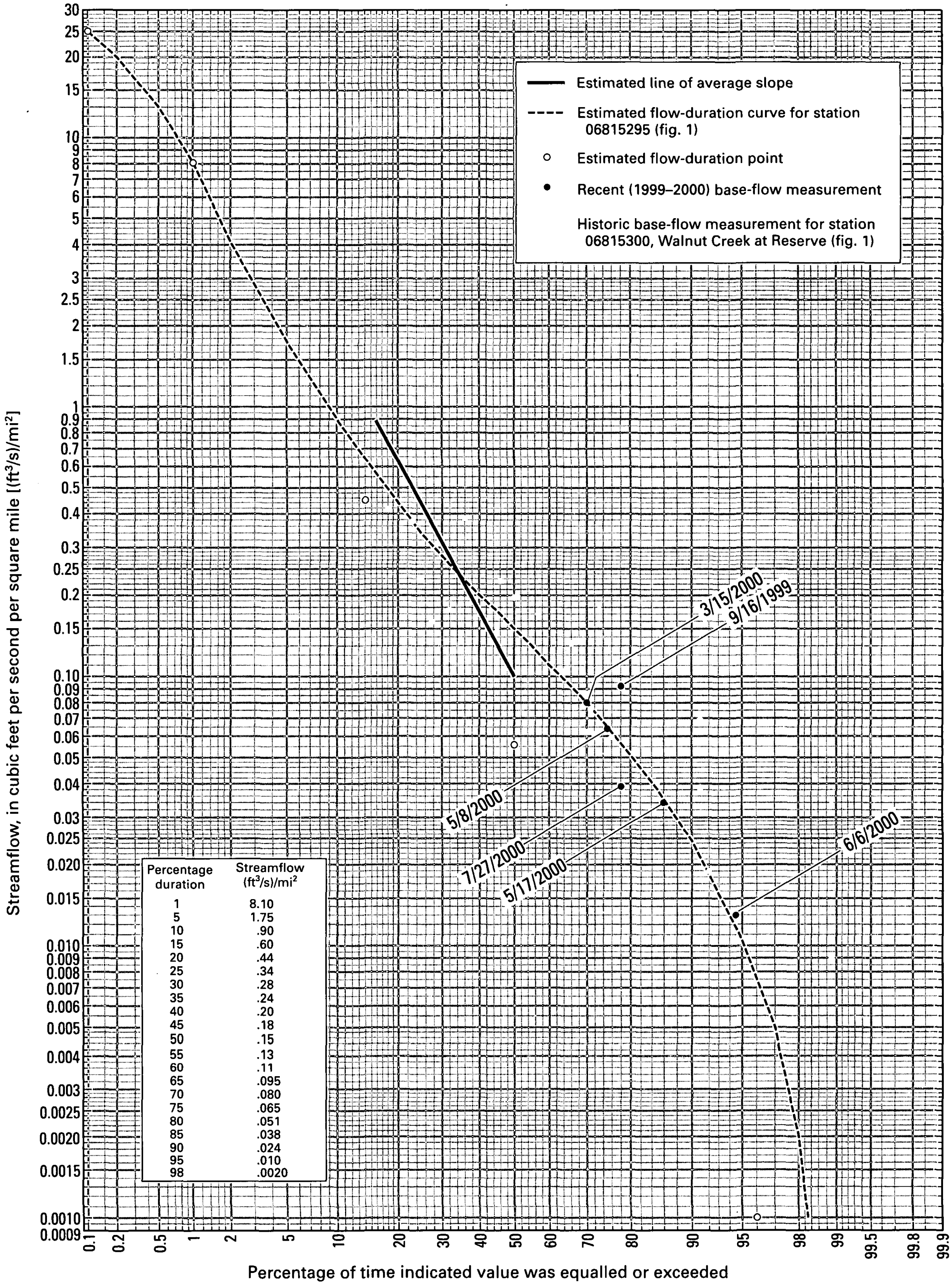
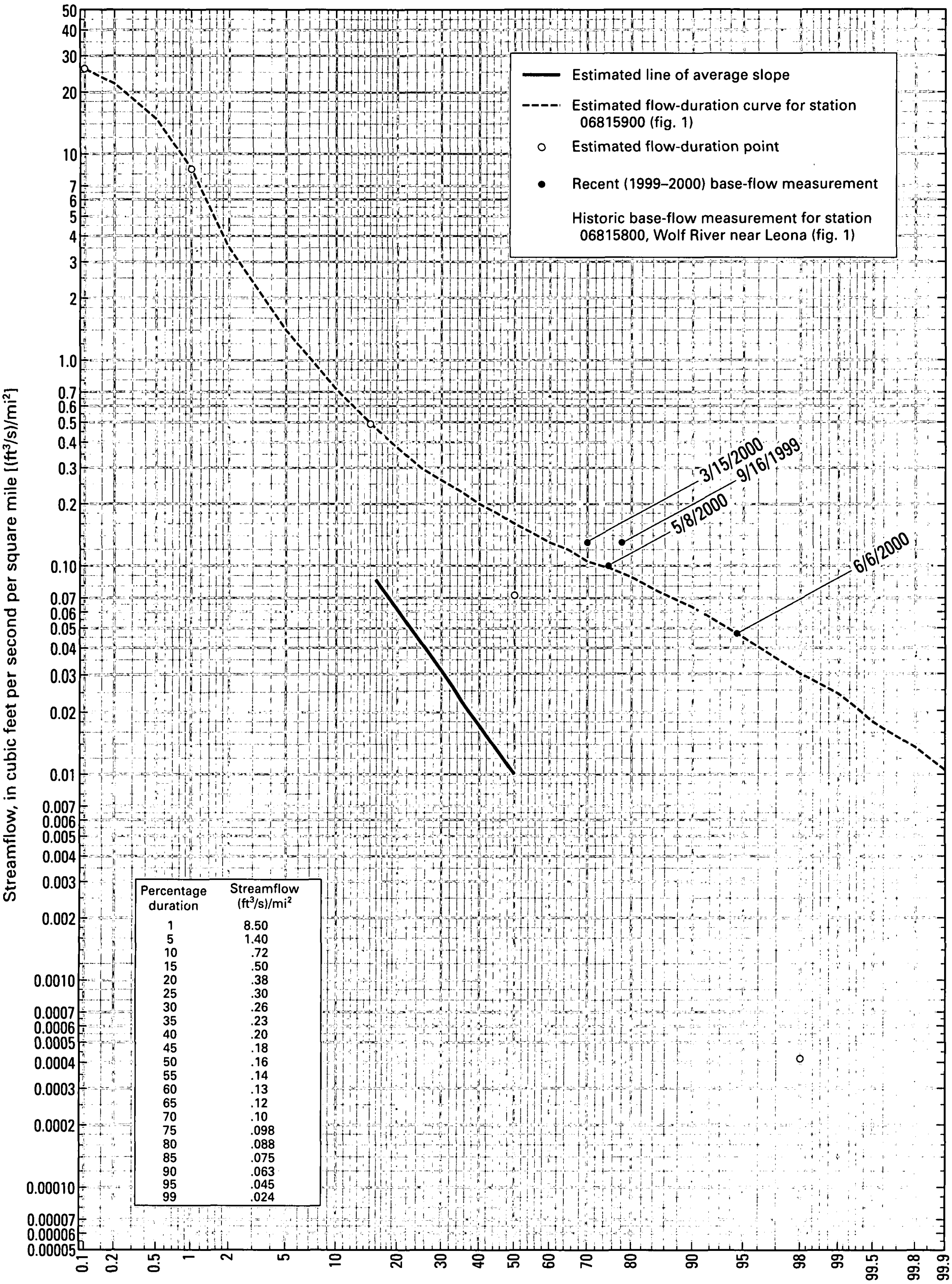
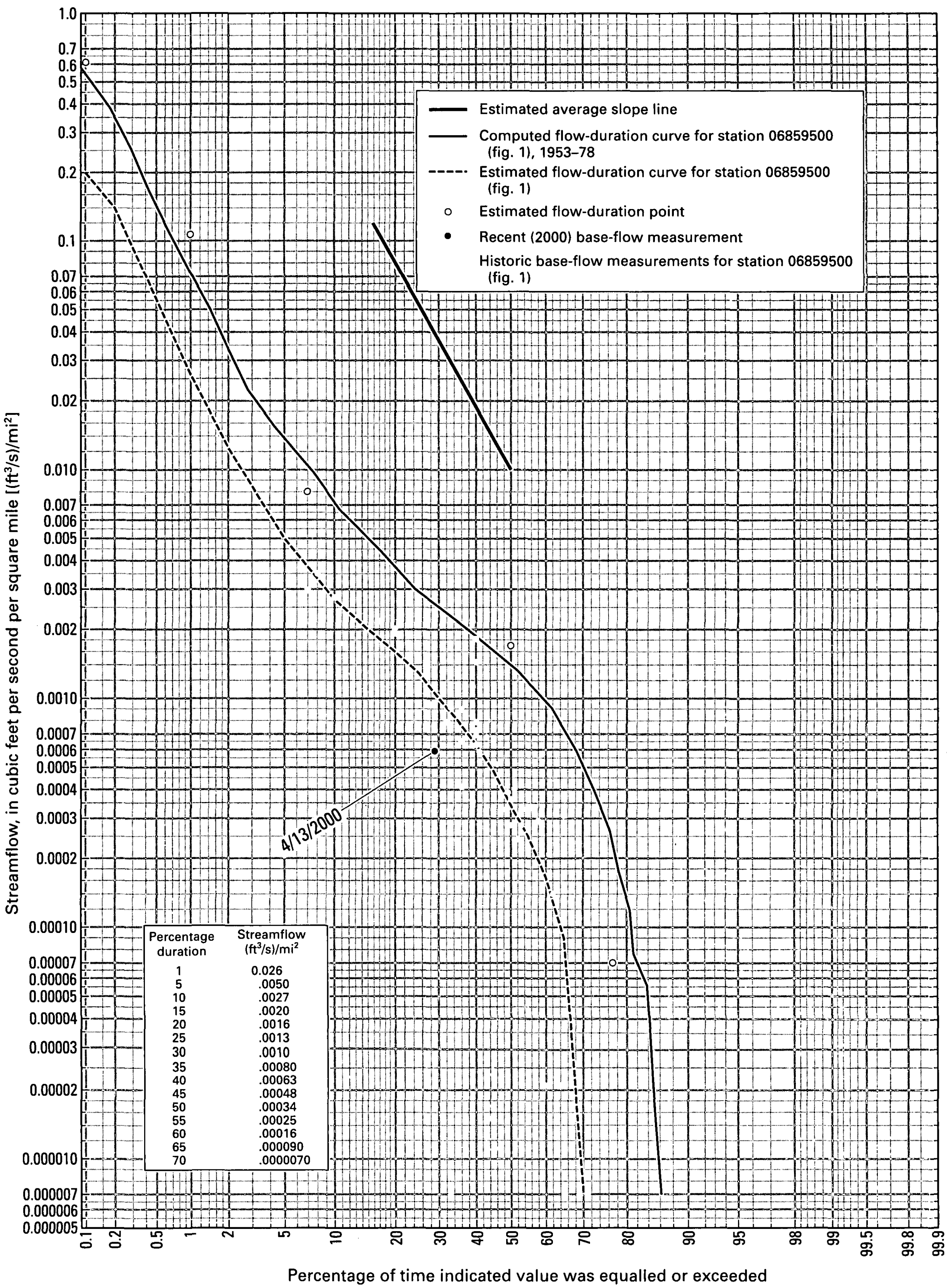


Figure 16. Estimated flow-duration curve for 1968–98 for site 06815295, Walnut Creek near Padonia. Location of site shown in figure 1.



Percentage duration	Streamflow (ft³/s)/mi²
1	8.50
5	1.40
10	.72
15	.50
20	.38
25	.30
30	.26
35	.23
40	.20
45	.18
50	.16
55	.14
60	.13
65	.12
70	.10
75	.098
80	.088
85	.075
90	.063
95	.045
99	.024

Figure 17. Estimated flow-duration curve for 1968–98 for site 06815900, Wolf River at Sparks. Location of site shown in figure 1.



Percentage duration	Streamflow $(ft^3/s)/mi^2$
1	0.026
5	.0050
10	.0027
15	.0020
20	.0016
25	.0013
30	.0010
35	.00080
40	.00063
45	.00048
50	.00034
55	.00025
60	.00016
65	.000090
70	.0000070

Figure 18. Estimated flow-duration curve for 1968–98 for site 06859500, Ladder Creek below Chalk Creek near Scott City. Location of site shown in figure 1.

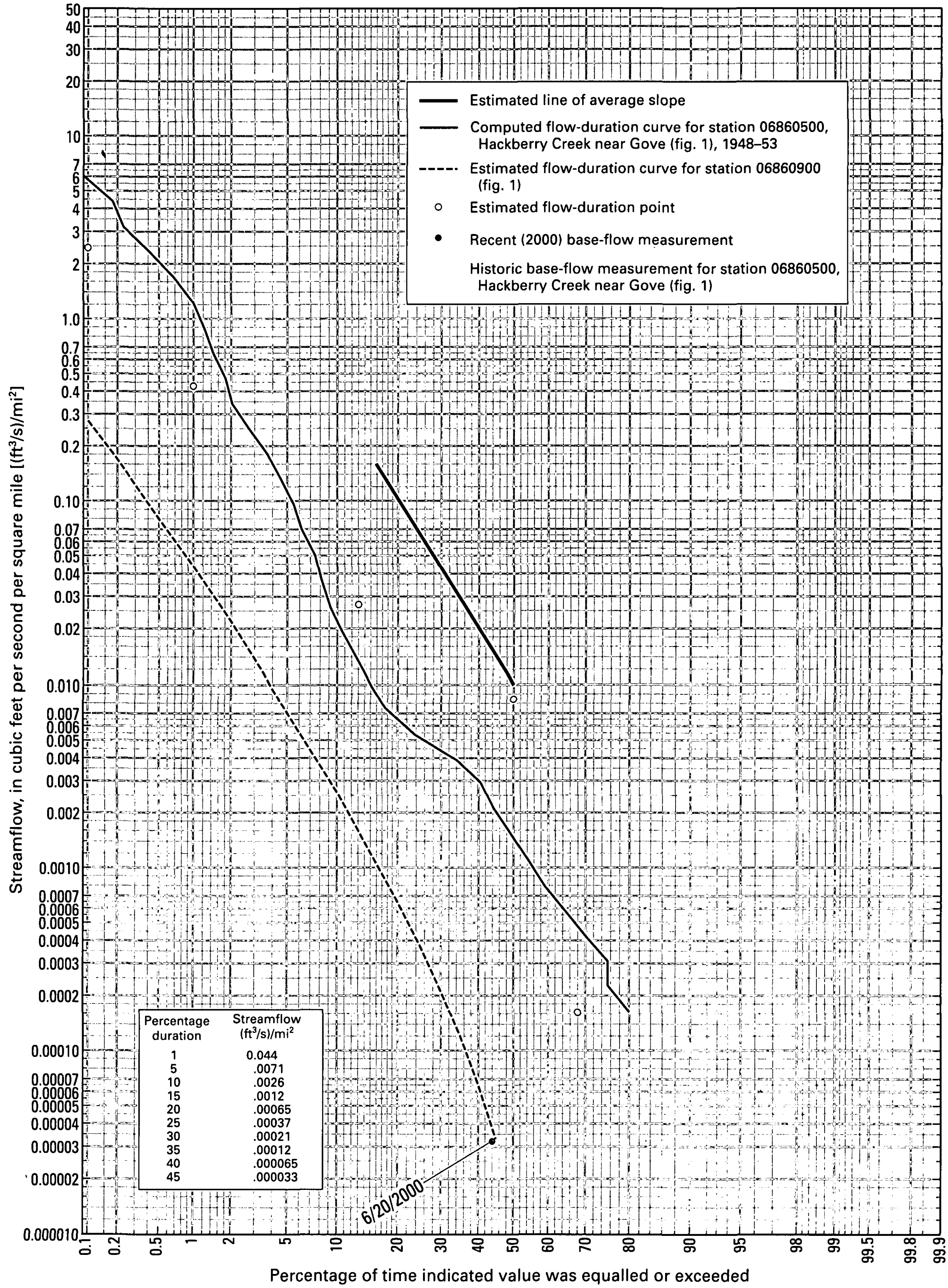
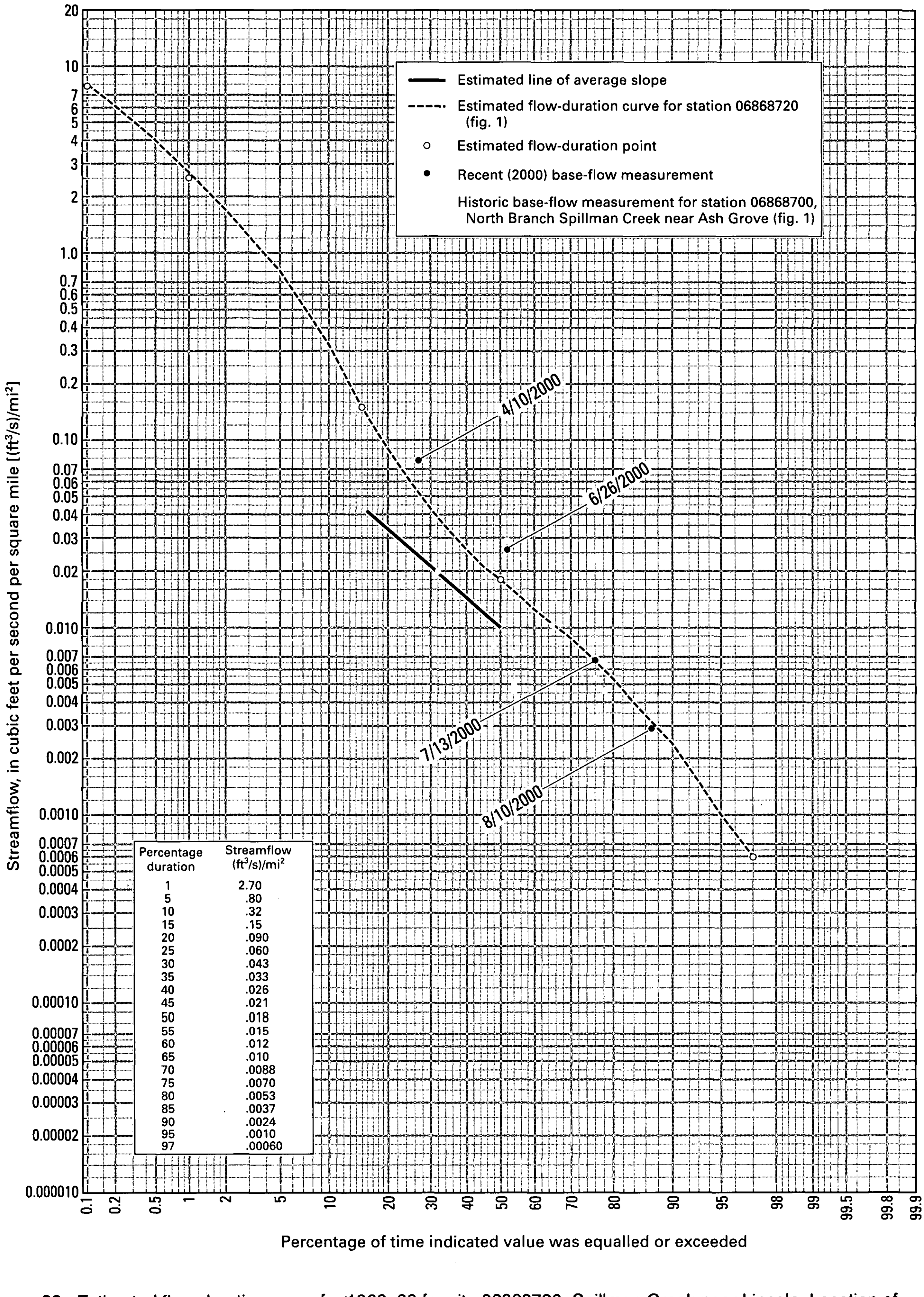


Figure 19. Estimated flow-duration curve for 1968–98 for site 06860900, Hackberry Creek near Trego Center. Location of site shown in figure 1.



Percentage duration	Streamflow $(ft^3/s)/mi^2$
1	2.70
5	.80
10	.32
15	.15
20	.090
25	.060
30	.043
35	.033
40	.026
45	.021
50	.018
55	.015
60	.012
65	.010
70	.0088
75	.0070
80	.0053
85	.0037
90	.0024
95	.0010
97	.00060

Figure 20. Estimated flow-duration curve for 1968–98 for site 06868720, Spillman Creek near Lincoln. Location of site shown in figure 1.

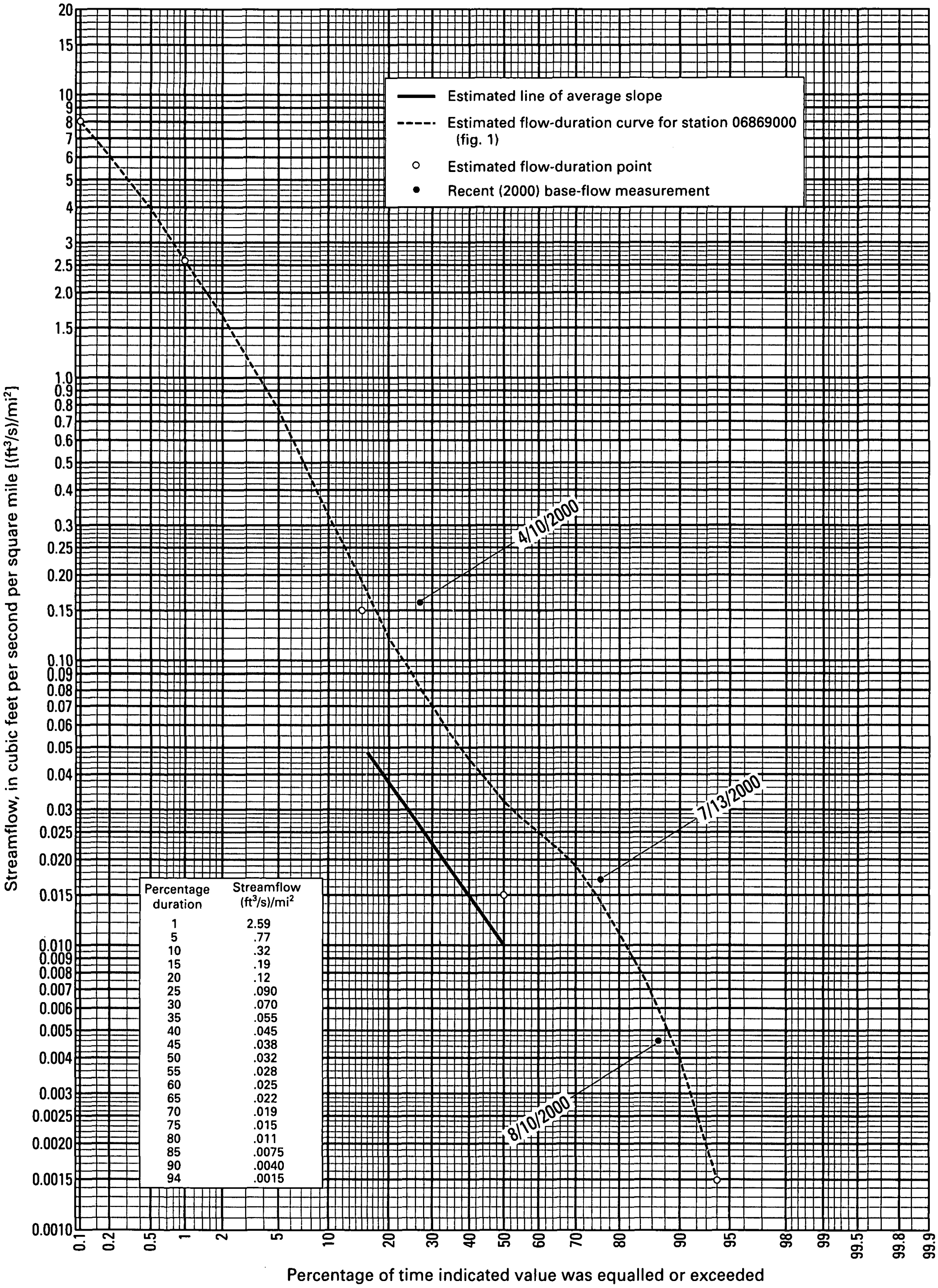
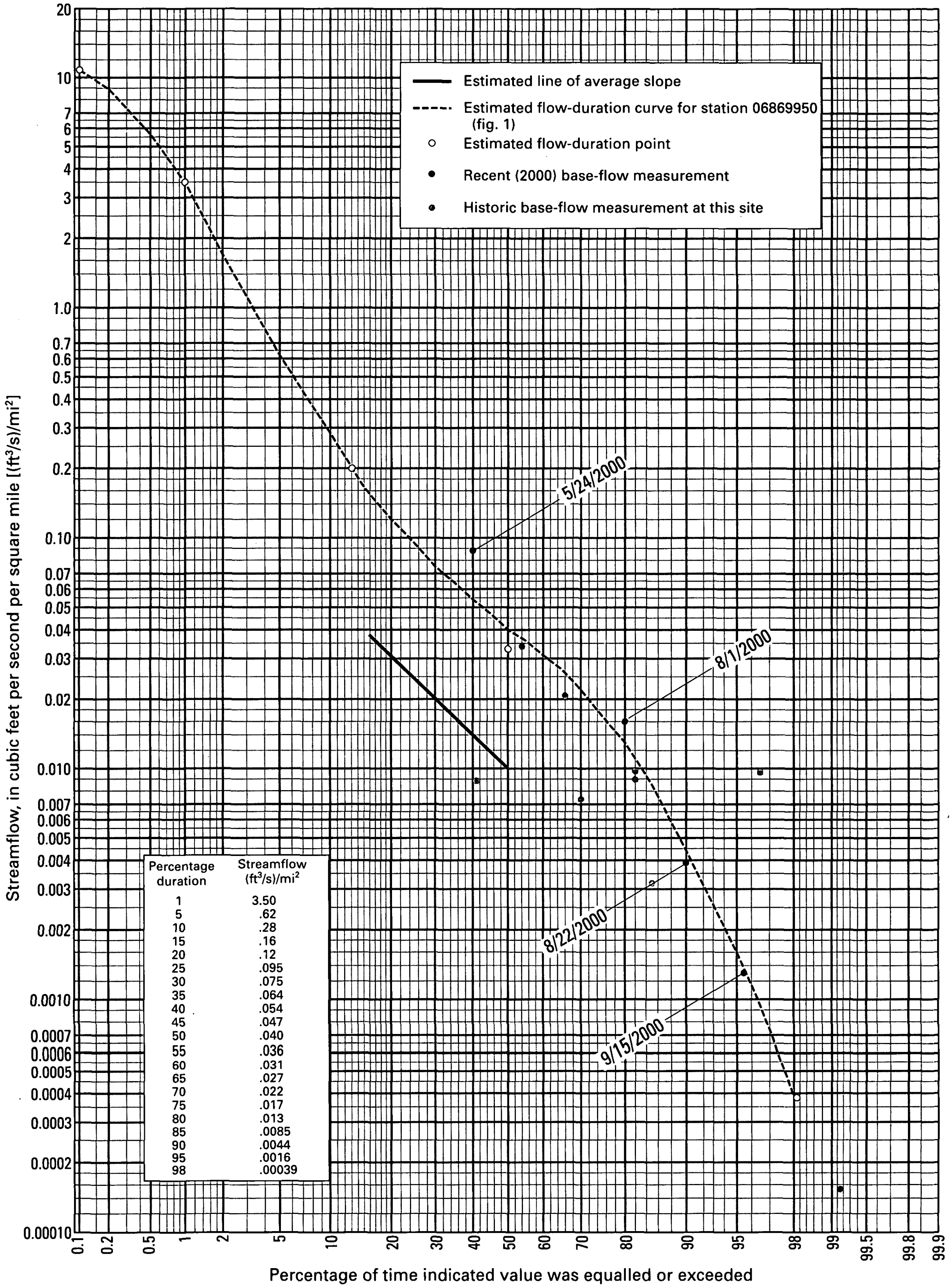
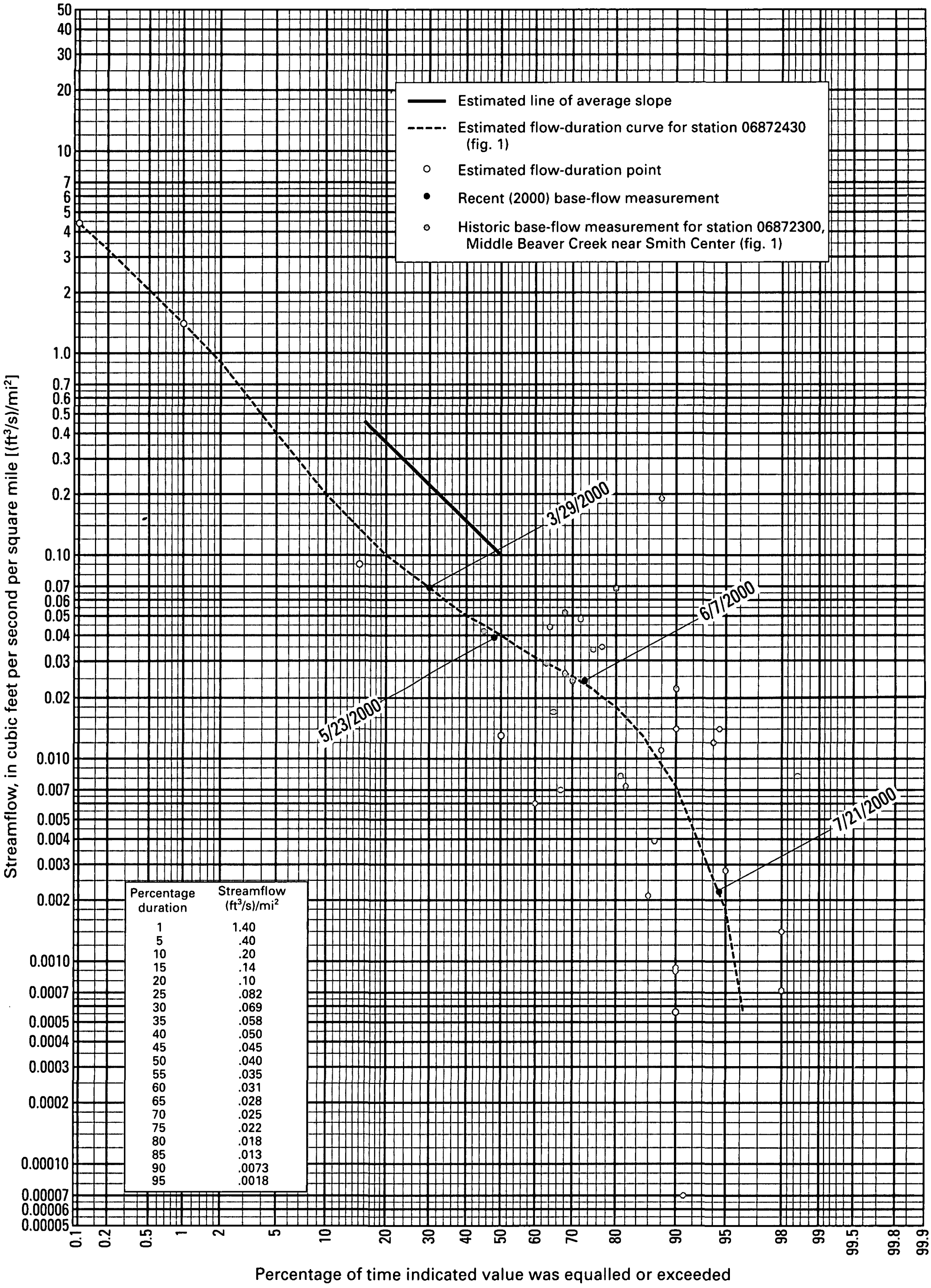


Figure 21. Estimated flow-duration curve for 1968–98 for site 06869000, Elkhorn Creek near Lincoln. Location of site shown in figure 1.



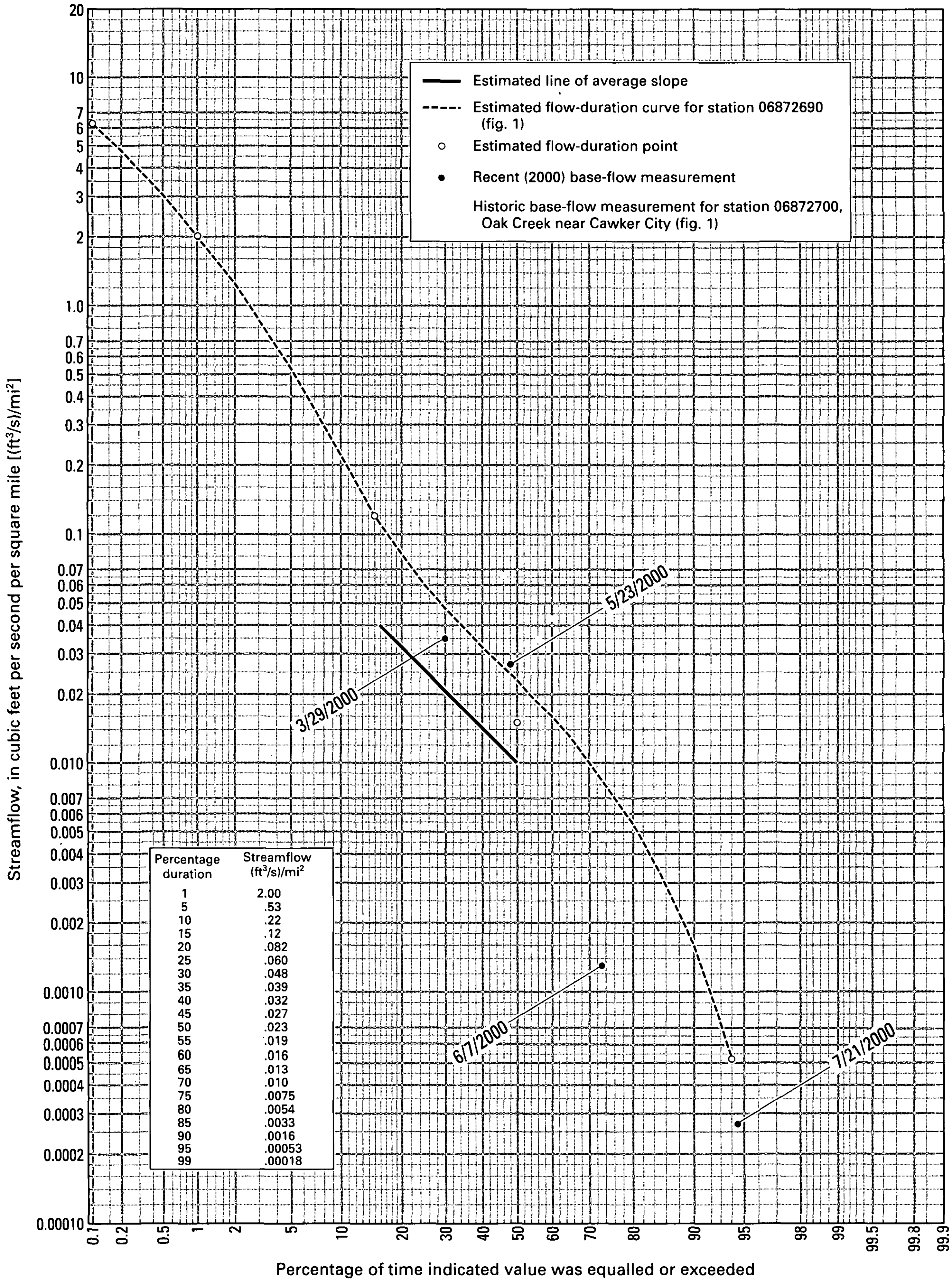
Percentage duration	Streamflow (ft³/s)/mi²
1	3.50
5	.62
10	.28
15	.16
20	.12
25	.095
30	.075
35	.064
40	.054
45	.047
50	.040
55	.036
60	.031
65	.027
70	.022
75	.017
80	.013
85	.0085
90	.0044
95	.0016
98	.00039

Figure 22. Estimated flow-duration curve for 1968–98 for site 06869950, Mulberry Creek near Salina. Location of site shown in figure 1.



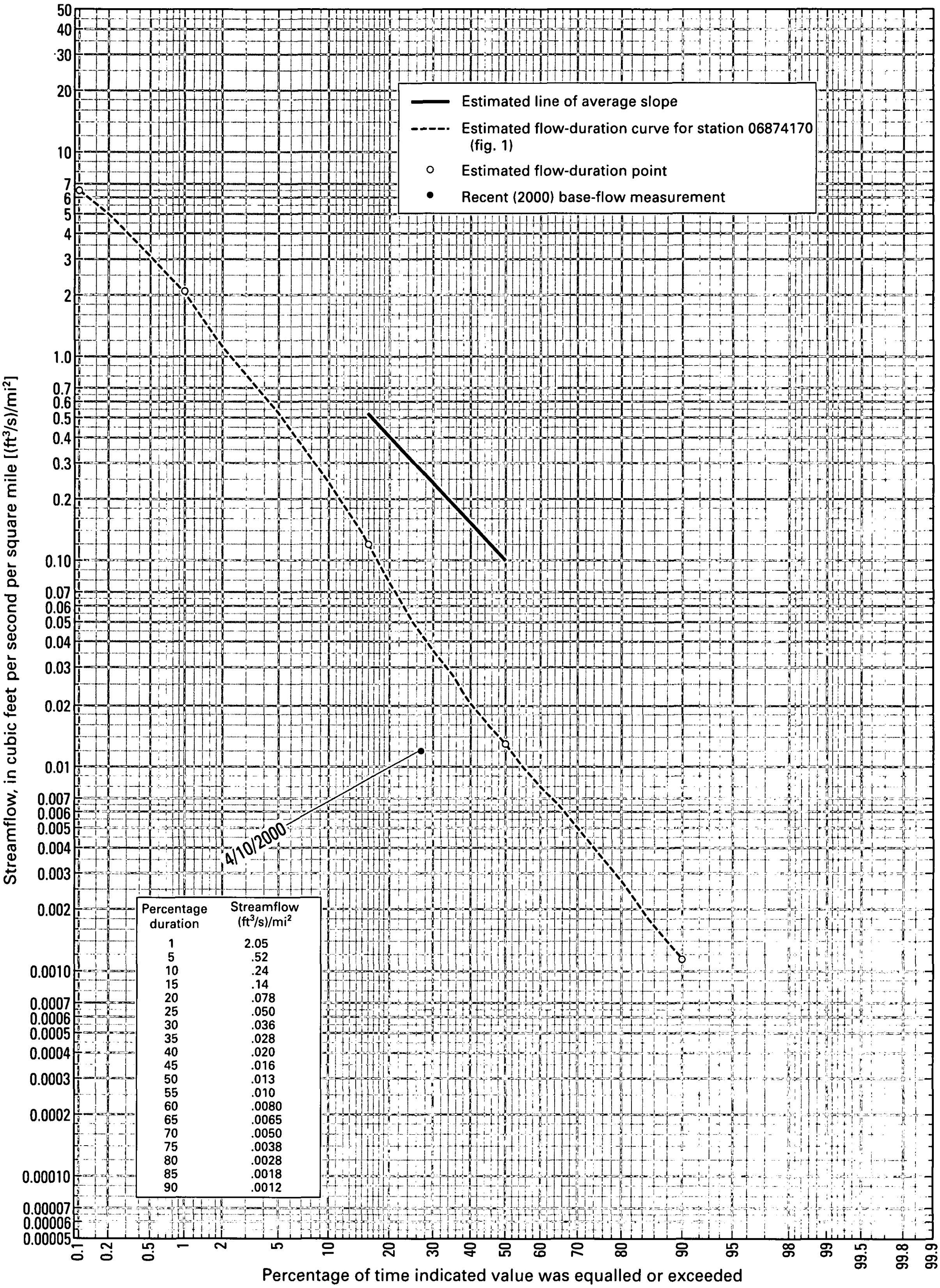
Percentage duration	Streamflow (ft³/s)/mi²
1	1.40
5	.40
10	.20
15	.14
20	.10
25	.082
30	.069
35	.058
40	.050
45	.045
50	.040
55	.035
60	.031
65	.028
70	.025
75	.022
80	.018
85	.013
90	.0073
95	.0018

Figure 23. Estimated flow-duration curve for 1968–98 for site 06872430, Beaver Creek near Gaylord. Location of site shown in figure 1.



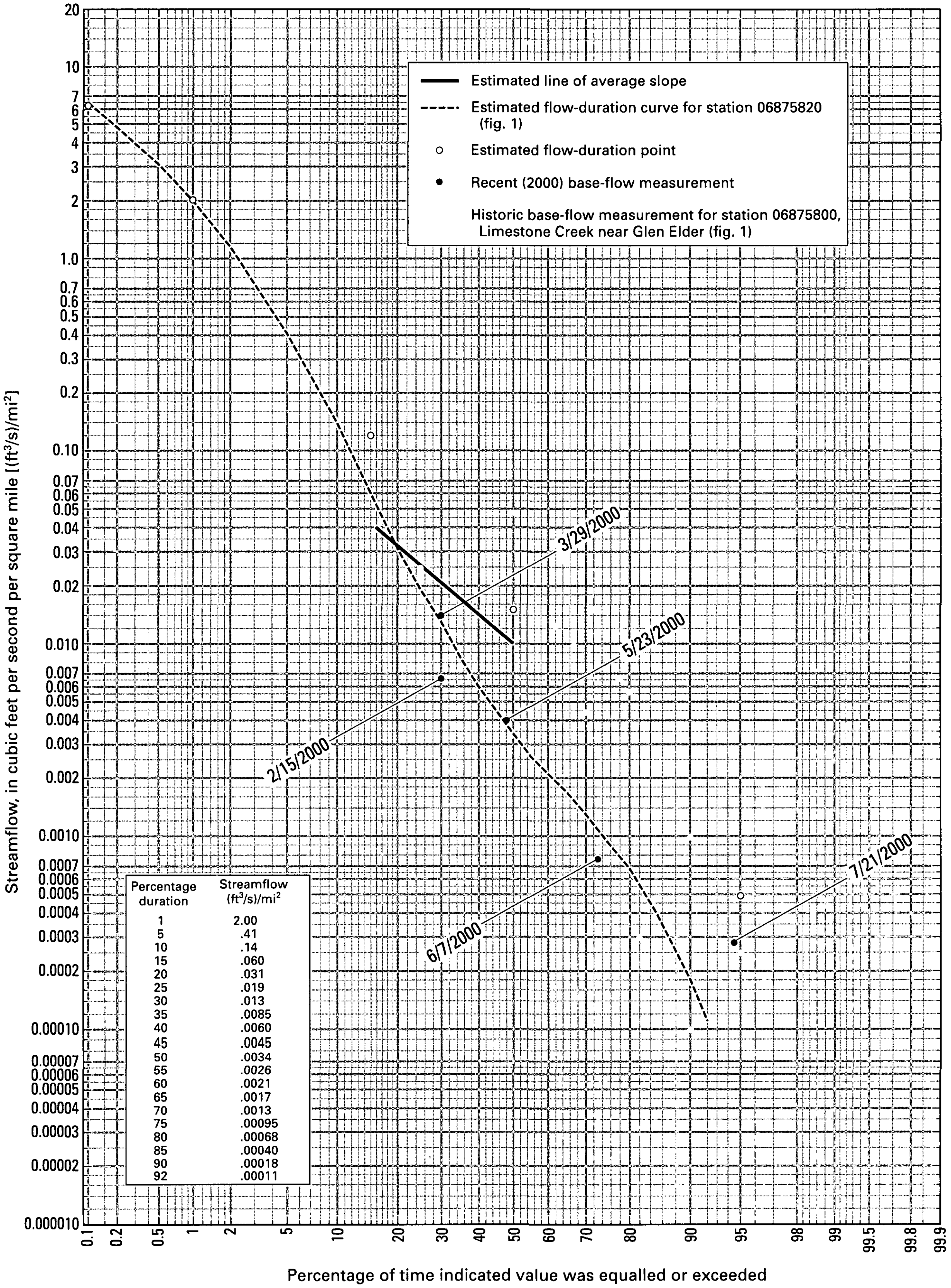
Percentage duration	Streamflow $(ft^3/s)/mi^2$
1	2.00
5	.53
10	.22
15	.12
20	.082
25	.060
30	.048
35	.039
40	.032
45	.027
50	.023
55	.019
60	.016
65	.013
70	.010
75	.0075
80	.0054
85	.0033
90	.0016
95	.00053
99	.00018

Figure 24. Estimated flow-duration curve for 1968–98 for site 06872690, Oak Creek northwest of Cawker City. Location of site shown in figure 1.



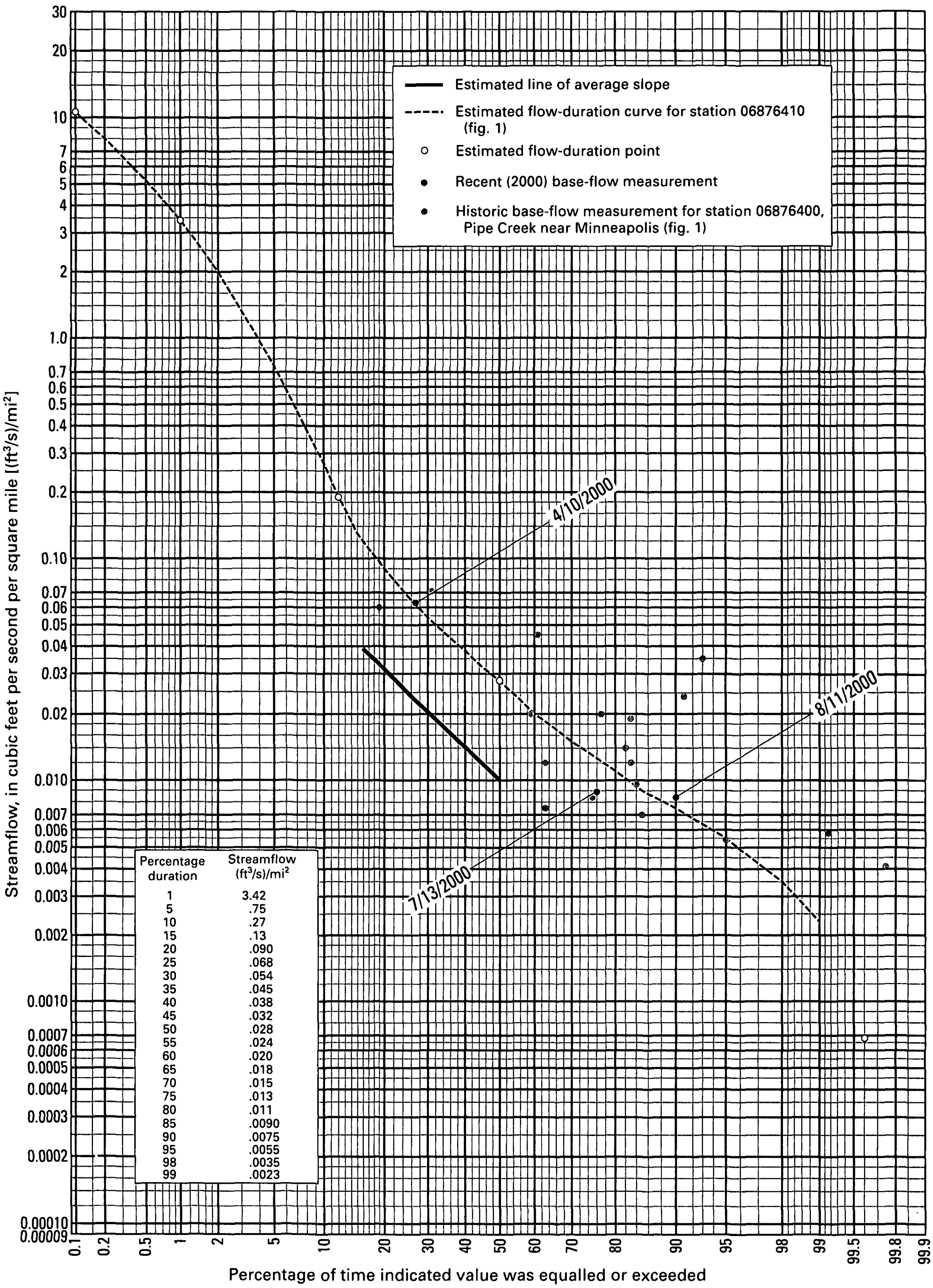
Percentage duration	Streamflow (ft³/s)/mi²
1	2.05
5	.52
10	.24
15	.14
20	.078
25	.050
30	.036
35	.028
40	.020
45	.016
50	.013
55	.010
60	.0080
65	.0065
70	.0050
75	.0038
80	.0028
85	.0018
90	.0012

Figure 25. Estimated flow-duration curve for 1968–98 for site 06874170, Twin Creek near Corinth. Location of site shown in figure 1.



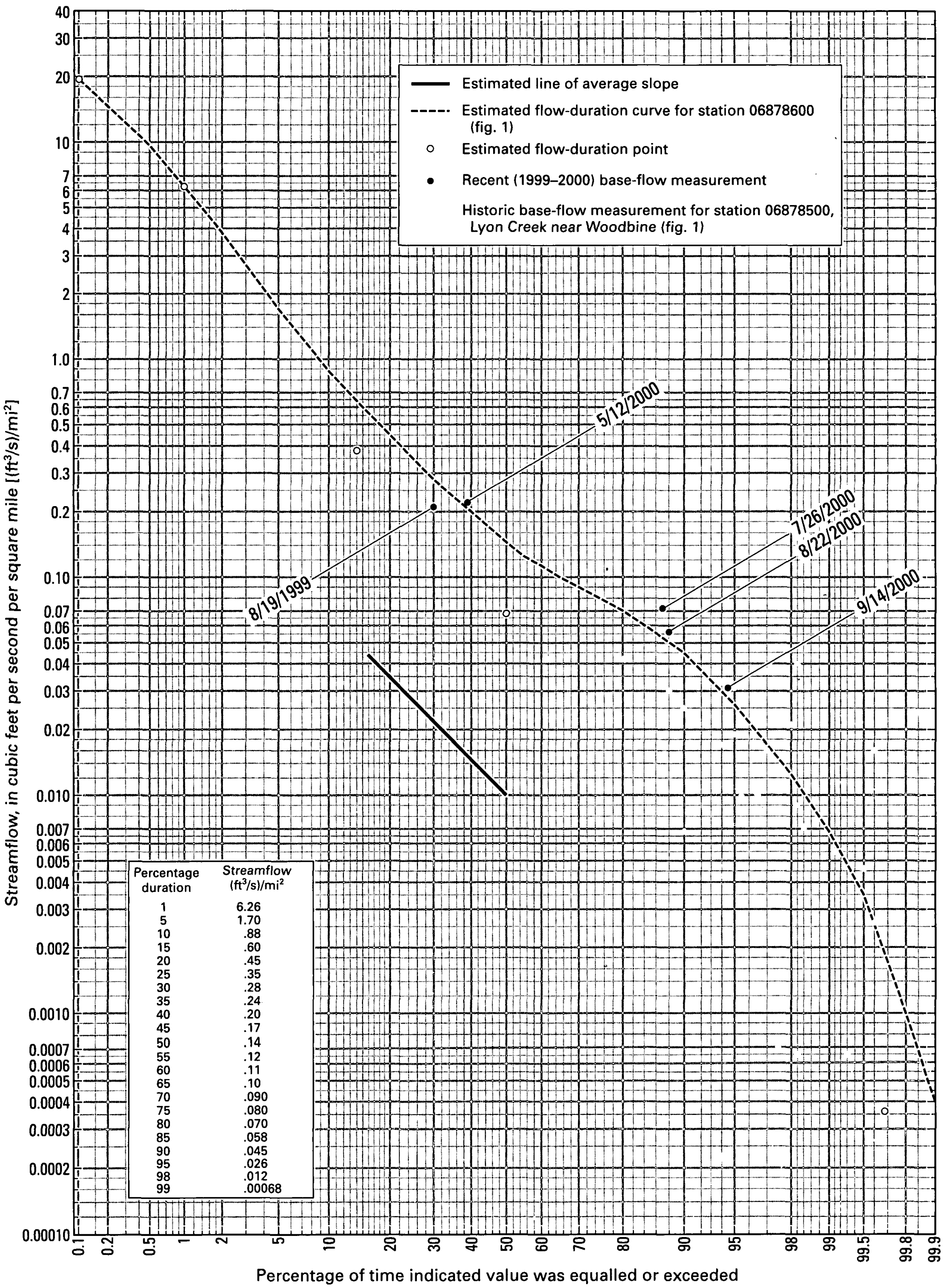
Percentage duration	Streamflow (ft³/s)/mi²
1	2.00
5	.41
10	.14
15	.060
20	.031
25	.019
30	.013
35	.0085
40	.0060
45	.0045
50	.0034
55	.0026
60	.0021
65	.0017
70	.0013
75	.00095
80	.00068
85	.00040
90	.00018
92	.00011

Figure 26. Estimated flow-duration curve for 1968–98 for site 06875820, Limestone Creek at Glen Elder. Location of site shown in figure 1.



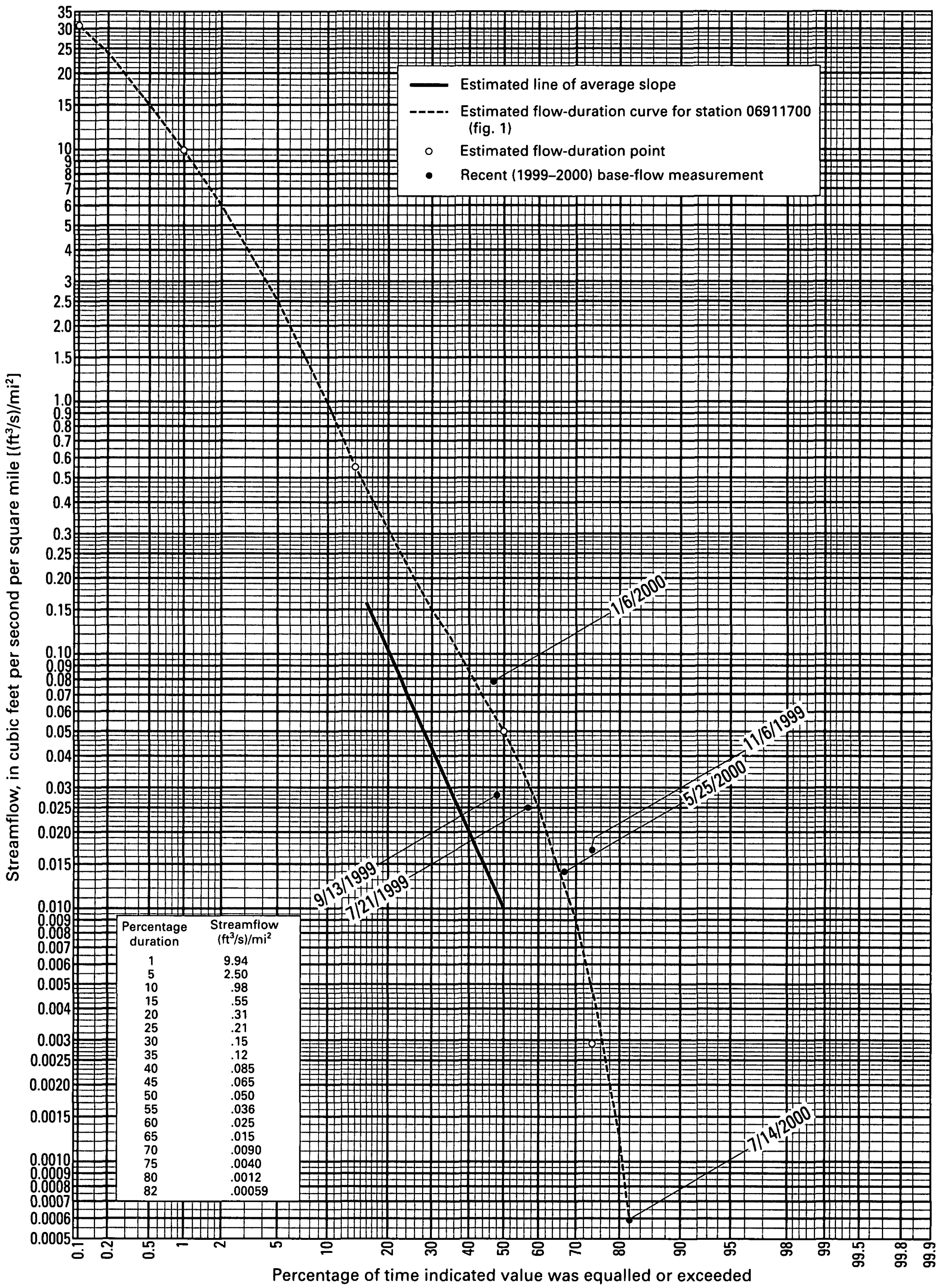
Percentage duration	Streamflow $(ft^3/s)/mi^2$
1	3.42
5	.75
10	.27
15	.13
20	.090
25	.068
30	.054
35	.045
40	.038
45	.032
50	.028
55	.024
60	.020
65	.018
70	.015
75	.013
80	.011
85	.0090
90	.0075
95	.0055
98	.0035
99	.0023

Figure 27. Estimated flow-duration curve for 1968–98 for site 06876410, Pipe Creek at Minneapolis. Location of site shown in figure 1.



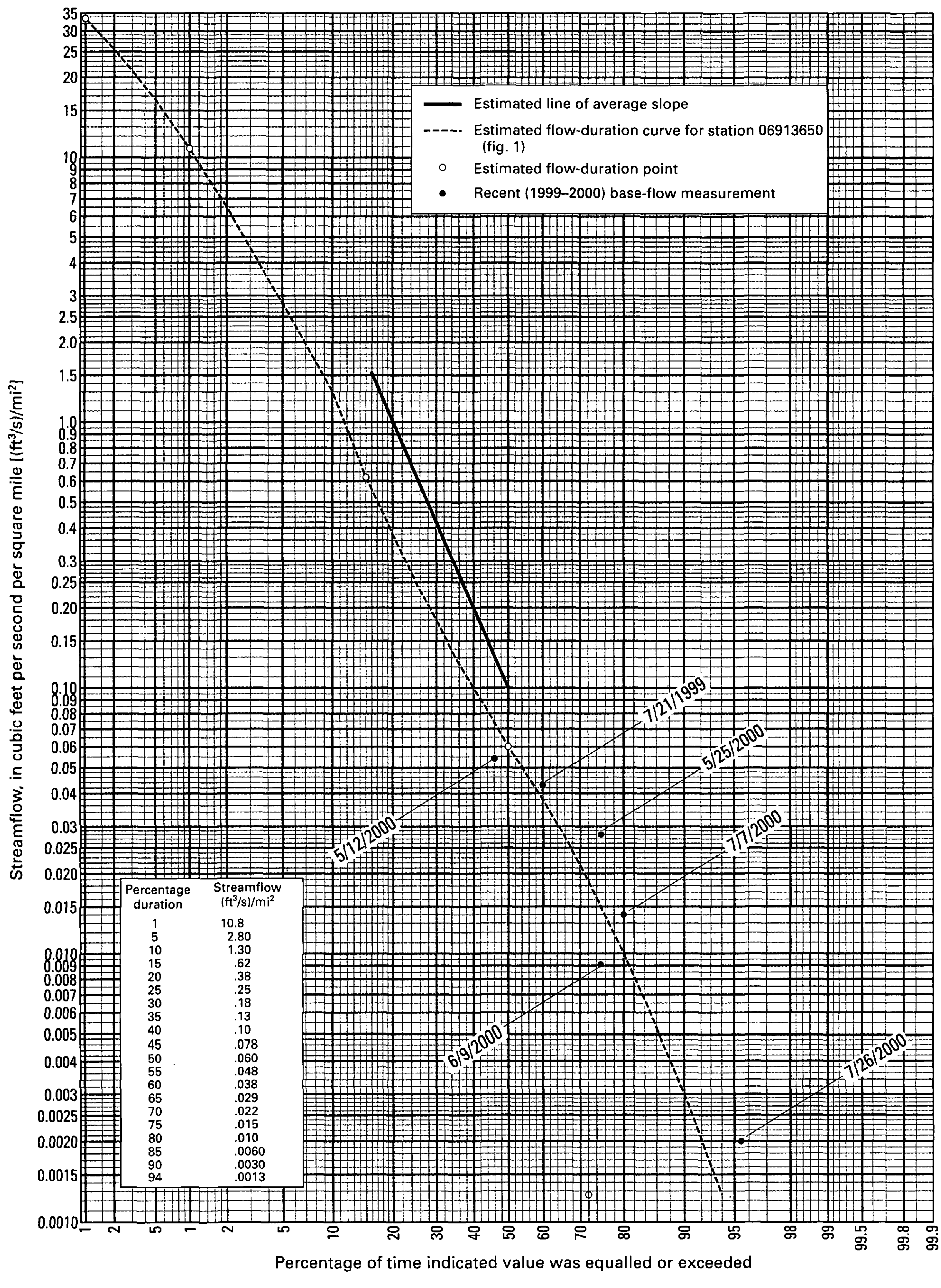
Percentage duration	Streamflow (ft³/s)/mi²
1	6.26
5	1.70
10	.88
15	.60
20	.45
25	.35
30	.28
35	.24
40	.20
45	.17
50	.14
55	.12
60	.11
65	.10
70	.090
75	.080
80	.070
85	.058
90	.045
95	.026
98	.012
99	.00068

Figure 28. Estimated flow-duration curve for 1968–98 for site 06878600, Lyon Creek near Wreford. Location of site shown in figure 1.



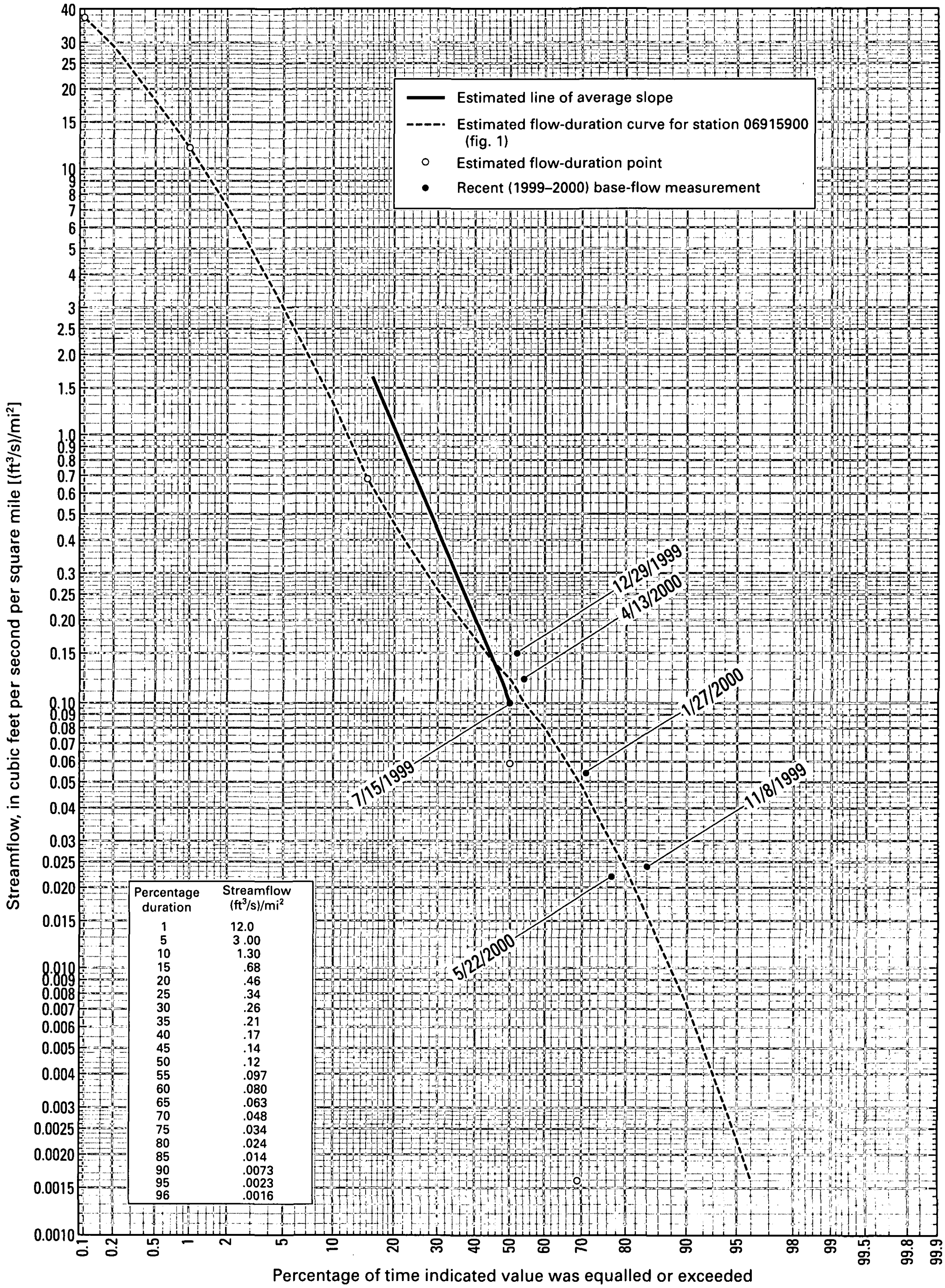
Percentage duration	Streamflow (ft³/s)/mi²
1	9.94
5	2.50
10	.98
15	.55
20	.31
25	.21
30	.15
35	.12
40	.085
45	.065
50	.050
55	.036
60	.025
65	.015
70	.0090
75	.0040
80	.0012
82	.00059

Figure 29. Estimated flow-duration curve for 1968–98 for site 06911700, Hundred and Ten Mile Creek near Scranton. Location of site shown in figure 1.



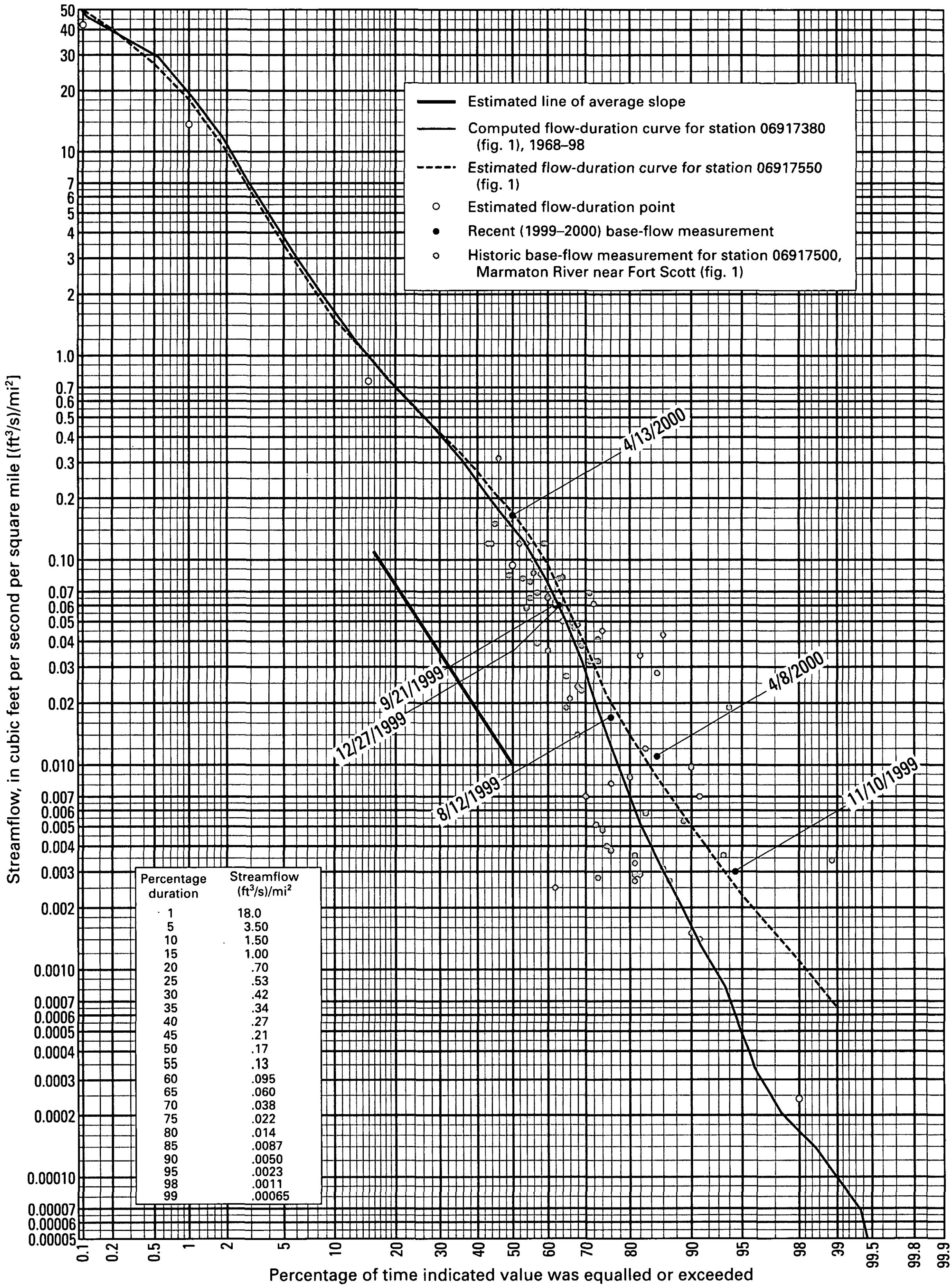
Percentage duration	Streamflow (ft³/s)/mi²
1	10.8
5	2.80
10	1.30
15	.62
20	.38
25	.25
30	.18
35	.13
40	.10
45	.078
50	.060
55	.048
60	.038
65	.029
70	.022
75	.015
80	.010
85	.0060
90	.0030
94	.0013

Figure 30. Estimated flow-duration curve for 1968–98 for site 06913650, Tauy Creek near Ottawa. Location of site shown in figure 1.



Percentage duration	Streamflow (ft³/s)/mi²
1	12.0
5	3.00
10	1.30
15	.68
20	.46
25	.34
30	.26
35	.21
40	.17
45	.14
50	.12
55	.097
60	.080
65	.063
70	.048
75	.034
80	.024
85	.014
90	.0073
95	.0023
96	.0016

Figure 31. Estimated flow-duration curve for 1968–98 for site 06915900, Middle Creek near La Cygne. Location of site shown in figure 1.



Percentage duration	Streamflow (ft³/s)/mi²
1	18.0
5	3.50
10	1.50
15	1.00
20	.70
25	.53
30	.42
35	.34
40	.27
45	.21
50	.17
55	.13
60	.095
65	.060
70	.038
75	.022
80	.014
85	.0087
90	.0050
95	.0023
98	.0011
99	.00065

Figure 32. Estimated flow-duration curve for 1968–98 for site 06917550, Marmaton River near Kansas-Missouri State line. Location of site shown in figure 1.

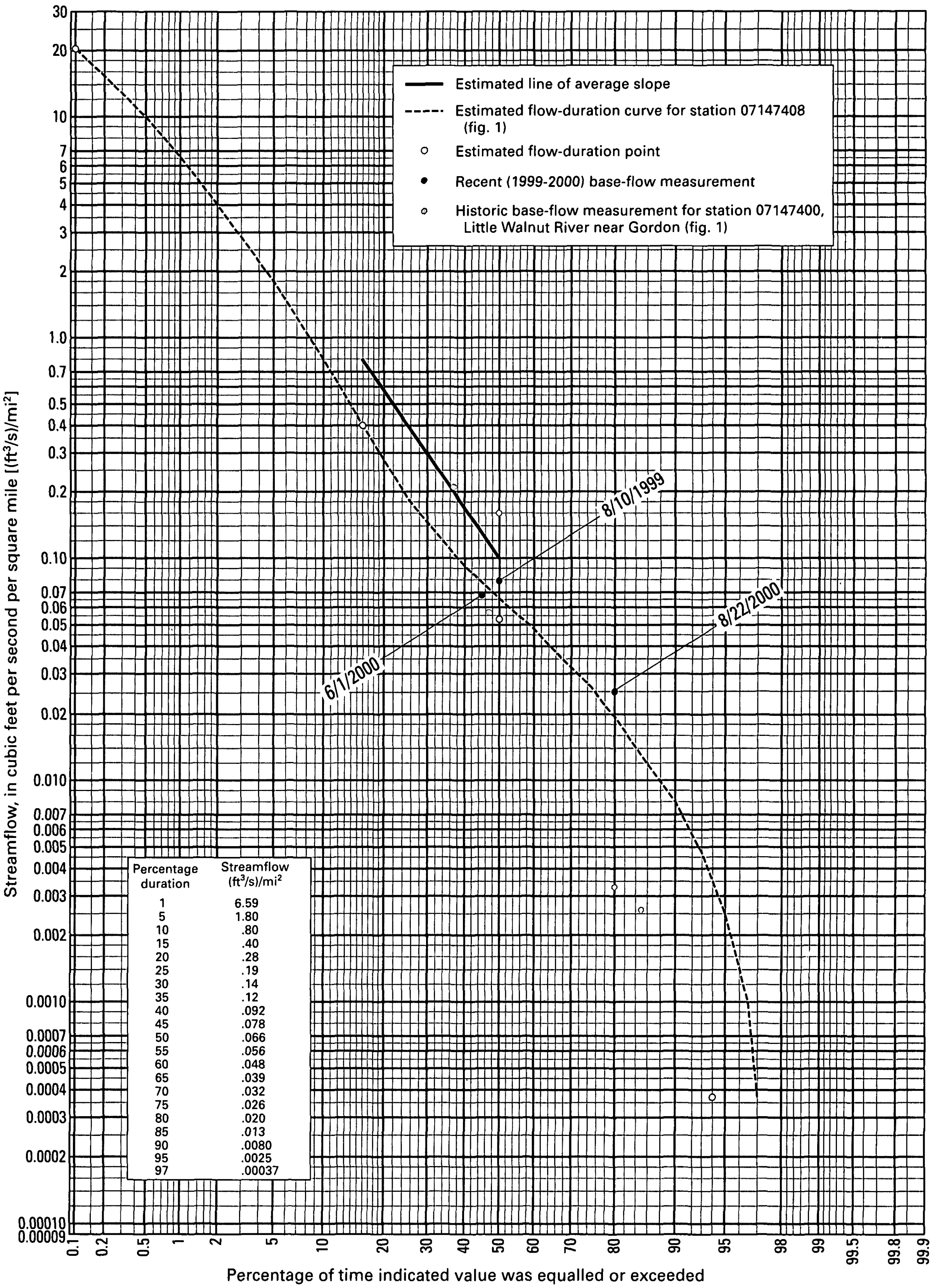
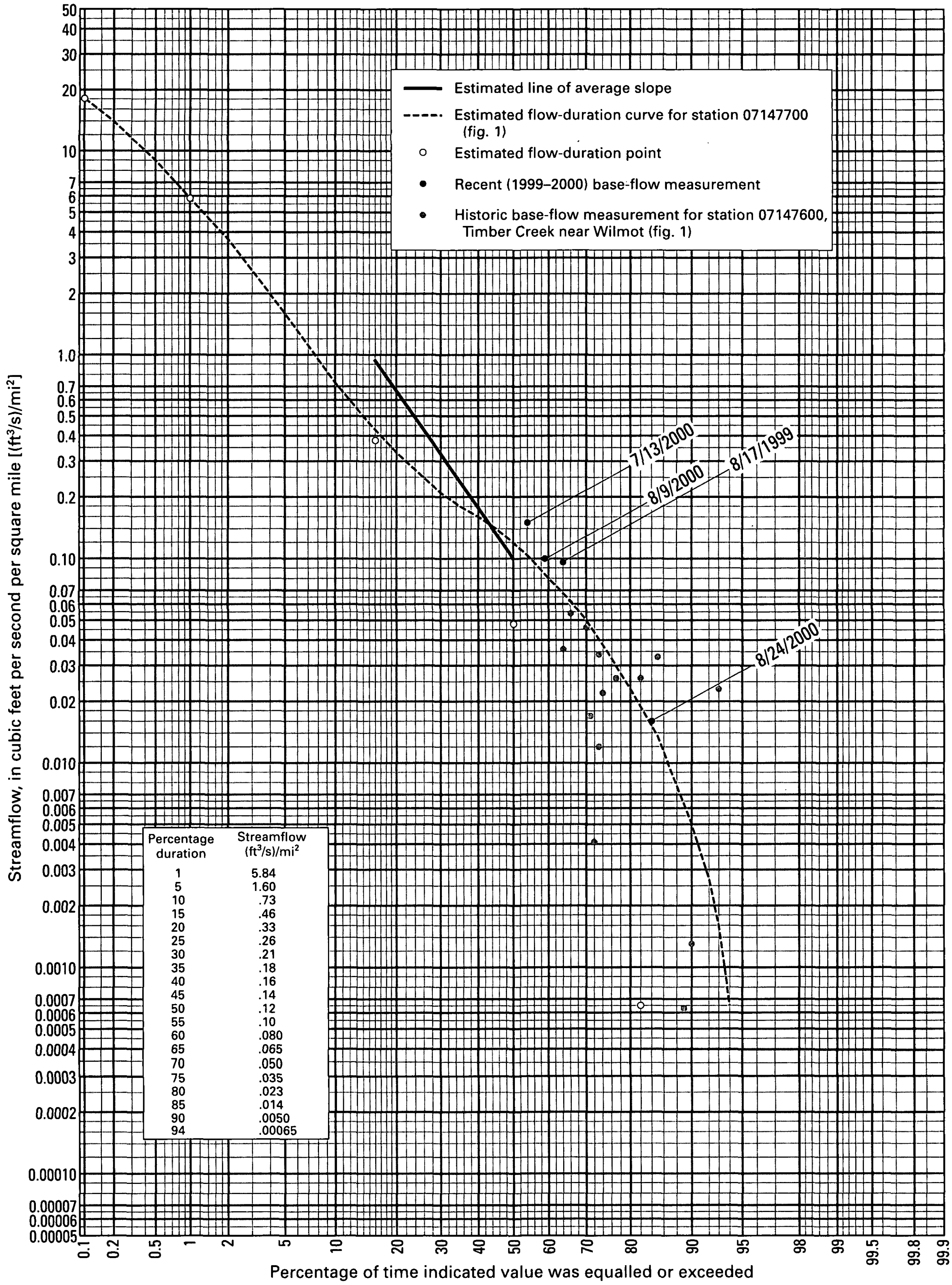
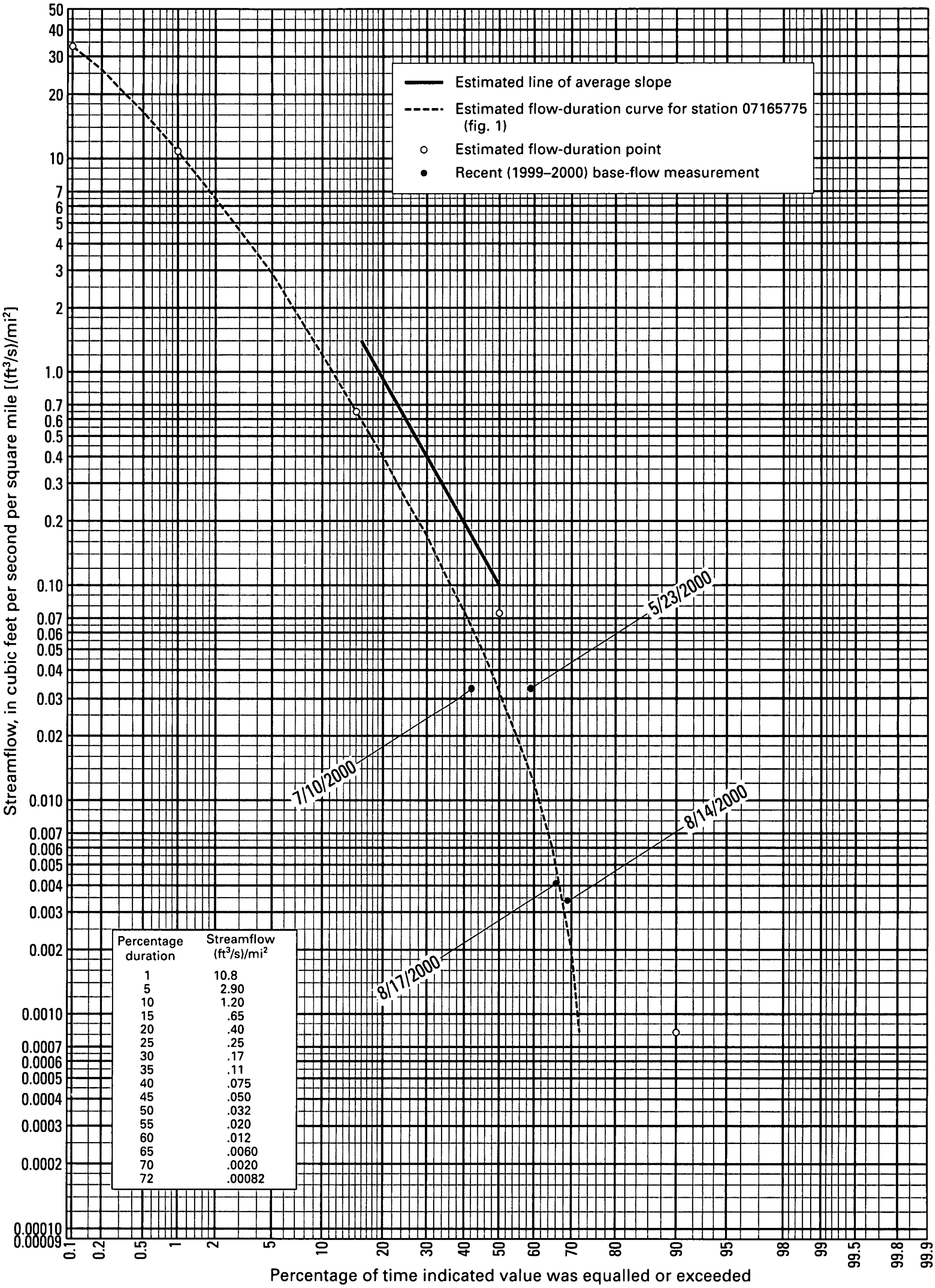


Figure 33. Estimated flow-duration curve for 1968–98 for site 07147408, Little Walnut River southeast of Gordon. Location of site shown in figure 1.



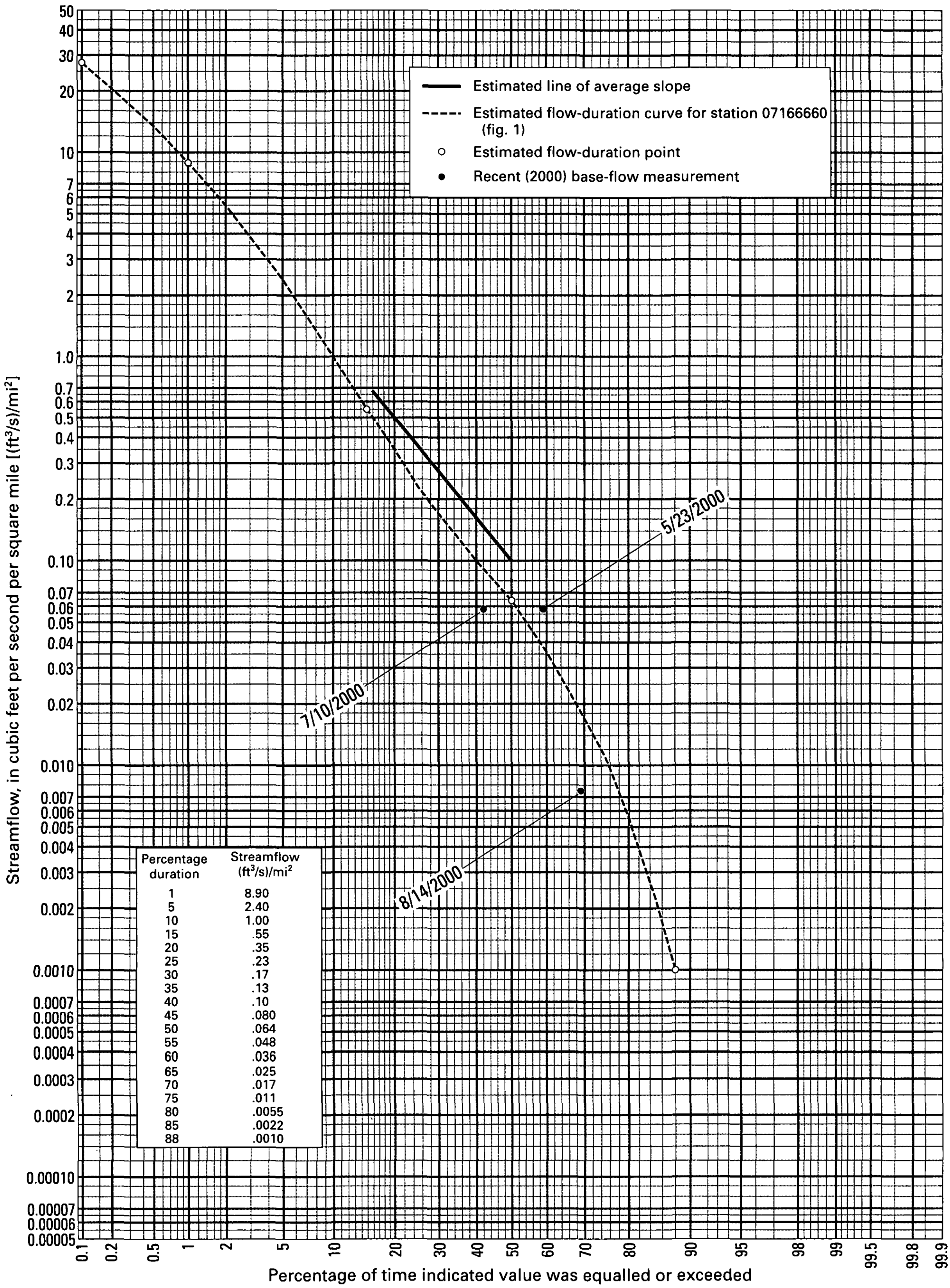
Percentage duration	Streamflow (ft³/s)/mi²
1	5.84
5	1.60
10	.73
15	.46
20	.33
25	.26
30	.21
35	.18
40	.16
45	.14
50	.12
55	.10
60	.080
65	.065
70	.050
75	.035
80	.023
85	.014
90	.0050
94	.00065

Figure 34. Estimated flow-duration curve for 1968–98 for site 07147700, Timber Creek near Winfield. Location of site shown in figure 1.



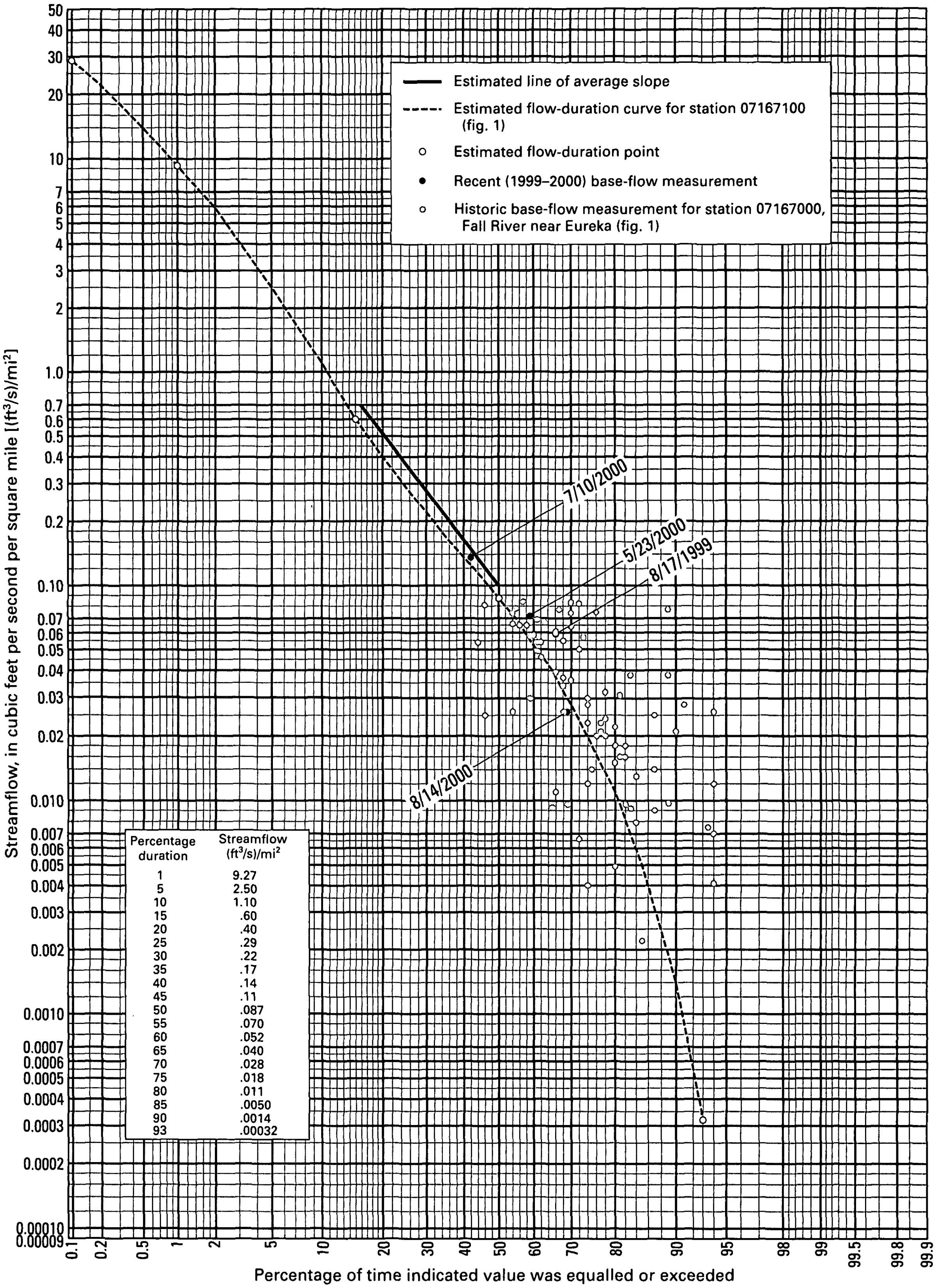
Percentage duration	Streamflow (ft³/s)/mi²
1	10.8
5	2.90
10	1.20
15	.65
20	.40
25	.25
30	.17
35	.11
40	.075
45	.050
50	.032
55	.020
60	.012
65	.0060
70	.0020
72	.00082

Figure 35. Estimated flow-duration curve for 1968–98 for site 07165775, West Creek near Quincy. Location of site shown in figure 1.



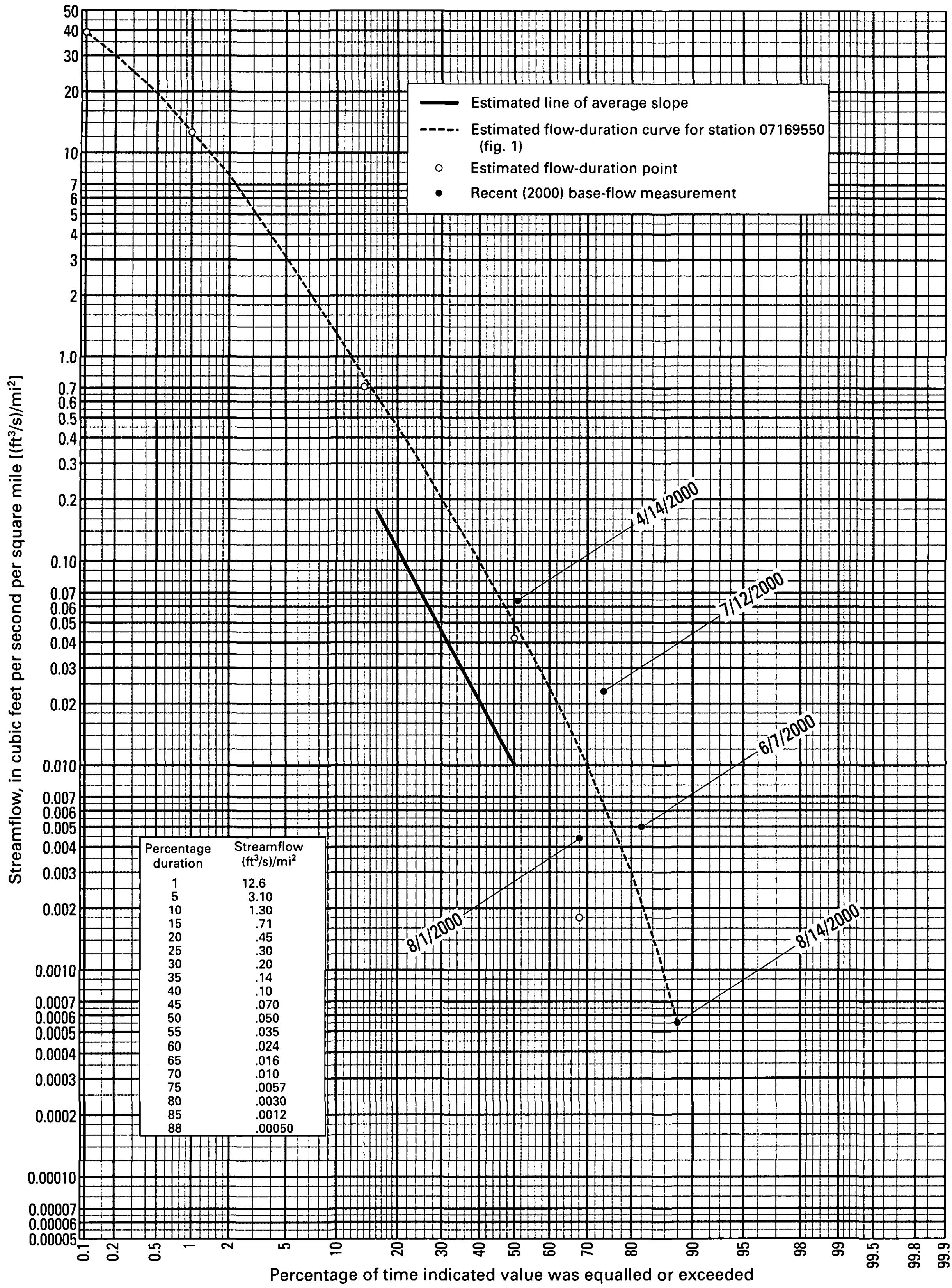
Percentage duration	Streamflow $(ft^3/s)/mi^2$
1	8.90
5	2.40
10	1.00
15	.55
20	.35
25	.23
30	.17
35	.13
40	.10
45	.080
50	.064
55	.048
60	.036
65	.025
70	.017
75	.011
80	.0055
85	.0022
88	.0010

Figure 36. Estimated flow-duration curve for 1968–98 for site 07166660, West Branch Fall River near Eureka. Location of site shown in figure 1.



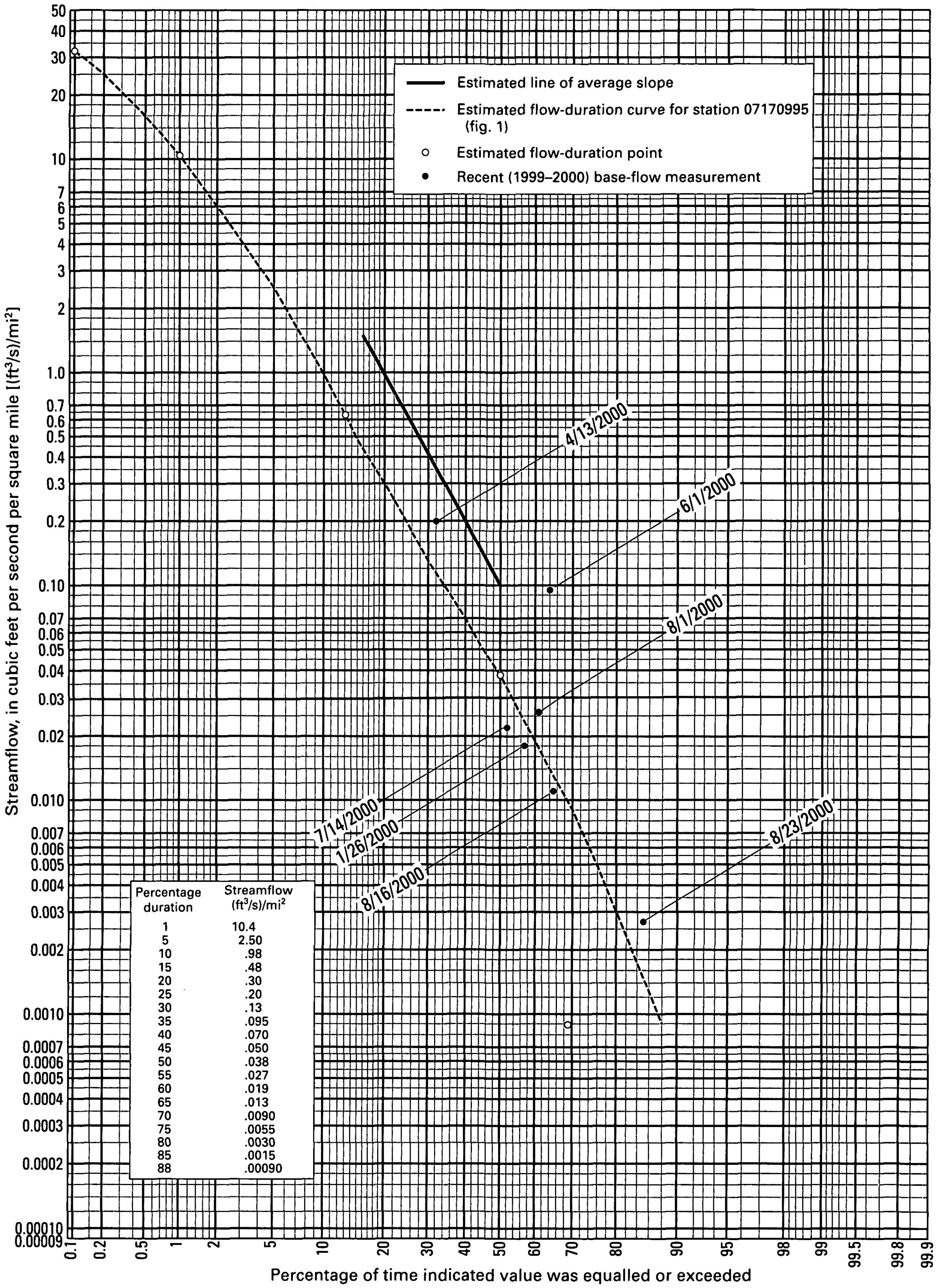
Percentage duration	Streamflow (ft³/s)/mi²
1	9.27
5	2.50
10	1.10
15	.60
20	.40
25	.29
30	.22
35	.17
40	.14
45	.11
50	.087
55	.070
60	.052
65	.040
70	.028
75	.018
80	.011
85	.0050
90	.0014
93	.00032

Figure 37. Estimated flow-duration curve for 1968–98 for site 07167100, Fall River near Climax. Location of site shown in figure 1.



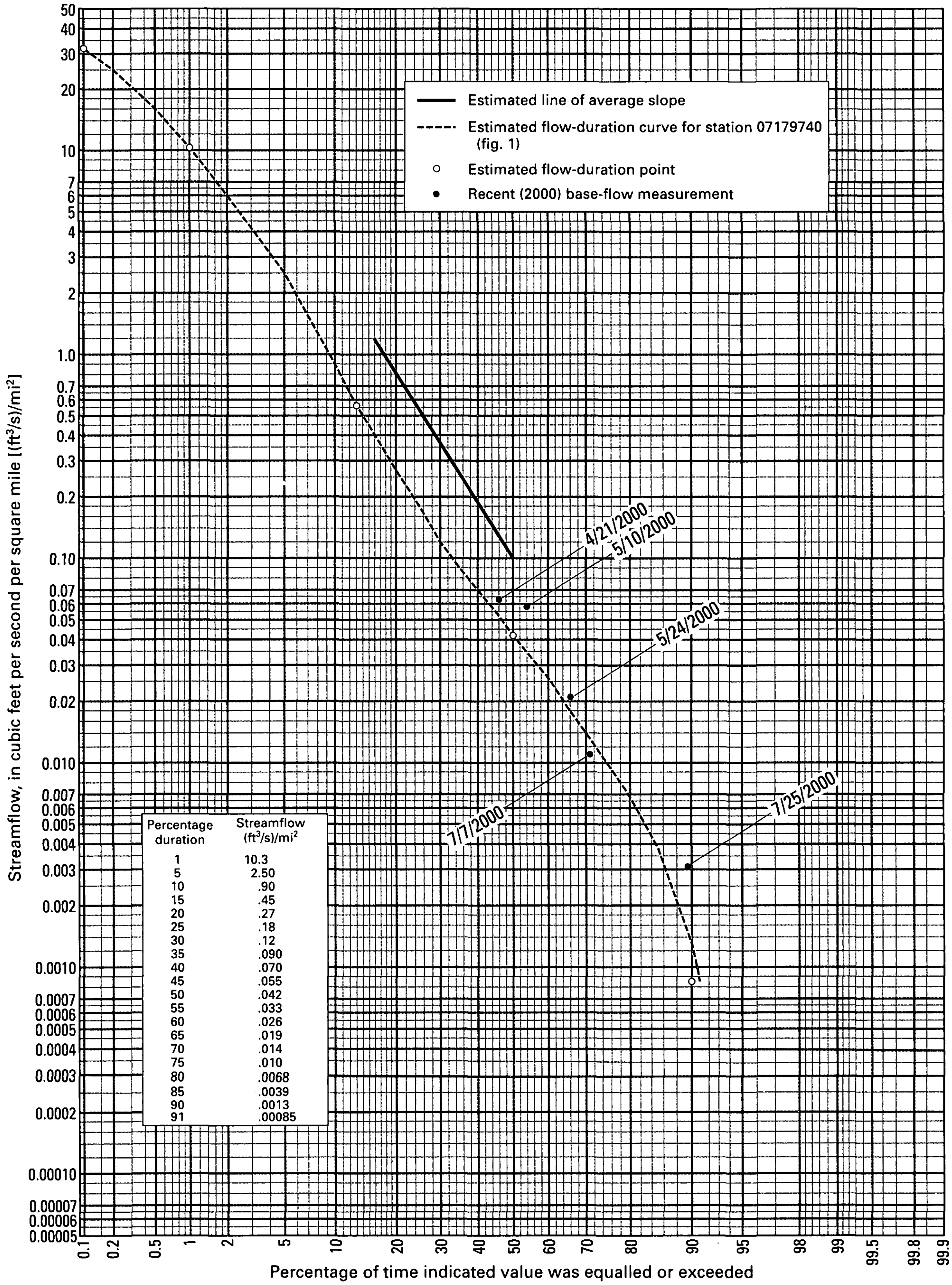
Percentage duration	Streamflow (ft³/s)/mi²
1	12.6
5	3.10
10	1.30
15	.71
20	.45
25	.30
30	.20
35	.14
40	.10
45	.070
50	.050
55	.035
60	.024
65	.016
70	.010
75	.0057
80	.0030
85	.0012
88	.00050

Figure 38. Estimated flow-duration curve for 1968–98 for site 07169550, Chetopa Creek near Neodesha. Location of site shown in figure 1.



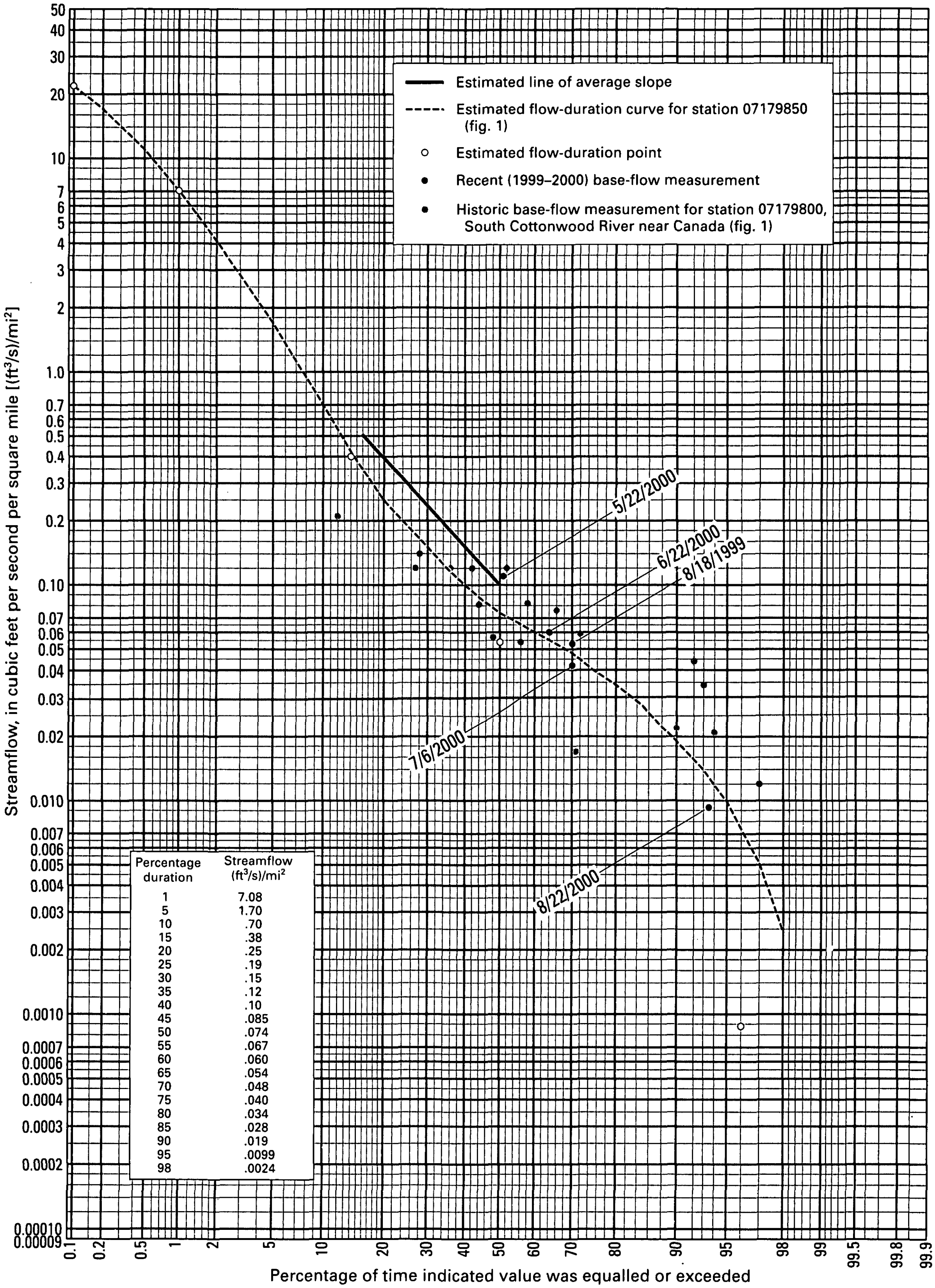
Percentage duration	Streamflow (ft³/s)/mi²
1	10.4
5	2.50
10	.98
15	.48
20	.30
25	.20
30	.13
35	.095
40	.070
45	.050
50	.038
55	.027
60	.019
65	.013
70	.0090
75	.0055
80	.0030
85	.0015
88	.00090

Figure 39. Estimated flow-duration curve for 1968–98 for site 07170995, Onion Creek near Coffeyville. Location of site shown in figure 1.



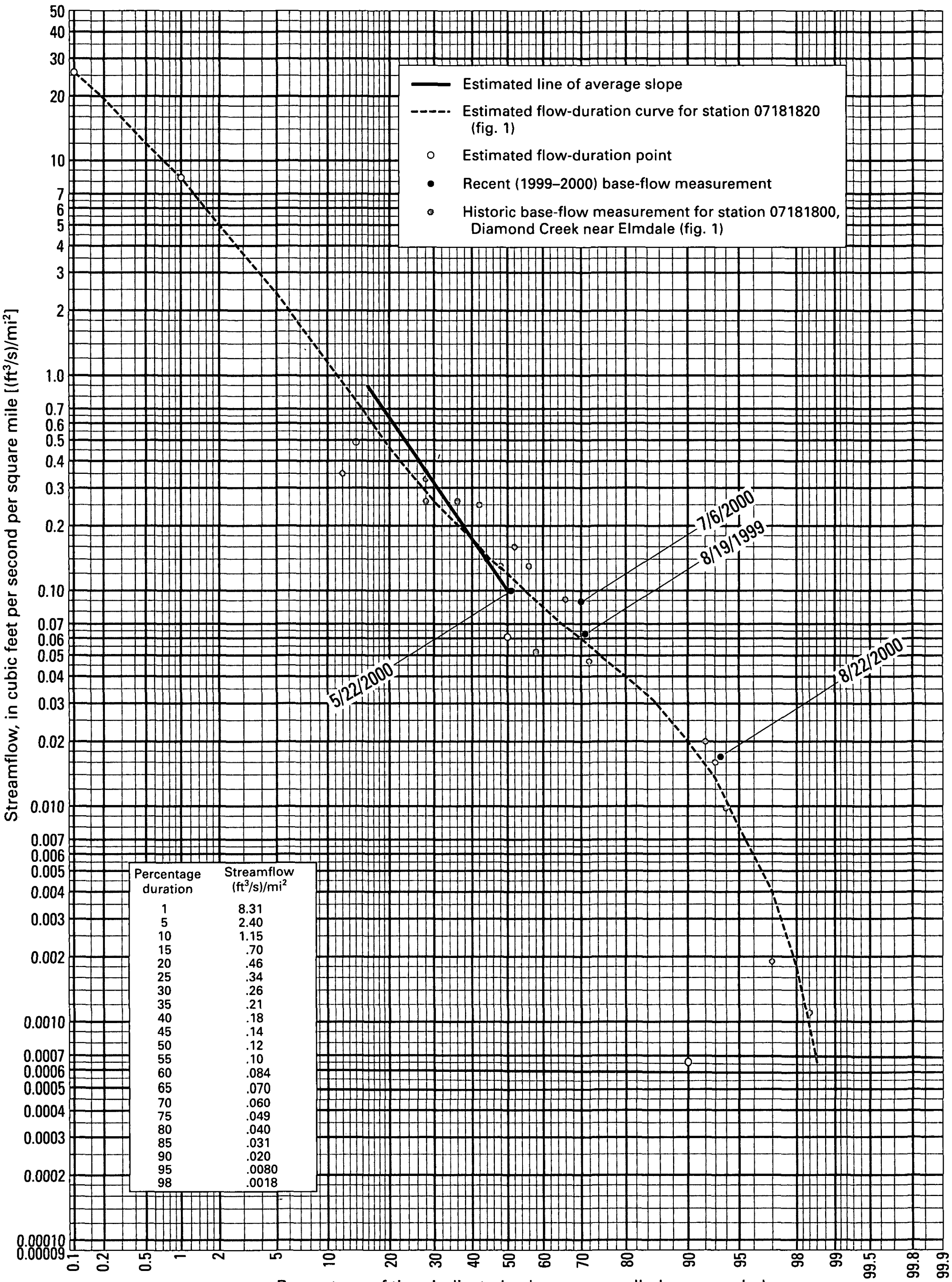
Percentage duration	Streamflow $(ft^3/s)/mi^2$
1	10.3
5	2.50
10	.90
15	.45
20	.27
25	.18
30	.12
35	.090
40	.070
45	.055
50	.042
55	.033
60	.026
65	.019
70	.014
75	.010
80	.0068
85	.0039
90	.0013
91	.00085

Figure 40. Estimated flow-duration curve for 1968–98 for site 07179740, Allen Creek near Emporia. Location of site shown in figure 1.



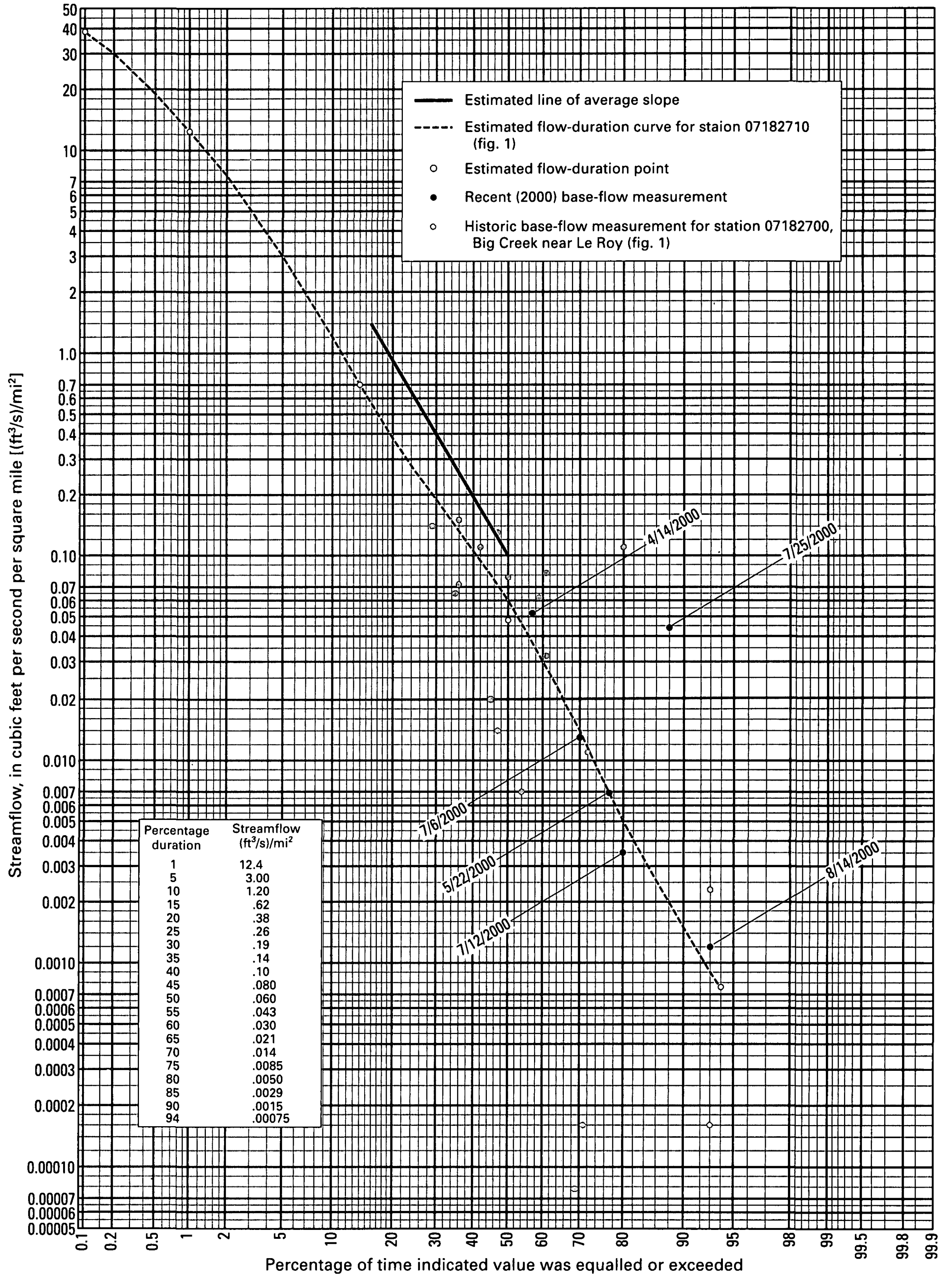
Percentage duration	Streamflow (ft³/s)/mi²
1	7.08
5	1.70
10	.70
15	.38
20	.25
25	.19
30	.15
35	.12
40	.10
45	.085
50	.074
55	.067
60	.060
65	.054
70	.048
75	.040
80	.034
85	.028
90	.019
95	.0099
98	.0024

Figure 41. Estimated flow-duration curve for 1968–98 for site 07179850, South Cottonwood River near Marion. Location of site shown in figure 1.



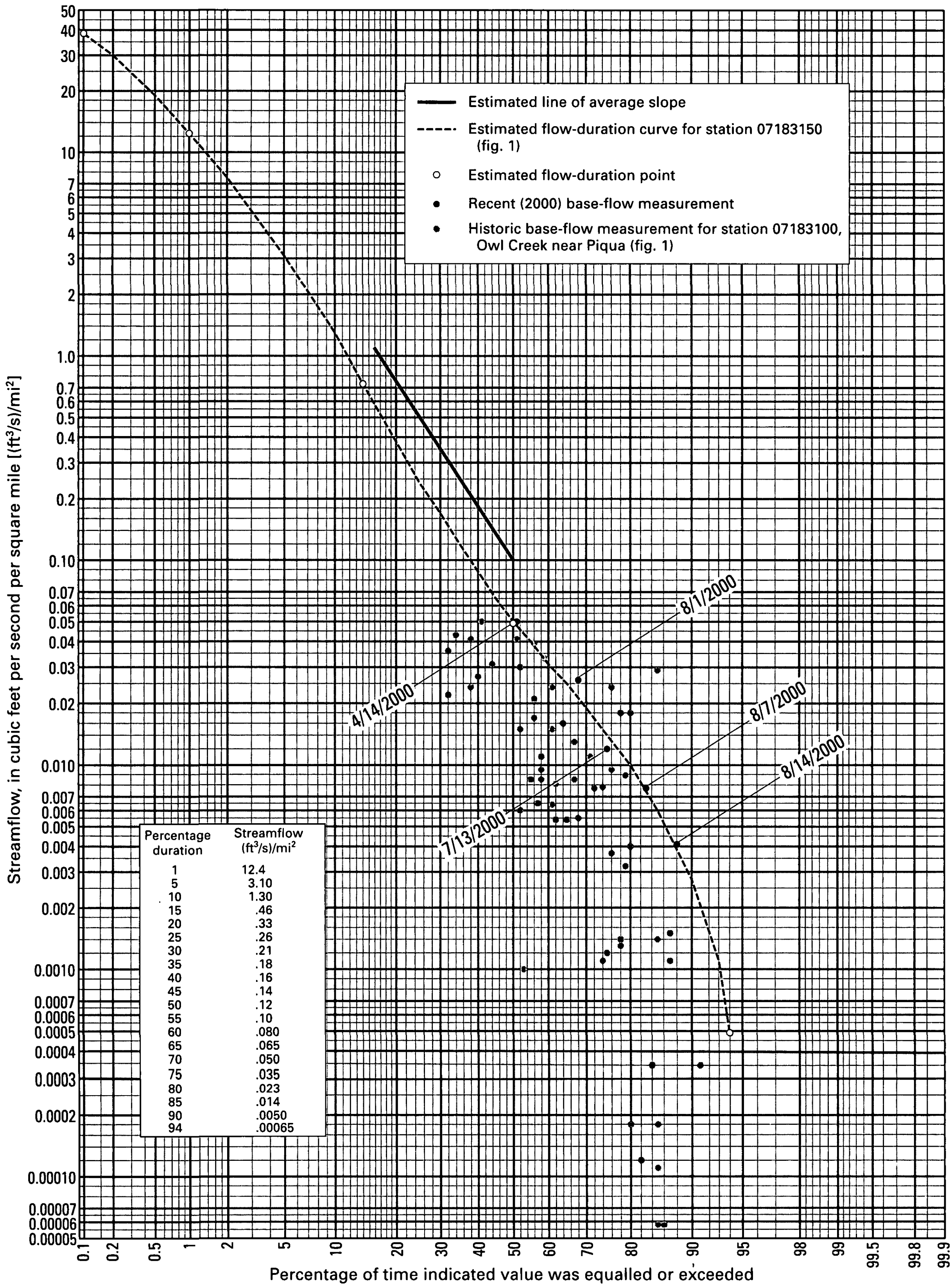
Percentage duration	Streamflow (ft³/s)/mi²
1	8.31
5	2.40
10	1.15
15	.70
20	.46
25	.34
30	.26
35	.21
40	.18
45	.14
50	.12
55	.10
60	.084
65	.070
70	.060
75	.049
80	.040
85	.031
90	.020
95	.0080
98	.0018

Figure 42. Estimated flow-duration curve for 1968–98 for site 07181820, Diamond Creek on Highway 50 near Elmdale. Location of site shown in figure 1.



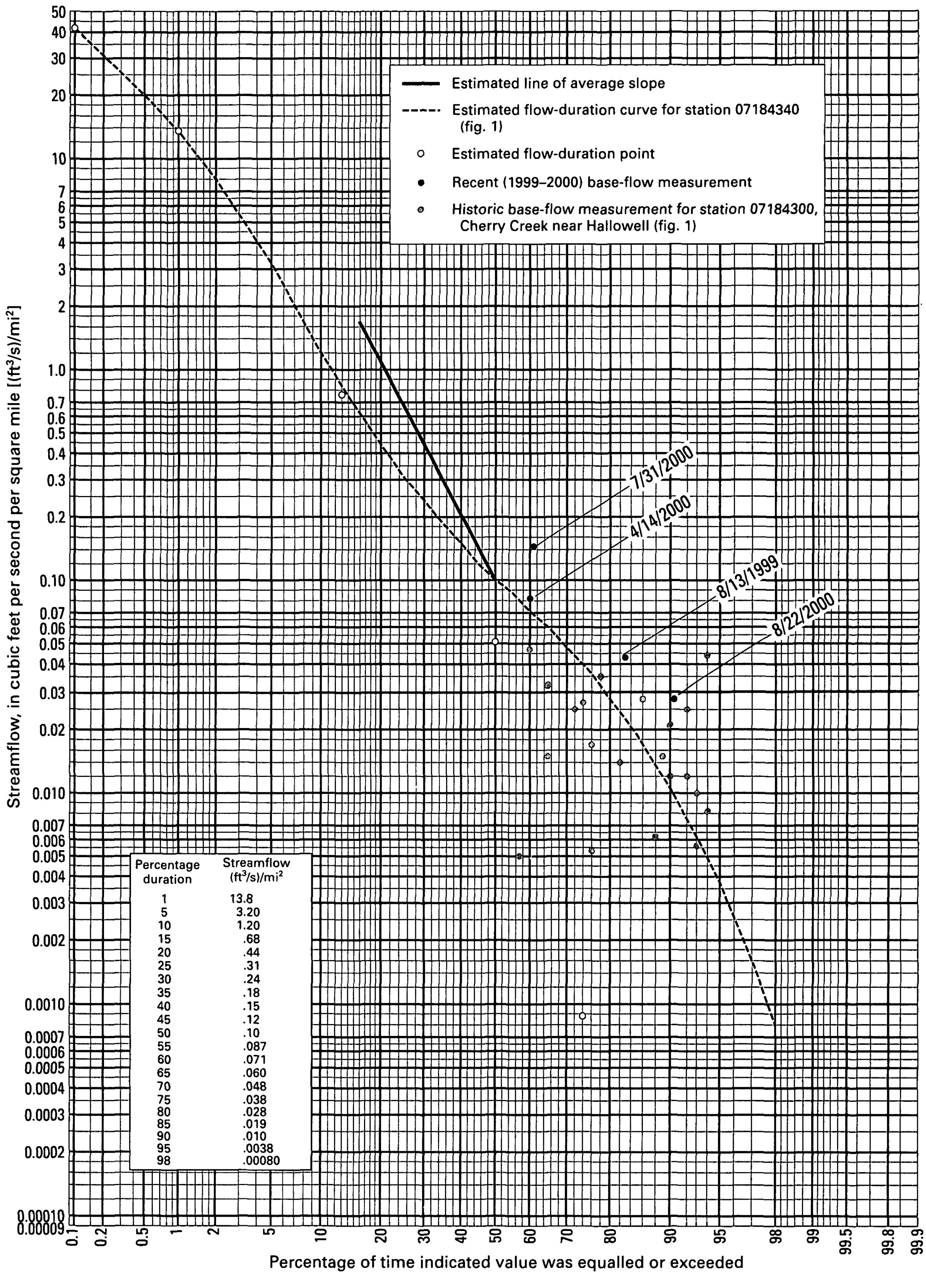
Percentage duration	Streamflow $(ft^3/s)/mi^2$
1	12.4
5	3.00
10	1.20
15	.62
20	.38
25	.26
30	.19
35	.14
40	.10
45	.080
50	.060
55	.043
60	.030
65	.021
70	.014
75	.0085
80	.0050
85	.0029
90	.0015
94	.00075

Figure 43. Estimated flow-duration curve for 1968-98 for site 07182710, Big Creek 2 miles west of Le Roy. Location of site shown in figure 1.



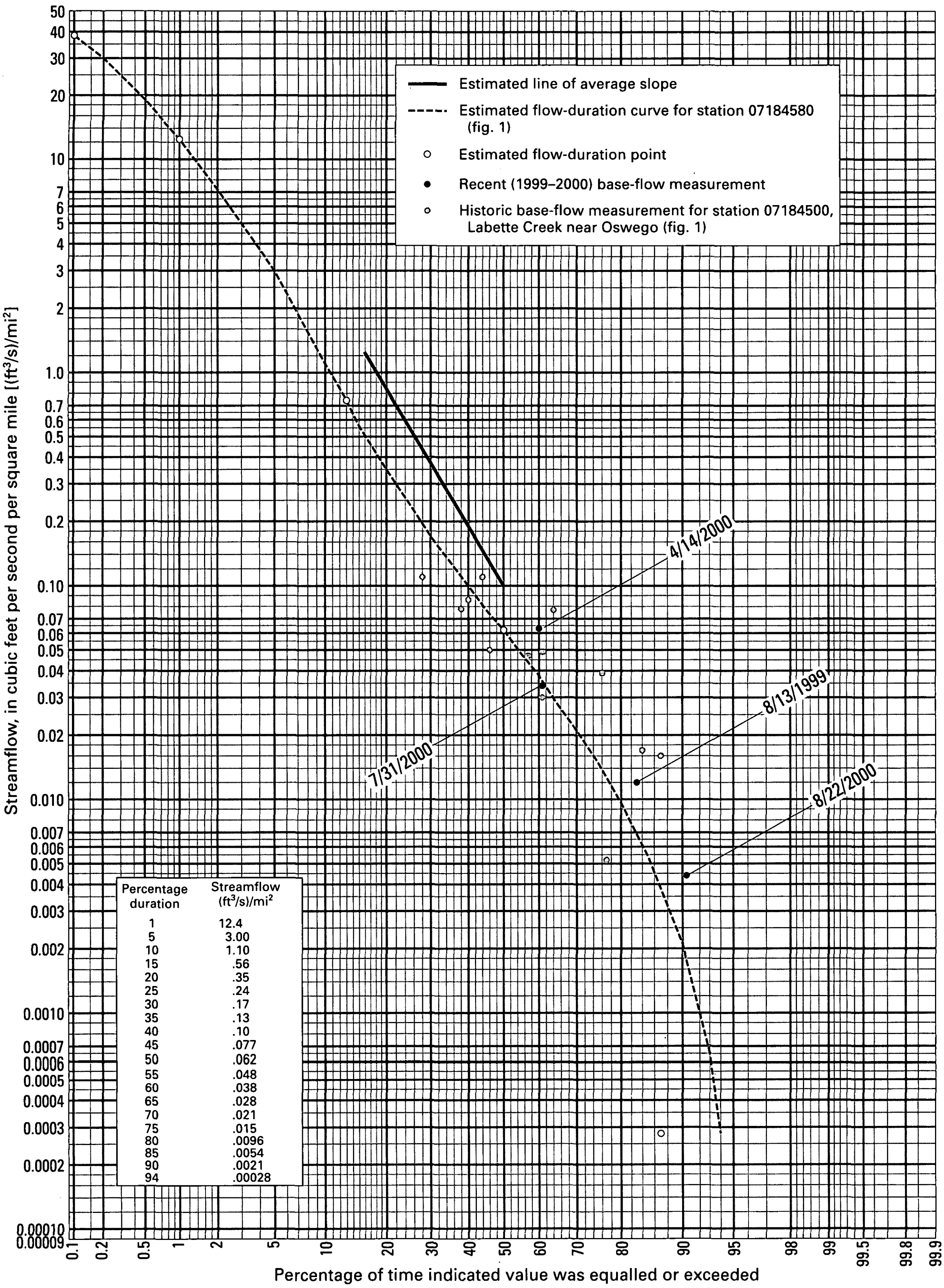
Percentage duration	Streamflow (ft³/s)/mi²
1	12.4
5	3.10
10	1.30
15	.46
20	.33
25	.26
30	.21
35	.18
40	.16
45	.14
50	.12
55	.10
60	.080
65	.065
70	.050
75	.035
80	.023
85	.014
90	.0050
94	.00065

Figure 44. Estimated flow-duration curve for 1968–98 for site 07183150, Owl Creek near Humboldt. Location of site shown in figure 1.



Percentage duration	Streamflow (ft³/s)/mi²
1	13.8
5	3.20
10	1.20
15	.68
20	.44
25	.31
30	.24
35	.18
40	.15
45	.12
50	.10
55	.087
60	.071
65	.060
70	.048
75	.038
80	.028
85	.019
90	.010
95	.0038
98	.00080

Figure 45. Estimated flow-duration curve for 1968–98 for site 07184340, Cherry Creek near Chetopa. Location of site shown in figure 1.



Percentage duration	Streamflow $(ft^3/s)/mi^2$
1	12.4
5	3.00
10	1.10
15	.56
20	.35
25	.24
30	.17
35	.13
40	.10
45	.077
50	.062
55	.048
60	.038
65	.028
70	.021
75	.015
80	.0096
85	.0054
90	.0021
94	.00028

Figure 46. Estimated flow-duration curve for 1968–98 for site 07184580, Labette Creek near Chetopa. Location of site shown in figure 1.

Appendix B. Site descriptions for 32 ungaged sites and 20 historic base-flow measurement sites in the Missouri, Smoky Hill-Saline, Solomon, Marais des Cygnes, Walnut, Verdigris, and Neosho River Basins in Kansas.

Description of low-flow, partial-record site on South Fork Nemaha River near Seneca, Kansas, site 06813900.

LOCATION.—Lat. 39°55'00", long. 96°03'00", sec. 25, T.1 S., R.12 E., Nemaha County, hydrologic unit 10240007, at bridge on county highway, 7 mi northeast of Seneca.

DRAINAGE AREA.—222 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 06814050, South Fork Big Nemaha River near Bern.

Description of ungaged site on South Fork Big Nemaha River near Bern, Kansas, site 06814050.

LOCATION.—Lat. 39°57'32", long. 96°02'06", in SE1/4SE1/4SE1/4 sec. 14, T.1 S., R.12 E., Nemaha County, hydrologic unit 10240007, at Highway 71 bridge, approximately 0.5 mi downstream from Turkey Creek.

DRAINAGE AREA.—558 mi^2.

Description of ungaged site on Walnut Creek near Padonia, Kansas, site 06815295.

LOCATION.—Lat. 39°56'14", long. 95°33'45", in SW1/4SW1/4NW1/4 sec. 30, T.1 S., R.17 E., Brown County, hydrologic unit 10240008, at county road bridge, approximately 100 ft downstream from railroad bridge.

DRAINAGE AREA.—101 mi^2.

Description of low-flow, partial-record site on Walnut Creek at Reserve, Kansas, site 06815300.

LOCATION.—Lat. 39°58'20", long. 95°33'10", sec. 7, T.1 S., R.17 E., Brown County, hydrologic unit 10240005, at bridge on U.S. Highway 73, 0.5 mi east of Reserve.

DRAINAGE AREA.—111 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 06815295, Walnut Creek near Padonia.

Description of low-flow, partial-record site on Wolf River near Leona, Kansas, site 06815800.

LOCATION.—Lat. 39°46'53", long. 95°19'16", sec. 20, T.3 S., R.19 E., Doniphan County, hydrologic unit 10240005, at bridge on county highway, 0.5 mi south of Leona.

DRAINAGE AREA.—160 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 06815900, Wolf River at Sparks.

Description of ungaged site on Wolf River at Sparks, Kansas, site 06815900.

LOCATION.—Lat. 39°51'13", long. 95°10'58", in SE1/4NE1/4NW1/4 sec. 28, T.2 S., R.20 E., Doniphan County, hydrologic unit 10240005, at State Highway 7 bridge over Wolf River.

DRAINAGE AREA.—239 mi^2.

Description of ungaged site on Ladder Creek below Chalk Creek near Scott City, Kansas, site 06859500.

LOCATION.—Lat. 38°47'20", long. 100°52'10", in SW1/4 sec. 34, T.14 S., R.32 W., Logan County, at county bridge, 21 mi north of Scott City and 0.5 mi west of U.S. Highway 83.

DRAINAGE AREA.—1,432 mi^2.

Description of discontinued streamflow-gaging station on Hackberry Creek near Gove, Kansas, site 06860500.

LOCATION.—Lat. 38°57'15", long. 100°29'05", sec. 1, T.13 S., R.29 W., Trego County, hydrologic unit 10260005, on State Highway 23 bridge south of Gove.

DRAINAGE AREA.—426 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 06860900, Hackberry Creek near Trego Center.

Description of ungaged site on Hackberry Creek near Trego Center, Kansas, site 06860900.

LOCATION.—Lat. 38°50'27", long. 100°03'30", in NE1/4NE1/4 sec. 14, T.14 S., R.25 W., Trego County, hydrologic unit 10260005 near left bank at upstream side of bridge on county road, 2.5 mi north and 2 mi west of station 06861000, Smoky Hill River near Arnold, Kansas.

DRAINAGE AREA.—616 mi^2.

Description of low-flow, partial-record site on North Branch Spillman Creek near Ash Grove, Kansas, site 06868700.

LOCATION.—Lat. 39°09'10", long. 98°23'50", sec. 26, T.10 S., R.10 W., Lincoln County, hydrologic unit 10260010, on State Highway 181 east of Ash Grove.

DRAINAGE AREA.—26.1 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 06868720, Spillman Creek near Lincoln.

Description of ungaged site on Spillman Creek near Lincoln, Kansas, site 06868720.

LOCATION.—Lat. 39°02'42", long. 98°13'31", in NW1/4NW1/4NW1/4 sec. 4, T.12 S., R.8 W., Lincoln County, hydrologic unit 10260010, at bridge over Spillman Creek.

DRAINAGE AREA.—168 mi^2.

Description of ungaged site on Elkhorn Creek near Lincoln, Kansas, site 06869000.

LOCATION.—Lat. 39°00'30", long. 98°05'44", in NE1/4NE1/4SE1/4 sec. 16, T.12 S., R.7 W., Lincoln County, hydrologic unit 10260010, at bridge over Elkhorn Creek.

DRAINAGE AREA.—68.1 mi^2.

Description of ungaged site on Mulberry Creek near Salina, Kansas, site 06869950.

LOCATION.—Lat. 38°50"40", long. 97°40'05", in SW1/4SW1/4 sec. 9, T.14 S., R.3 W., Saline County, hydrologic unit 10260010, on left downstream pier of county bridge, 2 mi downstream from Spring Creek, 2.25 mi west of Salina, and 9 mi upstream from mouth.

DRAINAGE AREA.—261 mi^2.

Description of low-flow, partial-record site on Middle Beaver Creek near Smith Center, Kansas, site 06872300.

LOCATION.—Lat. 39°48'00", long. 98°51'10", sec. 12, T.3 S., R.14 W., Smith County, hydrologic unit 10260012, at bridge 4 mi northwest of Smith Center.

DRAINAGE AREA.—71 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 06872430, Beaver Creek near Gaylord.

Description of ungaged site on Beaver Creek near Gaylord, Kansas, site 06872430.

LOCATION.—Lat. 39°40'48", long. 98°51'37", in SW1/4NW1/4NW1/4 sec. 25, T.4 S., R.14 W., Smith County, hydrologic unit 10260012, at bridge over Beaver Creek.

DRAINAGE AREA.—178 mi^2.

Description of ungaged site on Oak Creek northwest of Cawker City, Kansas, site 06872690.

LOCATION.—Lat. 39°32'17", long. 98°28'33", in NE1/4NW1/4NE1/4 sec. 18, T.6 S., R.10 W., Mitchell County, hydrologic unit 10260012, at bridge over Oak Creek.

DRAINAGE AREA.—188 mi^2.

Description of low-flow, partial-record site on Oak Creek near Cawker City, Kansas, site 06872700.

LOCATION.—Lat. 39°31'00", long. 98°29'00", sec. 19, T.6 S., R.10 W., Mitchell County, hydrologic unit 10260012, at U.S. Highway 24 bridge, 2 mi west of Cawker City.

DRAINAGE AREA.—194 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 06872690, Oak Creek northwest of Cawker City.

Description of ungaged site on Twin Creek near Corinth, Kansas, site 06874170.

LOCATION.—Lat. 39°24'57", long. 98°33'15", in SW1/4SW1/4NE1/4 sec. 28, T.7 S. R.11 W., Osborne County, hydrologic unit 10260014, at bridge over Twin Creek.

DRAINAGE AREA.—87.6 mi^2.

Description of low-flow, partial-record site on Limestone Creek near Glen Elder, Kansas, site 06875800.

LOCATION.—Lat. 39°32'18", long. 98°18'58", sec. 15, T.6 S., R.9 W., Mitchell County, hydrologic unit 10260015, at county highway bridge, 2 mi north of Glen Elder.

DRAINAGE AREA.—210 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 06875820, Limestone Creek at Glen Elder.

Description of ungaged site on Limestone Creek at Glen Elder, Kansas, site 06875820.

LOCATION.—Lat. 39°29'54", long. 98°17'57", in NW1/4SW1/4SW1/4 sec. 26, T.6 S., R.9 W., Mitchell County, hydrologic unit 10260015, at bridge over Limestone Creek.

DRAINAGE AREA.—211 mi^2.

Description of low-flow, partial-record site on Pipe Creek near Minneapolis, Kansas, site 06876400.

LOCATION.—Lat. 39°12'00", long. 97°39'00", sec. 9, T.10 S., R.3 W., Ottawa County, hydrologic unit 10260015, at county U.S. Highway 81 bridge, 5.25 mi northeast of Minneapolis.

DRAINAGE AREA.—135 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 06876410, Pipe Creek at Minneapolis.

Description of ungaged site on Pipe Creek at Minneapolis, Kansas, site 06876410.

LOCATION.—Lat. 39°08'39", long. 97°42'20", in SW1/4NW1/4NW1/4 sec. 31, T.10 S., R.3 W., Ottawa County, hydrologic unit 10260015, at bridge over Pipe Creek.

DRAINAGE AREA.—146 mi^2.

Description of low-flow, partial-record site on Lyon Creek near Woodbine, Kansas, site 06878500.

LOCATION.—Lat. 38°53'05", long. 96°54'35", sec. 31, T.13 S., R.5 E., Geary County, hydrologic unit 10260008, at county highway bridge, 7 mi north of Woodbine.

DRAINAGE AREA.—230 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 06878600, Lyon Creek near Wreford.

Description of ungaged site on Lyon Creek near Wreford, Kansas, site 06878600.

LOCATION.—Lat. 38°56'57", long. 96°51'29", in NE1/4NW1/4SE1/4 sec. 3, T.13 S., R.5 E., Geary County, hydrologic unit 10260008, at bridge over Lyon Creek.

DRAINAGE AREA.—267 mi^2.

Description of ungaged site on Hundred and Ten Mile Creek near Scranton, Kansas, site 06911700.

LOCATION.—Lat. 38°43'28", long. 95°39'10", in NW1/4NE1/4NE1/4 sec. 29, T.15 S., R.16 E., Osage County, hydrologic unit 10290101, at 189th Street bridge over Hundred and Ten Mile Creek.

DRAINAGE AREA.--33.9 mi^2.

Description of ungaged site on Tauy Creek near Ottawa, Kansas, site 06913650.

LOCATION.—Lat. 38°39'07", long. 95°12'58", in NE1/4NW1/4NE1/4 sec. 20, T.16 S., R.20 E., Franklin County, hydrologic unit 10290101, Sand Creek Road bridge over Tauy Creek.

DRAINAGE AREA.—79.5 mi^2.

Description of ungaged site on Middle Creek near La Cygne, Kansas, site 06915900.

LOCATION.—Lat. 38°20'43", long. 94°44'04", in NE1/4NE1/4NE1/4 sec. 3, T.20 S., R.24 E., Linn County, hydrologic unit 10290102, at State Highway 152 bridge over Middle Creek.

DRAINAGE AREA.—62.8 mi^2.

Description of discontinued streamflow-gaging station on Marmaton River near Fort Scott, Kansas, site 06917500.

LOCATION.—Lat. 37°51'47", long. 94°44'36", sec. 21, T.25 S., R.25 E., Bourbon County, hydrologic unit 10290104, at county highway low-water crossing 3 mi east of Fort Scott.

DRAINAGE AREA.—408 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 06917550, Marmaton River near Kansas-Missouri State line.

Description of ungaged site on Marmaton River near Kansas-Missouri State line, Kansas, site 06917550.

LOCATION.—Lat. 37°51'20", long. 94°38'24", in NW1/4NW1/4SW1/4 sec. 23, T.25 S., R.25 E., Bourbon County, hydrologic unit 10290104, at low-water crossing over Marmaton River.

DRAINAGE AREA.—421 mi^2.

Description of low-flow, partial-record site on Little Walnut River near Gordon, Kansas, site 07147400.

LOCATION.—Lat. 37°35'47", long. 96°55'24", in sec. 19, T.28 S., R.5 E., Butler County, hydrologic unit 11030018, at county highway bridge 4 mi east of Gordon.

DRAINAGE AREA.—253 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 07147408, Little Walnut River southeast of Gordon.

Description of ungaged site on Little Walnut River southeast of Gordon, Kansas, site 07147408.

LOCATION.—Lat. 37°33'45", long. 96°58'20", in NE1/4NE1/4NE1/4 sec. 3, T.29 S., R.4 E., Butler County, hydrologic unit 11030018, downstream from bridge over Little Walnut River.

DRAINAGE AREA.—267 mi^2.

Description of low-flow, partial-record site on Timber Creek near Wilmot, Kansas, site 07147600.

LOCATION.—Lat. 37°20'55", long. 96°52'45", sec. 16, T.31 S., R.5 E., Cowley County, hydrologic unit 11030018, at county highway bridge 1.9 mi south of Wilmot.

DRAINAGE AREA.—63 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 07147700, Timber Creek near Winfield.

Description of ungaged site on Timber Creek near Winfield, Kansas, site 07147700.

LOCATION.—Lat. 37°17'18", long. 96°58'26", in NW1/4NE1/4NE1/4 sec. 10, T.32 S., R.4 E., Cowley County, hydrologic unit 11030018, at bridge over Timber Creek.

DRAINAGE AREA.—154 mi^2.

Description of ungaged site on West Creek near Quincy, Kansas, site 07165775.

LOCATION.—Lat. 37°53'43", long. 96°02'42", in NE1/4NW1/4NW1/4 sec. 12, T.25 S., R.12 E., Greenwood County, hydrologic unit 11070101, at bridge over West Creek.

DRAINAGE AREA.—120 mi^2.

Description of ungaged site on West Branch Fall River near Eureka, Kansas, site 07166660.

LOCATION.—Lat. 37°53'14", long. 96°24'58", in SE1/4NE1/4NE1/4 sec. 9, T.25 S., R.9 E., Greenwood County, hydrologic unit 11070102, at bridge over West Branch Fall River.

DRAINAGE AREA.—96.5 mi^2.

Description of low-flow, partial-record site on Fall River near Eureka, Kansas, site 07167000.

LOCATION.—Lat. 37°47'00", long. 96°14'00", sec. 18, T.26 S., R.11 E., Greenwood County, hydrologic unit 11070102, 3 mi southeast of Eureka.

DRAINAGE AREA.—310 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 07167100, Fall River near Climax.

Description of ungaged site on Fall River near Climax, Kansas, site 07167100.

LOCATION.—Lat. 37°45'16", long. 96°11'38", in SE1/4NW1/4SW1/4 sec. 27, T.26 S., R.11 E., Greenwood County, hydrologic unit 11070102, at bridge over Fall River.

DRAINAGE AREA.—327 mi^2.

Description of ungaged site on Chetopa Creek near Neodesha, Kansas, site 07169550.

LOCATION.—Lat. 37°27'19", long. 95°39'01", in SW1/4NW1/4NW1/4 sec. 10, T.30 S., R.16 E., Wilson County, hydrologic unit 11070101, at bridge over Chetopa Creek.

DRAINAGE AREA.—54.4 mi^2.

Description of ungaged site on Onion Creek near Coffeyville, Kansas, site 07170995.

LOCATION.—Lat. 37°01'36", long. 95°39'23", in SE1/4NE1/4SE1/4 sec. 4, T.35 S., R.16 E., Montgomery County, hydrologic unit 11070103, at bridge over Onion Creek.

DRAINAGE AREA.—97.7 mi^2.

Description of ungaged site on Allen Creek near Emporia, Kansas, site 07179740.

LOCATION.—Lat. 38°26'13", long. 96°10'15", in NW1/4SW1/4SW1/4 sec. 35, T.18 S., R.11 E., Lyon County, hydrologic unit 11070201, at U.S. Highway 99 bridge over Allen Creek.

DRAINAGE AREA.—117 mi^2.

Description of low-flow, partial-record site on South Cottonwood River near Canada, Kansas, site 07179800.

LOCATION.—Lat. 38°20'00", long. 97°06'49", sec. 8, T.20 S., R.3 E., Marion County, hydrologic unit 11070202, at county highway bridge, 1.4 mi south of Canada.

DRAINAGE AREA.—110 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 07179850, South Cottonwood River near Marion.

Description of ungaged site on South Cottonwood River near Marion, Kansas, site 07179850.

LOCATION.—Lat. 38°20'53", long. 97°05'04", in NW1/4NW1/4NE1/4 sec. 3, T.20 S., R.3 E., Marion County, hydrologic unit 11070202, at bridge over the South Cottonwood River.

DRAINAGE AREA.—113 mi^2.

Description of low-flow, partial-record site on Diamond Creek near Elmdale, Kansas, site 07181800.

LOCATION.—Lat. 38°26'09", long. 96°39'51", sec. 4, T.19 S., R.7 E., Marion County, hydrologic unit 11070203, at county highway, 4 mi northwest of Elmdale.

DRAINAGE AREA.—134 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 07181820, Diamond Creek on Highway 50 near Elmdale.

Description of ungaged site on Diamond Creek on Highway 50 near Elmdale, Kansas, site 07181820.

LOCATION.—Lat. 38°23'39", long. 96°37'34", in NW1/4NW1/4NE1/4 sec. 3, T.20 S., R.7 E., Marion County, hydrologic unit 11070203, at bridge over Diamond Creek.

DRAINAGE AREA.—152 mi^2.

Description of low-flow, partial-record site on Big Creek near Le Roy, Kansas, site 07182700.

LOCATION.—Lat. 38°06'00", long. 95°43'00", sec. 36, T.22 S., R.15 E., Coffey County, hydrologic unit 11070204, at bridge northwest of Le Roy.

DRAINAGE AREA.—128 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 07182710, Big Creek 2 miles west of Le Roy.

Description of ungaged site on Big Creek 2 miles west of Leroy, Kansas, site 07182710.

LOCATION.—Lat. 38°04'58", long. 95°40'59", in SE1/4SW1/4SW1/4 sec. 32, T.22 S., R.16 E., Coffey County, hydrologic unit 11070204, at bridge over Big Creek.

DRAINAGE AREA.—131 mi^2.

Description of low-flow, partial-record site on Owl Creek near Piqua, Kansas, site 07183100.

LOCATION.—Lat. 37°51'00", long. 95°34'30", sec. 29, T.25 S., R.17 E., Allen County, hydrologic unit 11070204, at county highway bridge, 5.4 mi southwest of Piqua.

DRAINAGE AREA.—177 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 07183150, Owl Creek near Humboldt.

Description of ungaged site on Owl Creek near Humboldt, Kansas, site 07183150.

LOCATION.—Lat. 37°48'14", long. 95°28'16", in NW1/4NW1/4NW1/4 sec. 7, T.26 S., R.18 E., Allen County, hydrologic unit 11070204, at bridge over Owl Creek.

DRAINAGE AREA.—203 mi^2.

Description of low-flow, partial-record site on Cherry Creek near Hallowell, Kansas, site 07184300.

LOCATION.—Lat. 37°09'46", long. 94°59'43", sec. 21, T.33 S., R.22 E., Cherokee County, hydrologic unit 11070205, at county road bridge, 0.6 mi south of Hallowell.

DRAINAGE AREA.—90 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 07184340, Cherry Creek near Chetopa.

Description of ungaged site on Cherry Creek near Chetopa, Kansas, site 07184340.

LOCATION.—Lat. 37°05'30", long. 95°03'00", in SE1/4SE1/4SE1/4 sec. 12, T.34 S., R.21 E., Cherokee County, hydrologic unit 11070205, at bridge over Cherry Creek.

DRAINAGE AREA.—113 mi^2.

Description of low-flow, partial-record site on Labette Creek near Oswego, Kansas, site 07184500.

LOCATION.—Lat. 37°07'40", long. 95°09'10", sec. 11, T.33 S., R.20 E., Labette County, hydrologic unit 11070205, at State Highway 96 bridge, 5 mi north of Oswego.

DRAINAGE AREA.—211 mi^2.

REMARKS.--Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 07184580, Labette Creek near Chetopa.

Description of ungaged site on Labette Creek near Chetopa, Kansas, site 07184580.

LOCATION.—Lat. 37°05'46", long. 95°08'18", in SW1/4NW1/4SW1/4 sec. 8, T.34 S., R.21 E., Labette County, hydrologic unit 11070205, at bridge over Labette Creek.

DRAINAGE AREA.—353 mi^2.

Appendix C. Base-flow measurements made during 1999–2000 at 32 ungaged sites in the Missouri, Smoky Hill-Saline, Solomon, Marais des Cygnes, Walnut, Verdigris, and Neosho River Basins in Kansas. The percentage duration value in the last column is the duration percentage of the concurrently measured streamflow at the index station and is used as the duration percentage for the streamflow that was measured at the ungaged site.

[ft^3/s, cubic feet per second; $(ft^3/s)/mi^2$, cubic feet per second per square mile]

Ungaged site number and name (fig. 1)	Date (month/day/year)	Streamflow (ft^3/s)	Streamflow [$(ft^3/s)/mi^2$]	Percentage duration
06814050	7/21/1999	86.9	0.156	42
South Fork Big Nemaha River near Bern	3/15/2000	15.0	.054	67
	5/17/2000	13.5	.027	86
	7/26/2000	1.73	.024	82
	9/1/2000		.0031	97
06815295	9/16/1999	9.26	.092	78
Walnut Creek near Padonia	3/15/2000	8.06	.080	70
	5/8/2000	6.44	.064	75
	5/17/2000	3.42	.034	86
	6/6/2000	1.35	.013	94.5
	7/27/2000	3.92	.039	78
06815900	9/16/1999	31.0	.13	78
Wolf Creek at Sparks	3/15/2000	31.0	.13	70
	5/8/2000	23.9	.10	75
	6/6/2000	11.3	.047	94.5
06859500	4/13/2000	.85	.00059	29
Ladder Creek below Chalk Creek near Scott City				
06860900	6/20/00	.02	.000032	44
Hackberry Creek near Trego Center				
06868720	4/10/2000	13.1	.078	27
Spillman Creek near Lincoln	6/26/2000	4.40	.026	52
	7/13/2000	1.12	.067	76
	8/10/2000	.49	.0029	87
06869000	4/10/2000	10.7	.16	27
Elkhorn Creek near Lincoln	7/13/2000	1.17	.017	76
	8/10/2000	.31	.0046	87
06869950	5/24/2000	23.1	.088	40
Mulberry Creek near Salina	8/1/2000	4.18	.016	80
	8/22/2000	1.02	.0039	90
	9/15/2000	.34	.0013	95.5

Appendix C. Base-flow measurements made during 1999–2000 at 32 ungaged sites in the Missouri, Smoky Hill-Saline, Solomon, Marais des Cygnes, Walnut, Verdigris, and Neosho River Basins in Kansas—Continued

Ungaged site number and name (fig. 1)	Date (month/day/year)	Streamflow (ft^3/s)	Streamflow [$(ft^3/s)/mi^2$]	Percentage duration
06872430	3/29/2000	12.3	0.069	30
Beaver Creek near Gaylord	5/23/2000	6.88	.039	48
	6/7/2000	4.29	.024	73
	7/21/2000	.40	.0022	94.5
06872690	3/29/2000	6.59	.035	30
Oak Creek northwest of Cawker City	5/23/2000	5.10	.027	48
	6/7/2000	.24	.0013	73
	7/21/2000	.05	.00027	94.5
06874170	4/10/00	1.08	.012	27
Twin Creek near Corinth				
06875820	2/15/2000	1.39	.0066	30
Limestone Creek at Glen Elder	3/29/2000	2.93	.014	30
	5/23/2000	.85	.0040	48
	6/7/2000	.16	.00076	73
	7/21/2000	.06	.00028	94.5
06876410	4/10/2000	9.21	.063	27
Pipe Creek near Minneapolis	7/13/2000	1.30	.0089	76
	8/11/2000	1.23	.0084	90
06878600	8/19/1999	56.6	.21	30
Lyon Creek near Wreford	5/12/2000	58.0	.22	39
	7/26/2000	19.1	.072	87
	8/22/2000	15.0	.056	88
	9/14/2000	8.23	.031	94.5
06911700	7/21/1999	.85	.025	57
Hundred and Ten Mile Creek near Scranton	9/13/1999	.96	.028	48
	11/3/1999	.58	.017	74
	1/6/2000	2.66	.078	47
	5/25/2000	.47	.014	67
	7/14/2000	.02	.00059	82
06913650	7/21/1999	3.44	.043	60
Tauy Creek near Ottawa	1/12/2000	4.27	.054	46
	5/25/2000	2.20	.028	75
	6/9/2000	.72	.0091	75
	7/7/2000	1.13	.014	80
	7/26/2000	.16	.0020	95.5

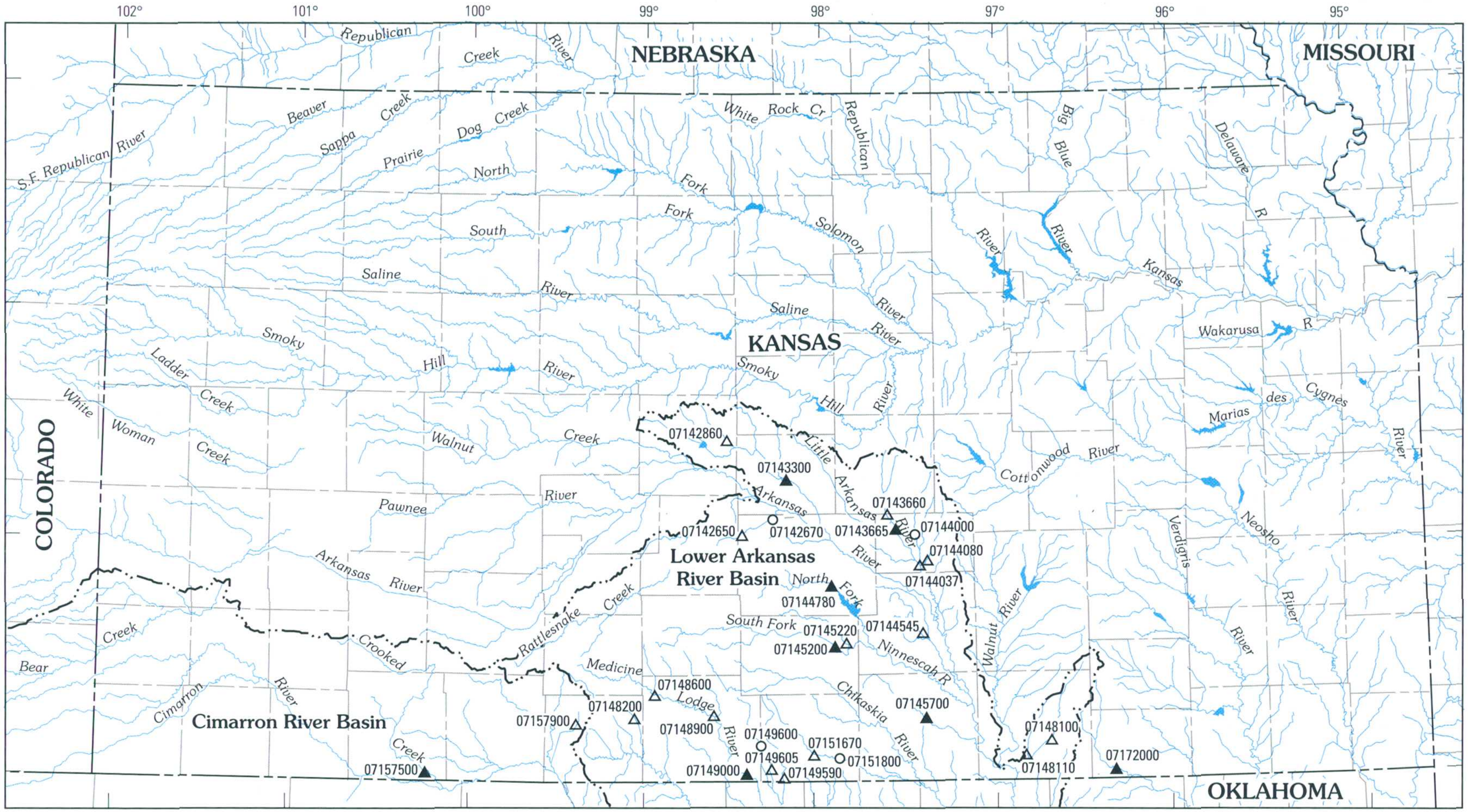
Appendix C. Base-flow measurements made during 1999–2000 at 32 ungaged sites in the Missouri, Smoky Hill-Saline, Solomon, Marais des Cygnes, Walnut, Verdigris, and Neosho River Basins in Kansas—Continued

Ungaged site number and name (fig. 1)	Date (month/day/year)	Streamflow (ft^3/s)	Streamflow [(ft^3/s)/mi^2]	Percentage duration
06915900	7/15/1999	6.37	0.10	50
Middle Creek near La Cygne	11/8/1999	1.53	.024	84
	12/29/1999	9.21	.15	52
	1/27/2000	3.41	.054	71
	4/13/2000	7.32	.12	54
	5/22/2000	1.36	.022	77
06917550	8/12/1999	7.28	.017	76
Marmaton River near Kansas-Missouri State line	9/21/1999	25.1	.060	62
	11/10/1999	1.25	.0030	94.5
	12/27/1999	25.4	.060	63
	4/13/2000	69.7	.165	50
	6/8/2000	4.84	.011	85
07147408	8/17/1999	21.2	.079	50
Little Walnut River southeast of Gordon	6/1/2000	18.3	.068	45
	8/22/2000	6.73	.025	80
07147700	8/17/1999	14.8	.096	64
Timber Creek near Winfield	2/9/2000	15.4	.10	59
	7/13/2000	22.7	.15	54
	8/24/2000	2.42	.016	84
07165775	8/17/1999	.50	.0041	66
West Creek near Quincy	5/23/2000	4.08	.033	59
	7/10/2000	4.00	.033	42
	8/14/2000	.41	.0034	69
07166660	5/23/2000	5.63	.058	59
West Branch Fall River near Eureka	7/10/2000	5.63	.058	42
	8/14/2000	.72	.0075	69
07167100	8/17/1999	18.4	.059	66
Fall River near Climax	5/23/2000	22.5	.072	59
	7/10/2000	42.0	.135	42
	8/14/2000	7.98	.026	69
07169550	4/14/2000	3.46	.064	51
Chetopa Creek near Neodesha	6/07/2000	.27	.0050	82
	7/12/2000	1.24	.023	74
	8/1/2000	.24	.0044	68
	8/14/2000	.03	.00055	88

Appendix C. Base-flow measurements made during 1999–2000 at 32 ungaged sites in the Missouri, Smoky Hill-Saline, Solomon, Marais des Cygnes, Walnut, Verdigris, and Neosho River Basins in Kansas—Continued

Ungaged site number and name (fig. 1)	Date (month/day/year)	Streamflow (ft^3/s)	Streamflow [$(ft^3/s)/mi^2$]	Percentage duration
07170995	8/16/1999	1.10	0.011	65
Onion Creek near Coffeyville	1/26/2000	1.78	.018	57
	4/13/2000	19.8	.20	32
	6/1/2000	9.28	.095	64
	7/14/2000	2.12	.022	52
	8/1/2000	2.58	.026	61
	8/23/2000	.26	.0027	85
07179740	4/21/2000	7.41	.063	46
Allen Creek near Emporia	5/10/2000	6.77	.058	54
	5/24/2000	2.45	.021	66
	7/7/2000	1.31	.011	71
	7/25/2000	.36	.0031	89.5
07179850	8/18/1999	5.95	.053	70
South Cottonwood River near Marion	5/22/2000	12.9	.11	51
	6/22/2000	6.77	.060	64
	7/6/2000	4.73	.042	70
	8/22/2000	1.05	.0093	93.5
07181820	8/19/1999	9.52	.063	71
Diamond Creek on Highway 50 near Elmdale	5/22/2000	15.2	.10	51
	7/6/2000	13.5	.089	70
	8/22/2000	2.58	.017	93.5
07182710	4/14/2000	6.85	.052	57
Big Creek 2 miles west of Le Roy	5/22/2000	.90	.0069	77
	7/6/2000	1.75	.013	70
	7/12/2000	.46	.0035	80
	7/25/2000	5.73	.044	88
	8/14/2000	.16	.0012	93
07183150	4/14/2000	10.2	.05	51
Owl Creek near Humboldt	6/7/2000	1.56	.0077	83
	7/13/2000	2.39	.012	75
	8/1/2000	5.36	.026	68
	8/14/2000	.84	.0041	88
07184340	8/13/1999	4.84	.043	83
Cherry Creek near Chetopa	4/14/2000	9.24	.082	60
	7/31/2000	16.4	.145	61
	8/22/2000	3.14	.028	90.5
07184580	8/13/1999	4.14	.012	83
Labette Creek near Chetopa	4/14/2000	22.3	.063	60
	7/31/2000	12.2	.034	61
	8/22/2000	1.56	.0044	90.5

Appendix D. Location of selected ungaged sites, index stations, and historic base-flow measurements sites in the Cimarron and lower Arkansas River Basins in Kansas and estimated flow-duration curves and tables for 16 ungaged sites in the Cimarron and lower Arkansas River Basins in Kansas from a previous study (Studley, 2000).



Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°

Basin delineation for lower Arkansas River Basin from Kansas Department of Health and Environment, 1999c

0 50 100 MILES
0 50 100 KILOMETERS

EXPLANATION

—·—·— Boundary of river basin

07148900 △ Ungaged site and number

07157500 ▲ Index station and number

07149600 ○ Historic base-flow-measurement site and number

07144200 □ Streamflow-gaging station and number used to test Furness method for estimating flow-duration curves

Figure 47. Location of selected ungaged sites, index stations, and historic base-flow measurements sites in the Cimarron and lower Arkansas River Basins in Kansas from a previous study (Studley, 2000).

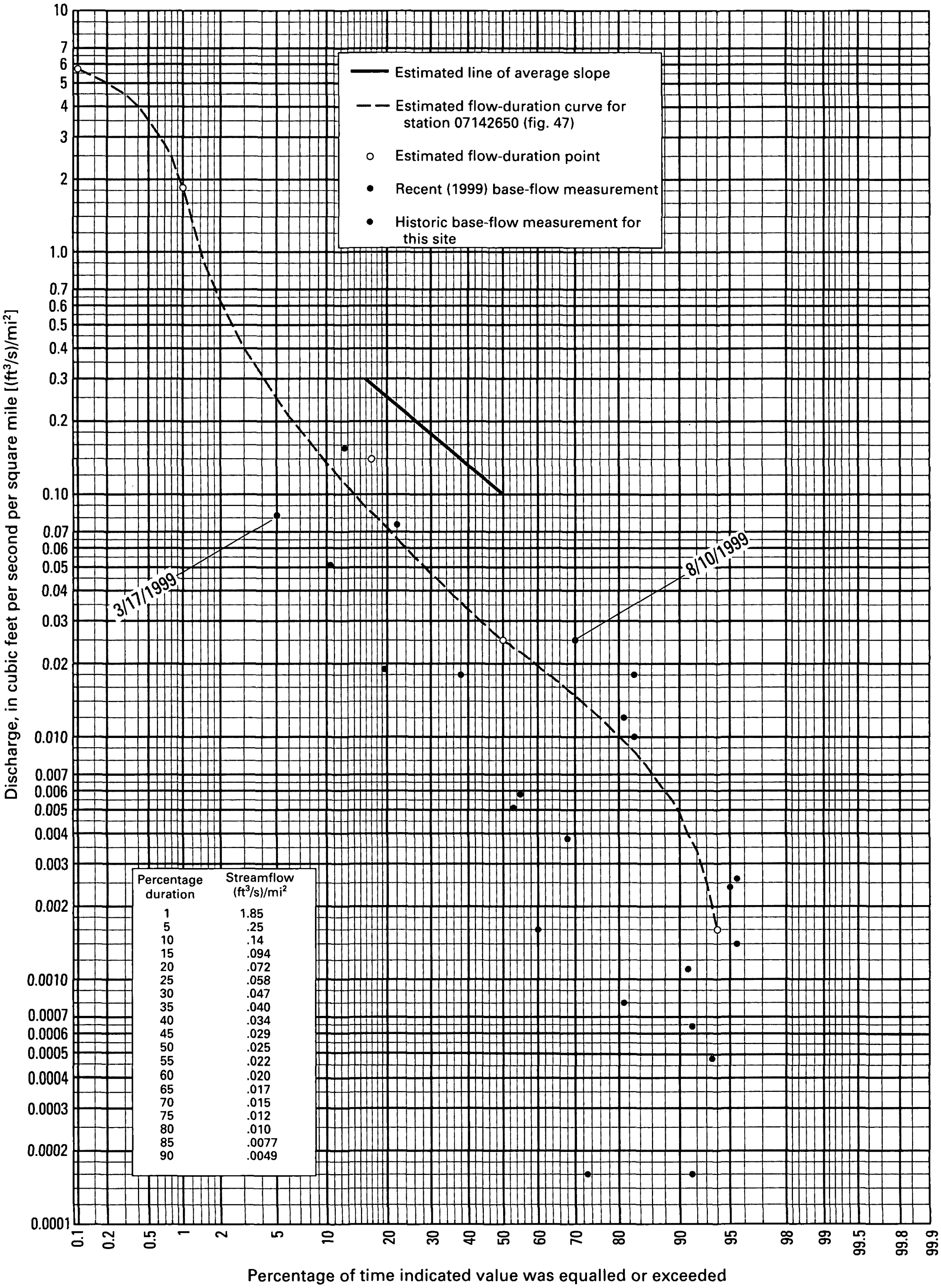


Figure 48. Estimated flow-duration curve for 1968–98 for site 07142650, Peace Creek near Sylvia. Location of site shown in figure 47.

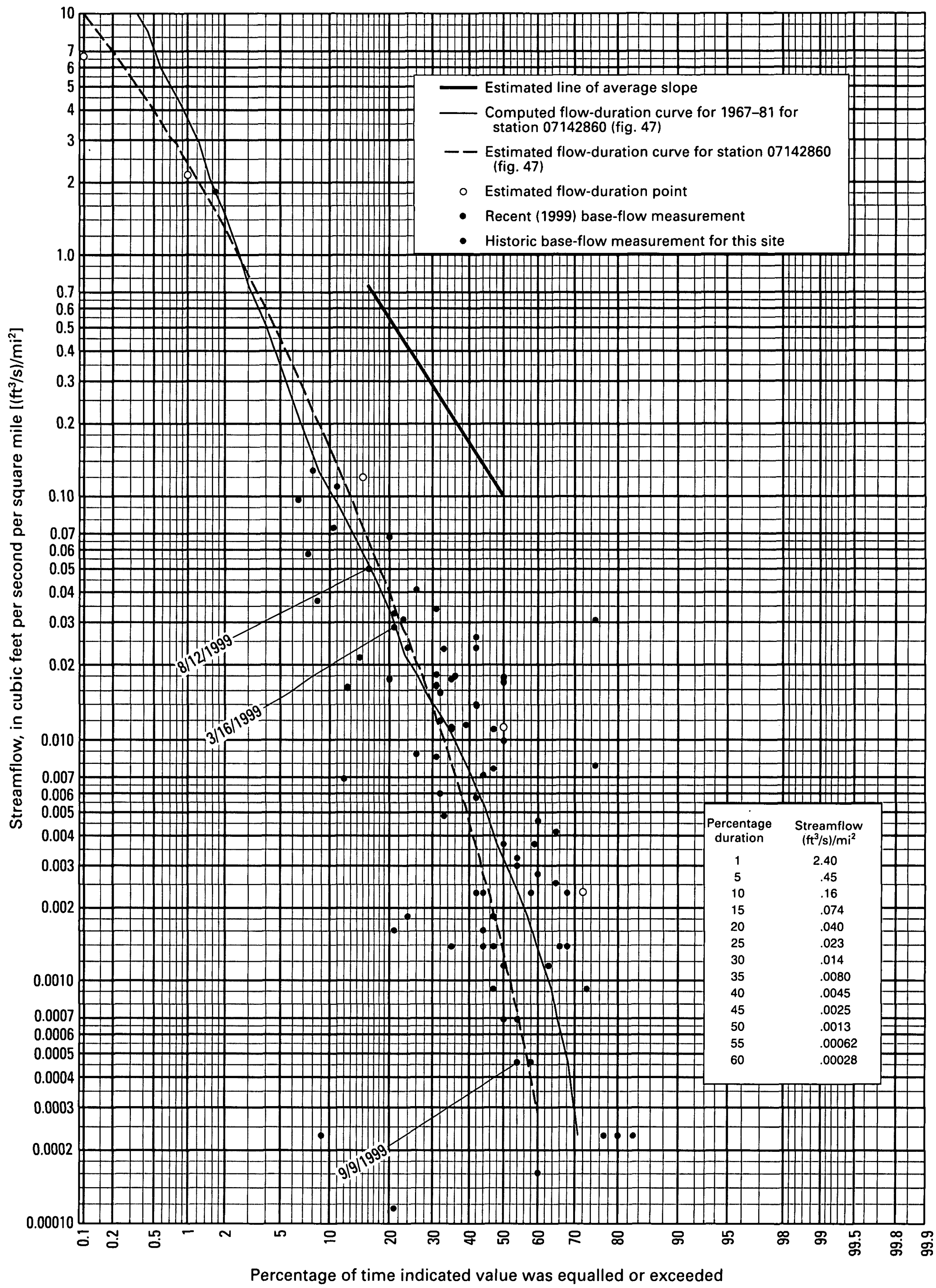
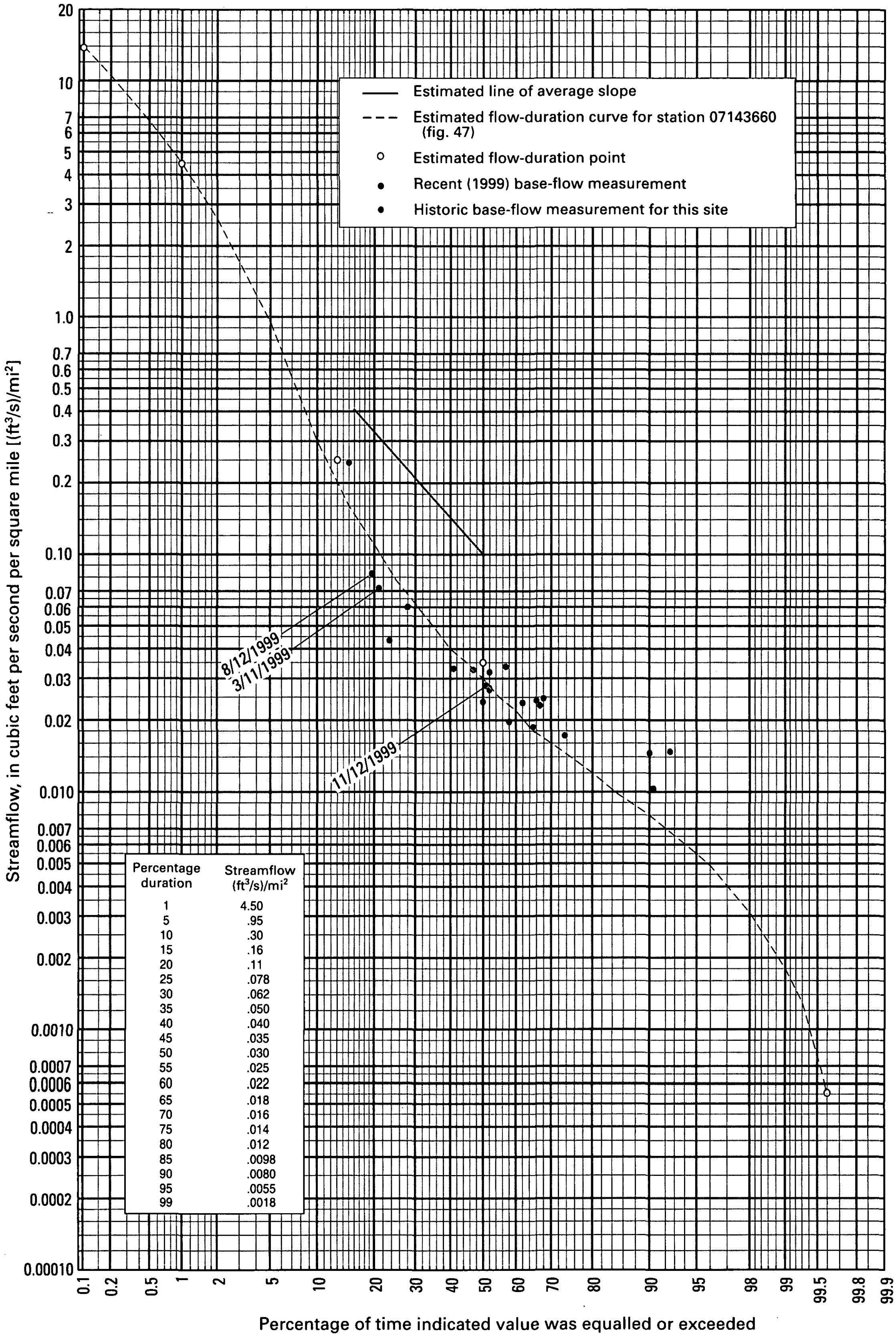
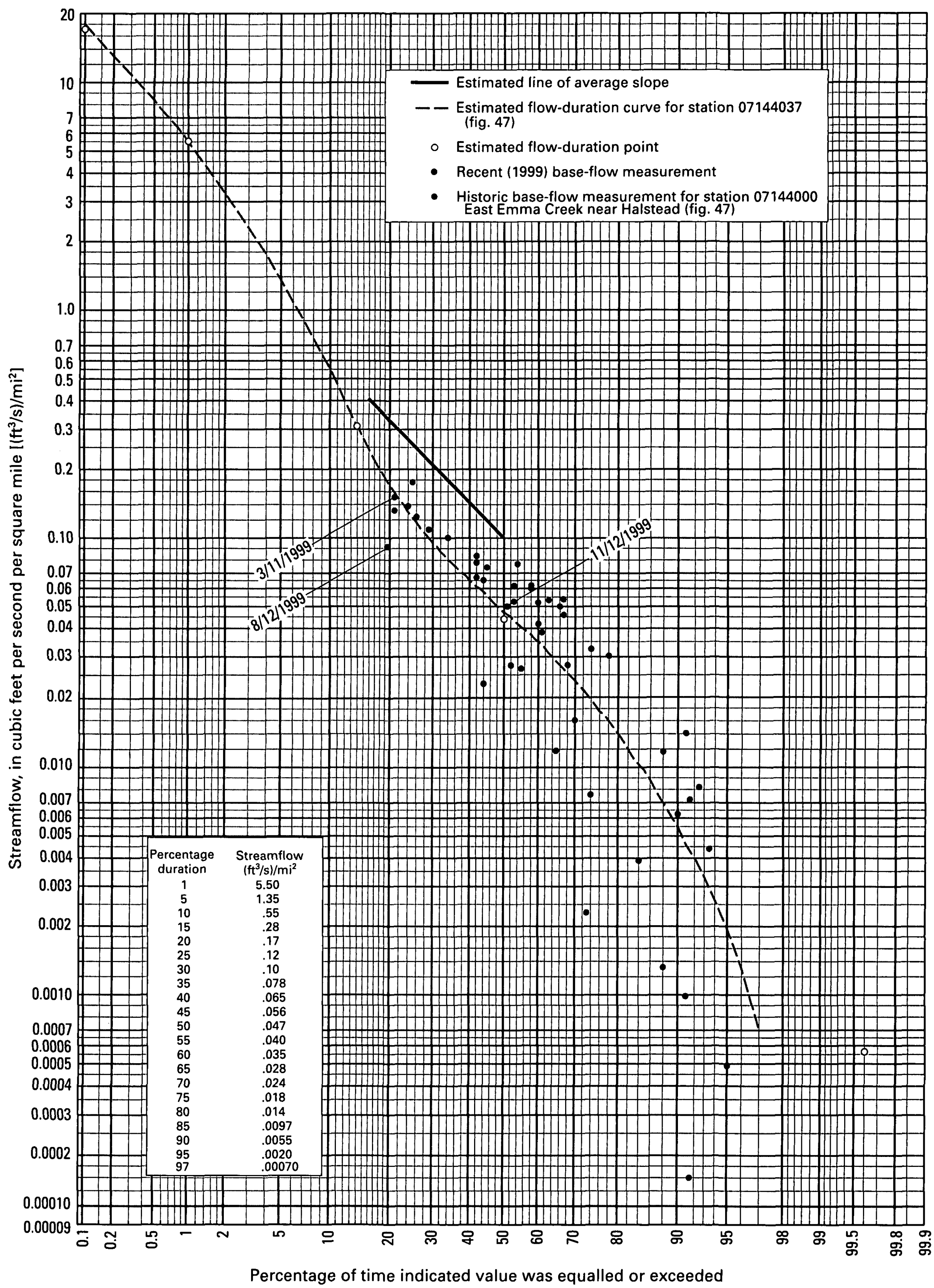


Figure 49. Estimated flow-duration curve for 1968–98 for site 07142860, Cow Creek near Claflin. Location of site shown in figure 47.



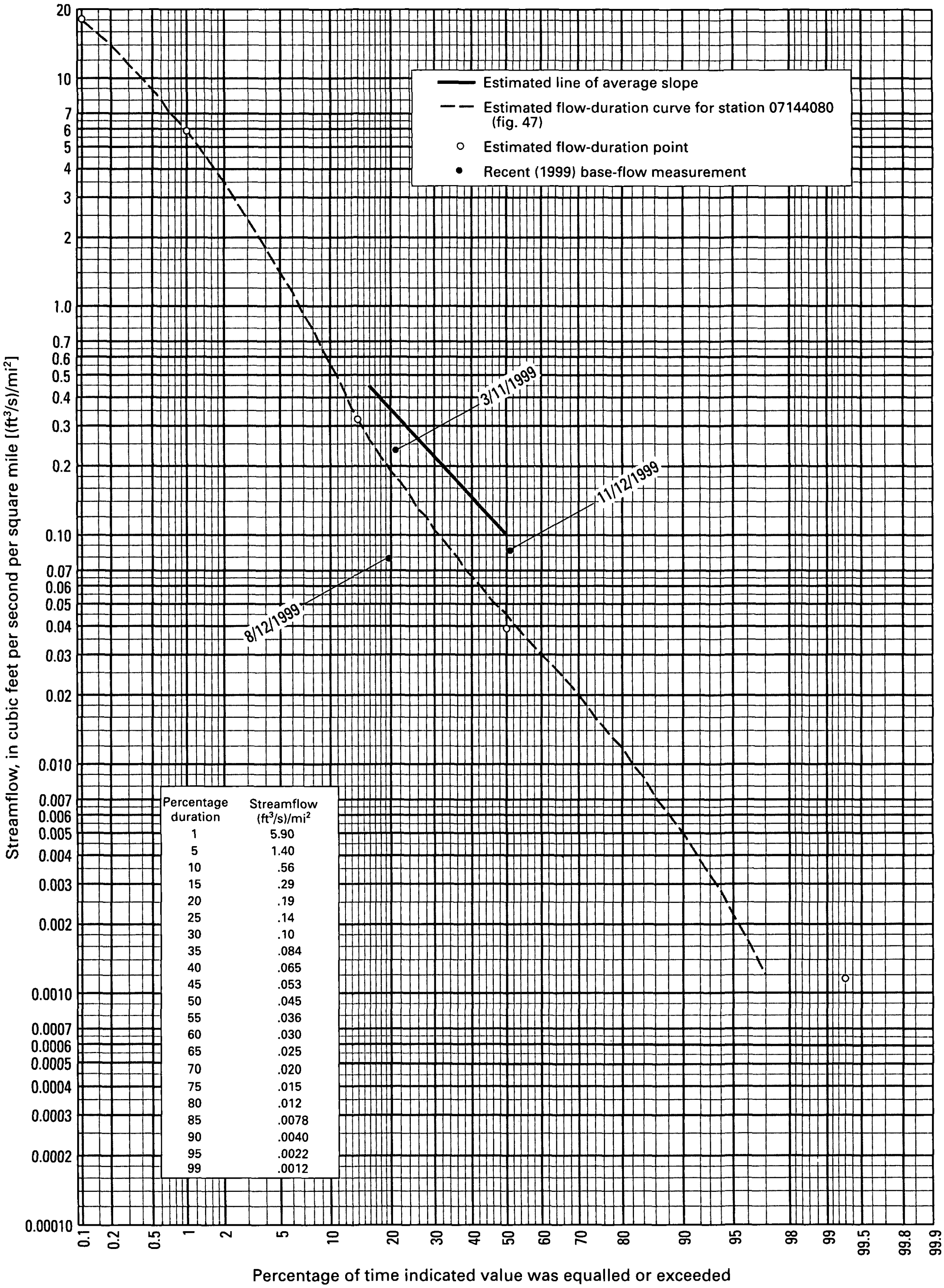
Percentage duration	Streamflow $(ft^3/s)/mi^2$
1	4.50
5	.95
10	.30
15	.16
20	.11
25	.078
30	.062
35	.050
40	.040
45	.035
50	.030
55	.025
60	.022
65	.018
70	.016
75	.014
80	.012
85	.0098
90	.0080
95	.0055
99	.0018

Figure 50. Estimated flow-duration curve for 1968–98 for site 07143660, Turkey Creek near Buhler. Location of site shown in figure 47.



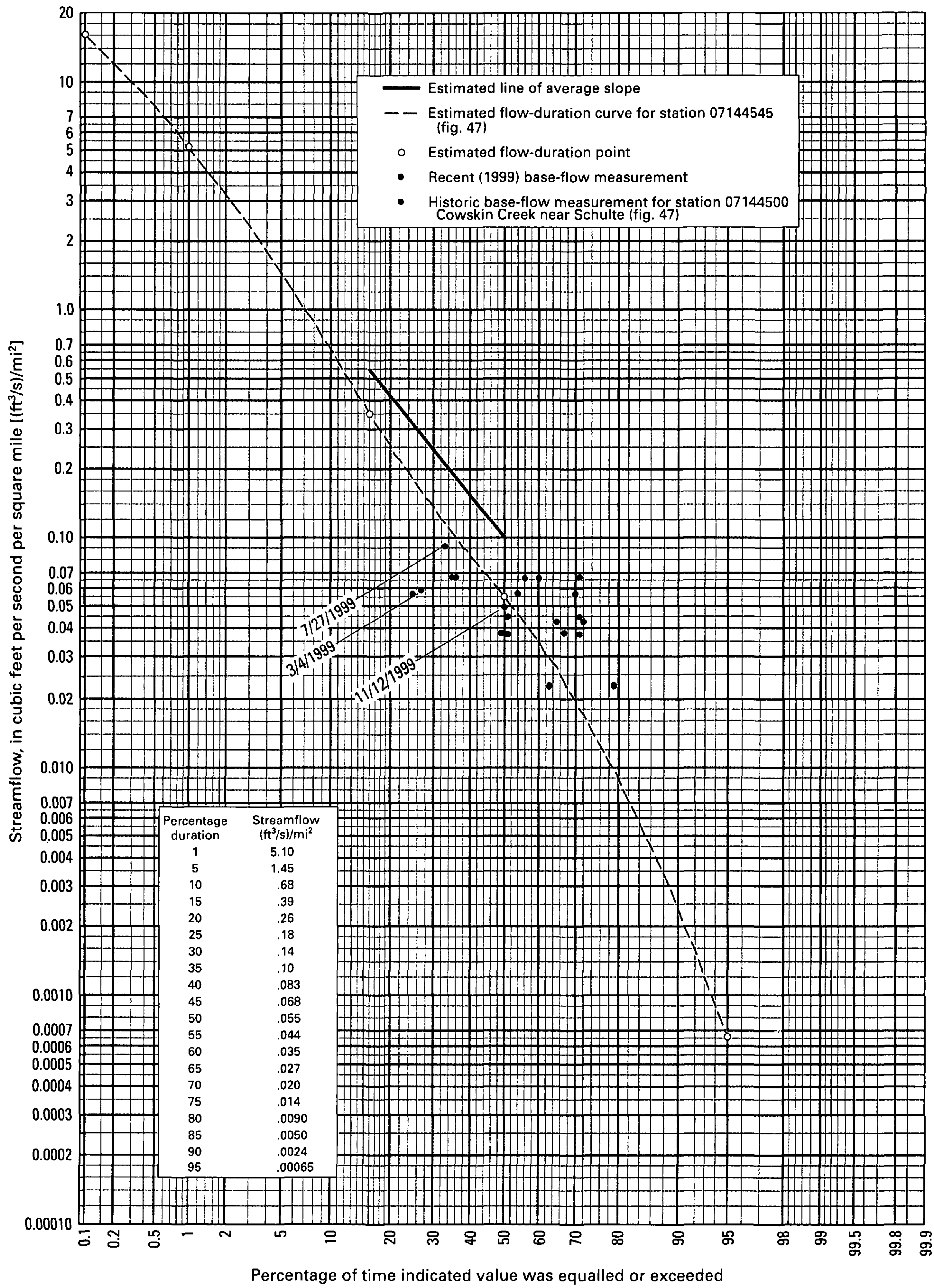
Percentage duration	Streamflow (ft³/s)/mi²
1	5.50
5	1.35
10	.55
15	.28
20	.17
25	.12
30	.10
35	.078
40	.065
45	.056
50	.047
55	.040
60	.035
65	.028
70	.024
75	.018
80	.014
85	.0097
90	.0055
95	.0020
97	.00070

Figure 51. Estimated flow-duration curve for 1968–98 for site 07144037, Emma Creek 3 miles north and 0.75 mile west of Sedgwick. Location of site shown in figure 47.



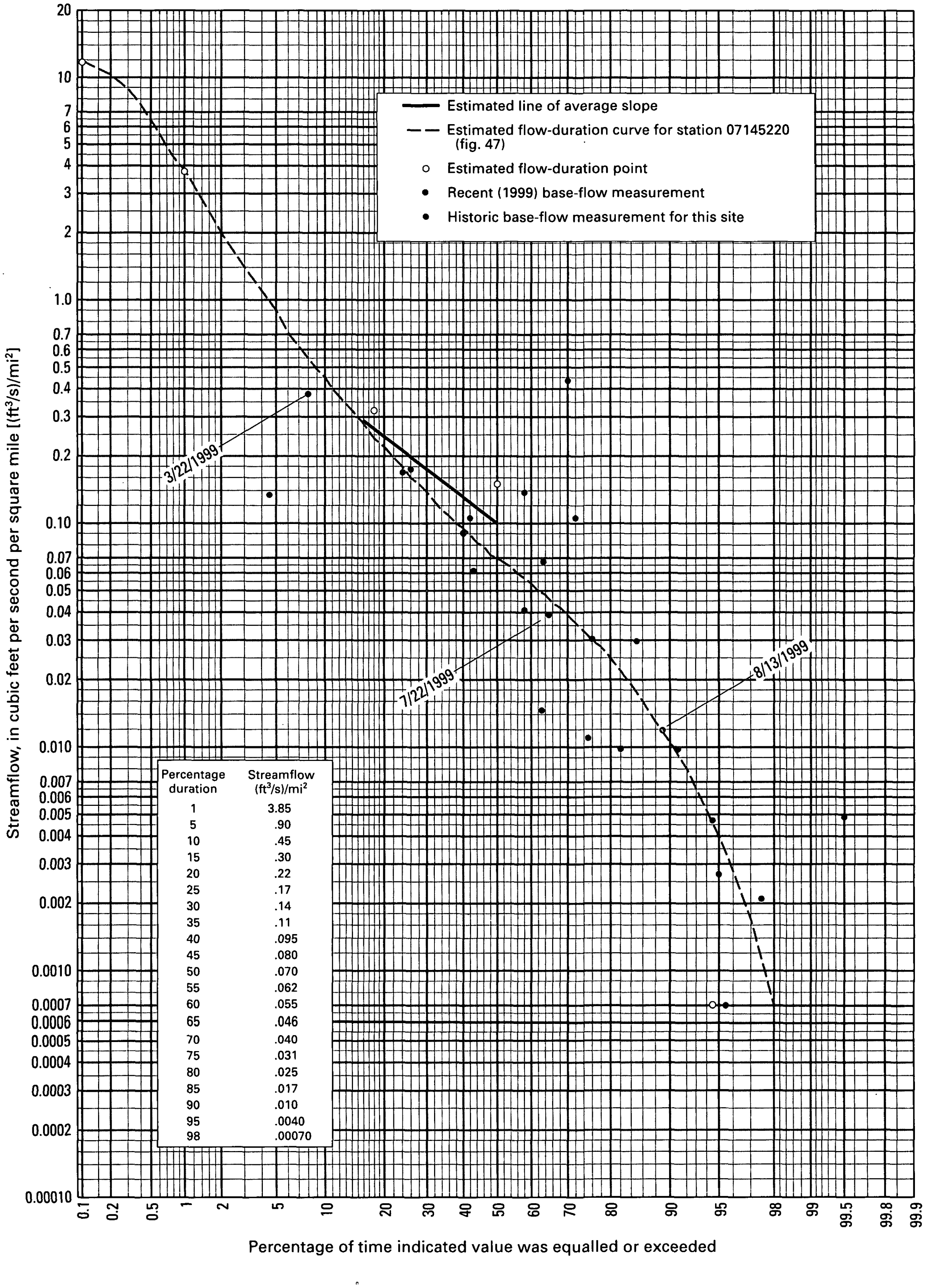
Percentage duration	Streamflow $(ft^3/s)/mi^2$
1	5.90
5	1.40
10	.56
15	.29
20	.19
25	.14
30	.10
35	.084
40	.065
45	.053
50	.045
55	.036
60	.030
65	.025
70	.020
75	.015
80	.012
85	.0078
90	.0040
95	.0022
99	.0012

Figure 52. Estimated flow-duration curve for 1968–98 for site 07144080, Sand Creek 3 miles north and 2 miles east of Sedgwick. Location of site shown in figure 47.



Percentage duration	Streamflow $(ft^3/s)/mi^2$
1	5.10
5	1.45
10	.68
15	.39
20	.26
25	.18
30	.14
35	.10
40	.083
45	.068
50	.055
55	.044
60	.035
65	.027
70	.020
75	.014
80	.0090
85	.0050
90	.0024
95	.00065

Figure 53. Estimated flow-duration curve for 1968–98 for site 07144545, Cowskin Creek near Oatville. Location of site shown in figure 47.



Percentage duration	Streamflow (ft³/s)/mi²
1	3.85
5	.90
10	.45
15	.30
20	.22
25	.17
30	.14
35	.11
40	.095
45	.080
50	.070
55	.062
60	.055
65	.046
70	.040
75	.031
80	.025
85	.017
90	.010
95	.0040
98	.00070

Figure 54. Estimated flow-duration curve for 1968–98 for site 07145220, Smoots Creek near Murdock. Location of site shown in figure 47.

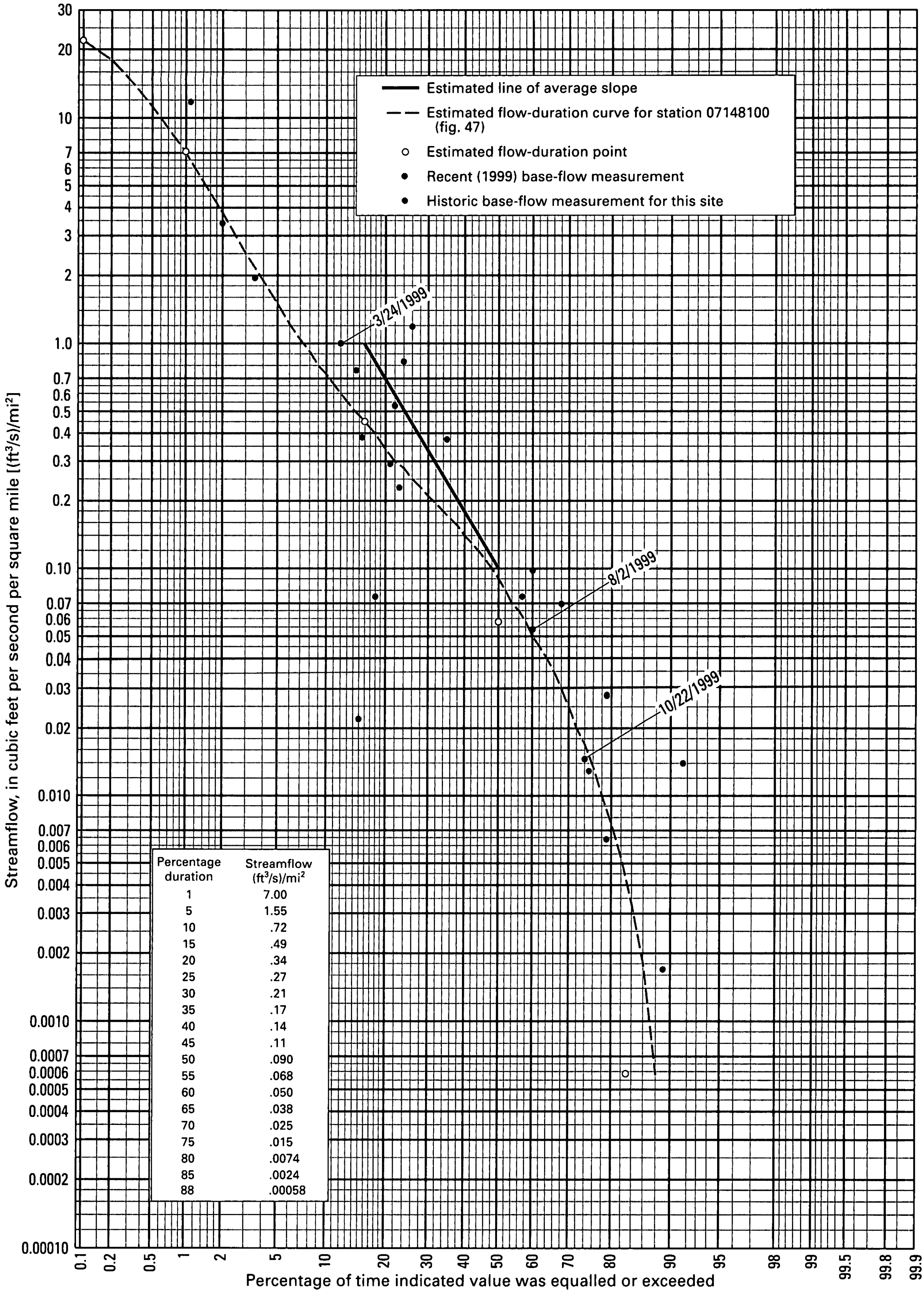
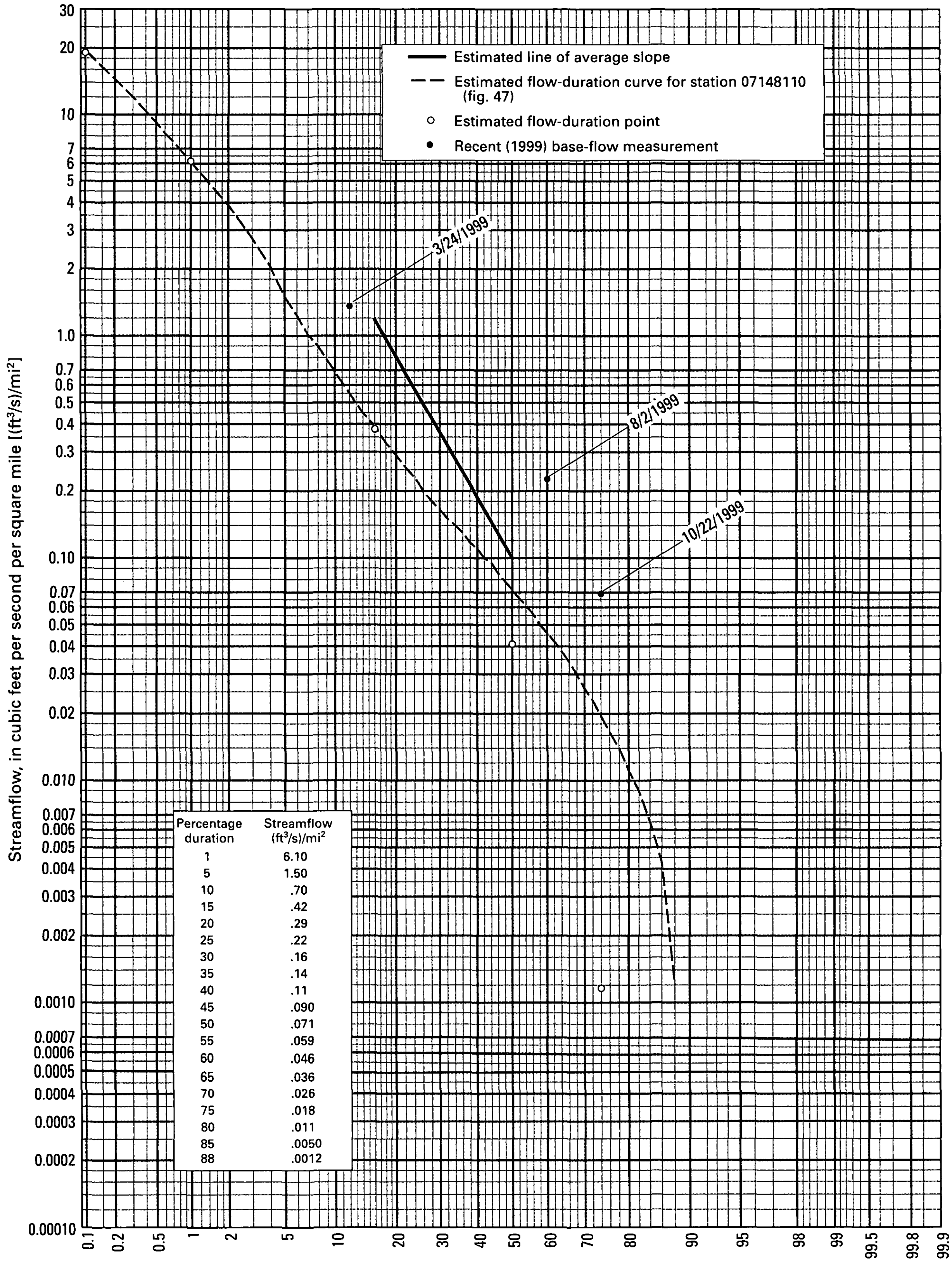
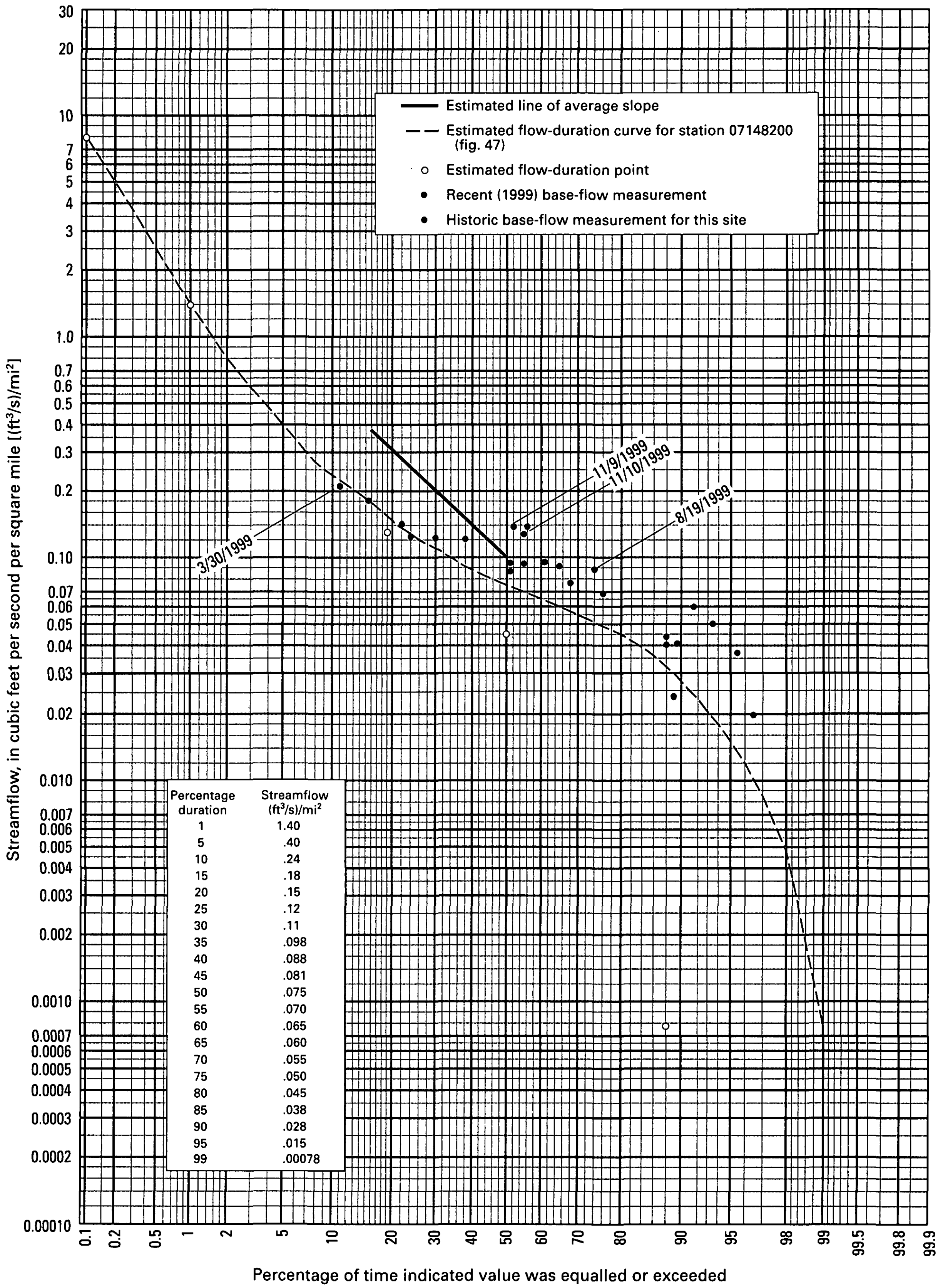


Figure 55. Estimated flow-duration curve for 1968–98 for site 07148100, Grouse Creek near Dexter. Location of site shown in figure 47.



Percentage duration	Streamflow (ft³/s)/mi²
1	6.10
5	1.50
10	.70
15	.42
20	.29
25	.22
30	.16
35	.14
40	.11
45	.090
50	.071
55	.059
60	.046
65	.036
70	.026
75	.018
80	.011
85	.0050
88	.0012

Figure 56. Estimated flow-duration curve for 1968–98 for site 07148110, Silver Creek at Highway 166 east of Arkansas City. Location of site shown in figure 47.



Percentage duration	Streamflow ($(ft^3/s)/mi^2$)
1	1.40
5	.40
10	.24
15	.18
20	.15
25	.12
30	.11
35	.098
40	.088
45	.081
50	.075
55	.070
60	.065
65	.060
70	.055
75	.050
80	.045
85	.038
90	.028
95	.015
99	.00078

Figure 57. Estimated flow-duration curve for 1968–98 for site 07148200, Mule Creek near Wilmore. Location of site shown in figure 47.

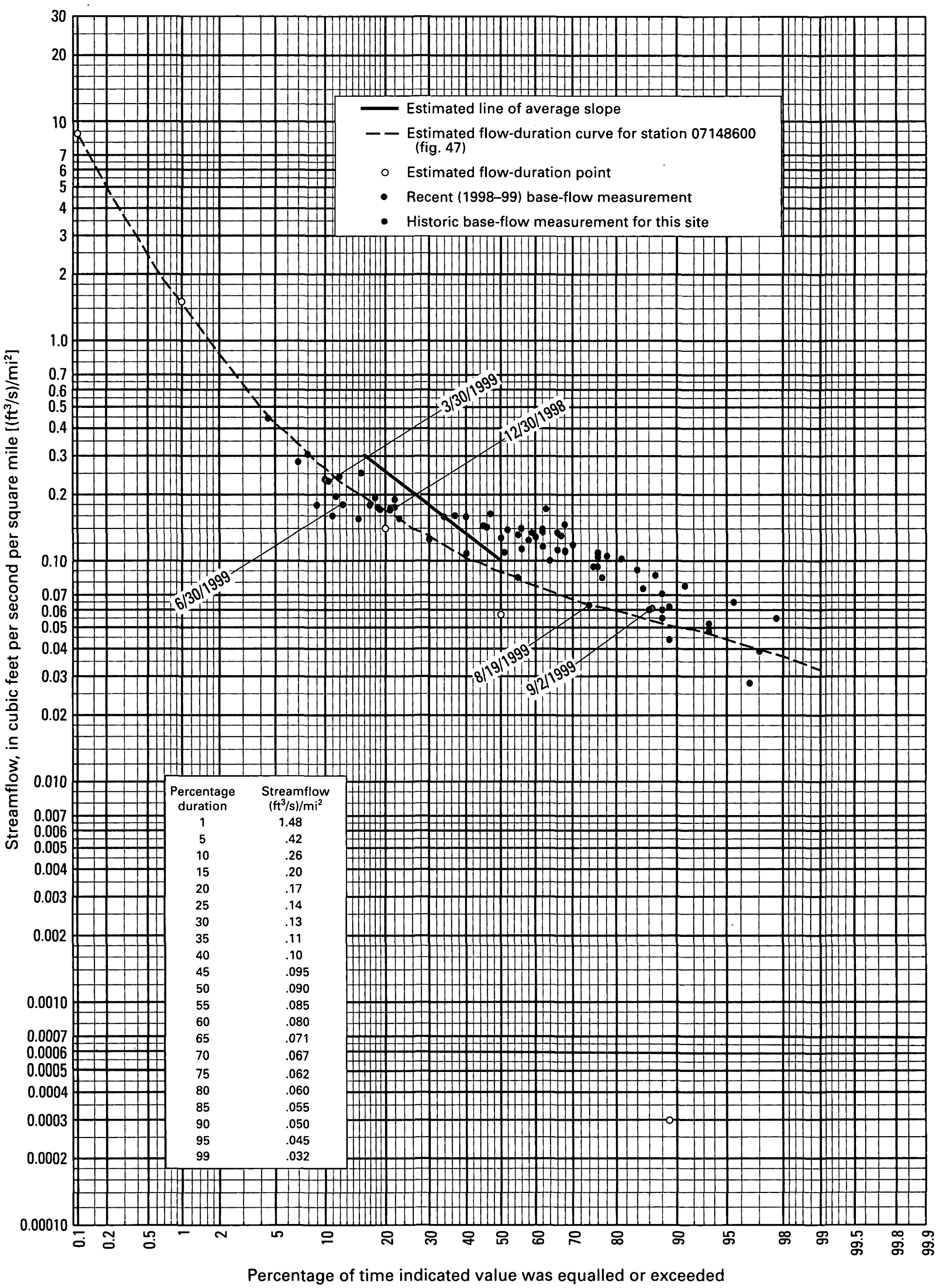
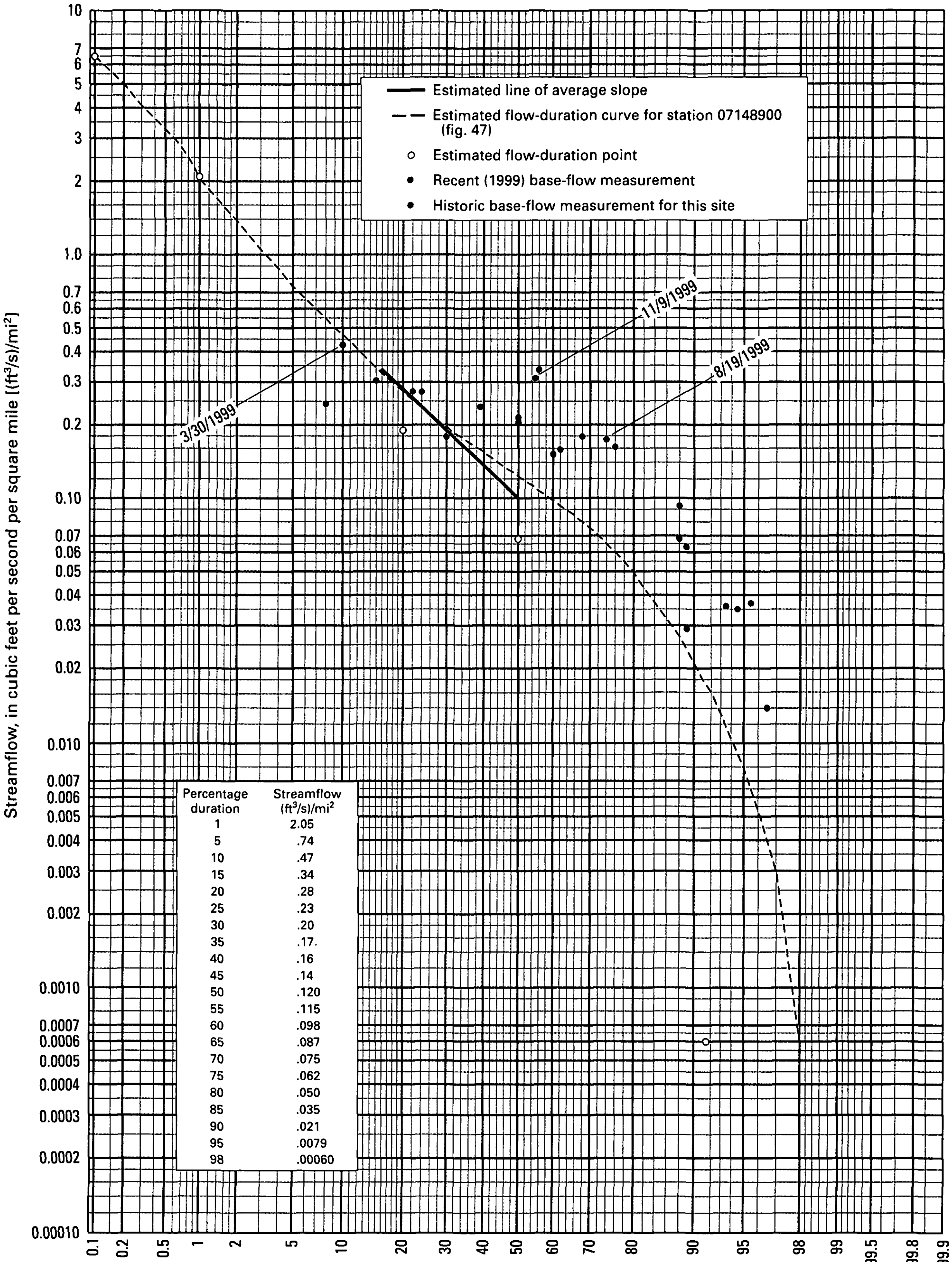
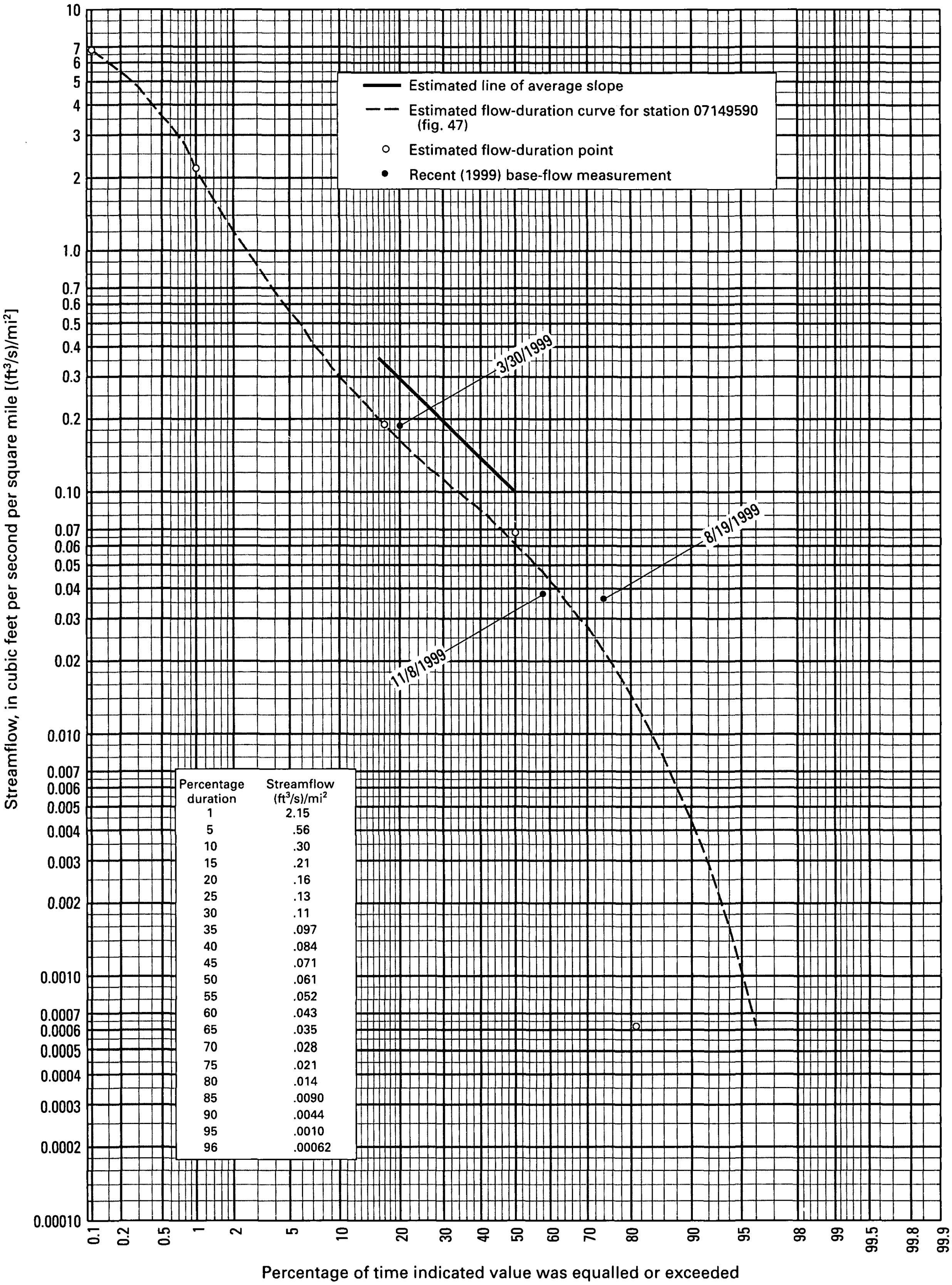


Figure 58. Estimated flow-duration curve for 1968–98 for site 07148600, Medicine Lodge River at Sun City. Location of site shown in figure 47.



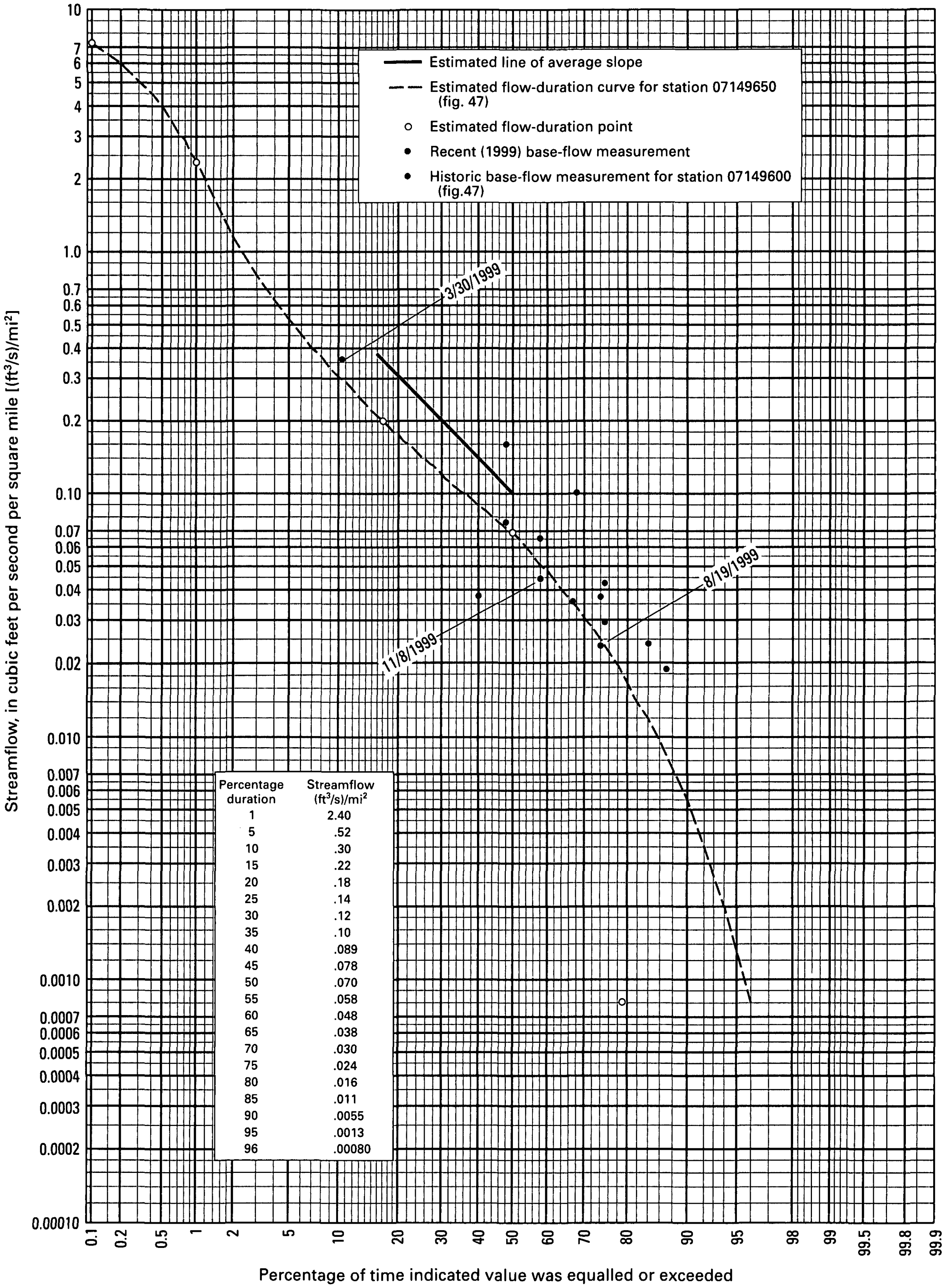
Percentage duration	Streamflow (ft³/s)/mi²
1	2.05
5	.74
10	.47
15	.34
20	.28
25	.23
30	.20
35	.17.
40	.16
45	.14
50	.120
55	.115
60	.098
65	.087
70	.075
75	.062
80	.050
85	.035
90	.021
95	.0079
98	.00060

Figure 59. Estimated flow-duration curve for 1968–98 for site 07148900, Elm Creek at Medicine Lodge. Location of site shown in figure 47.



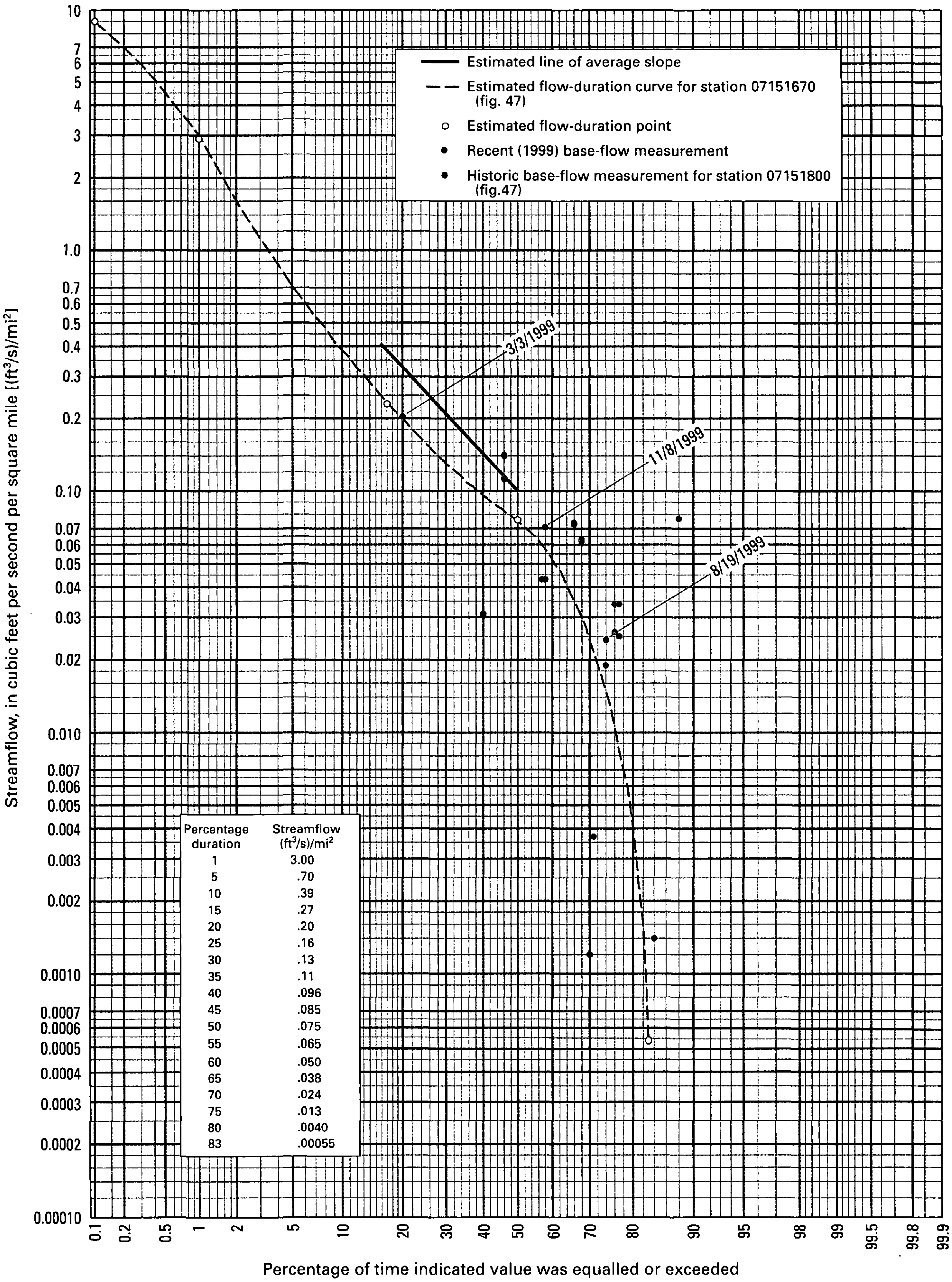
Percentage duration	Streamflow $(ft^3/s)/mi^2$
1	2.15
5	.56
10	.30
15	.21
20	.16
25	.13
30	.11
35	.097
40	.084
45	.071
50	.061
55	.052
60	.043
65	.035
70	.028
75	.021
80	.014
85	.0090
90	.0044
95	.0010
96	.00062

Figure 60. Estimated flow-duration curve for 1968–98 for site 07149590, Sandy Creek near Waldron. Location of site shown in figure 47.



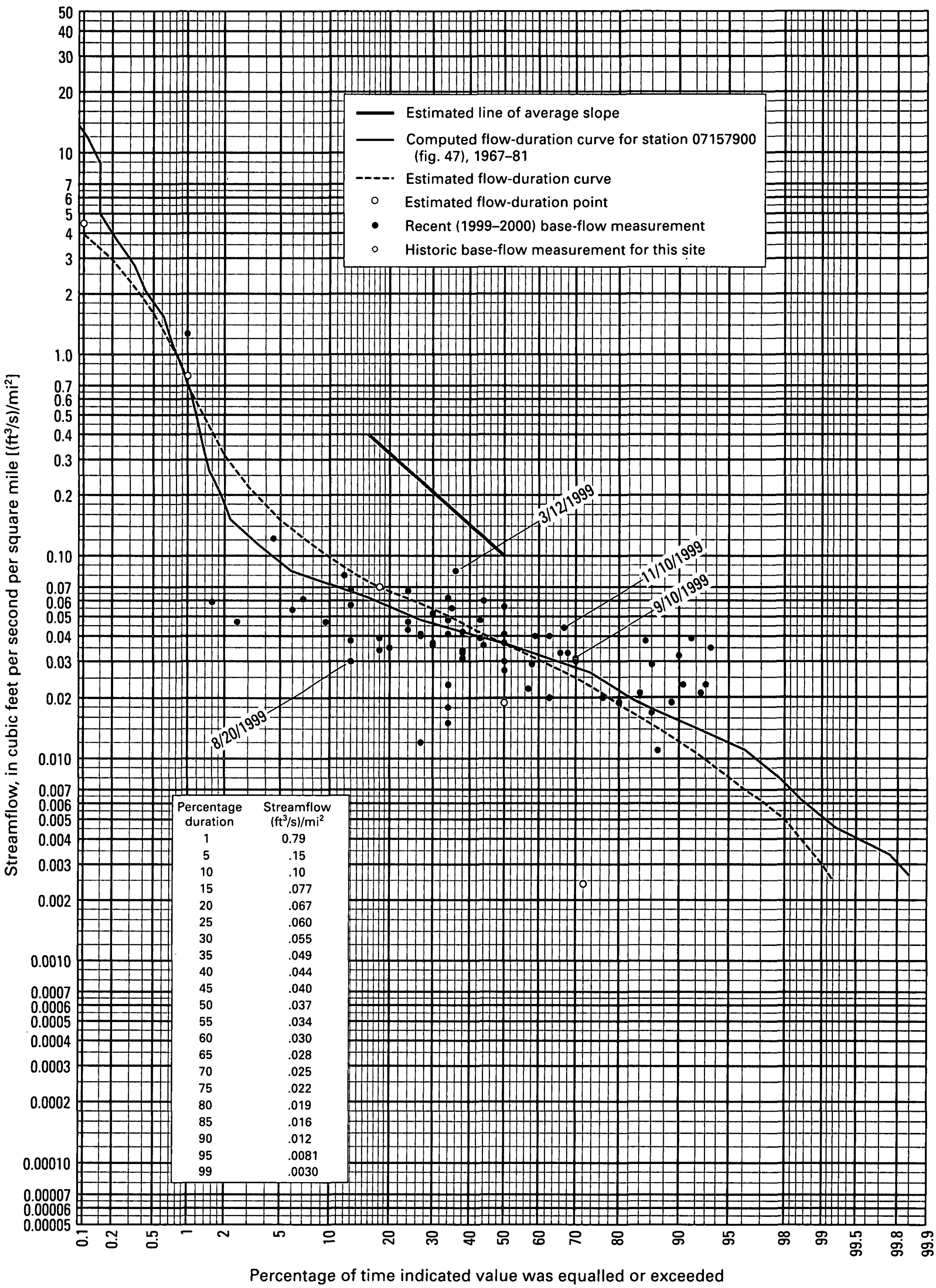
Percentage duration	Streamflow (ft³/s)/mi²
1	2.40
5	.52
10	.30
15	.22
20	.18
25	.14
30	.12
35	.10
40	.089
45	.078
50	.070
55	.058
60	.048
65	.038
70	.030
75	.024
80	.016
85	.011
90	.0055
95	.0013
96	.00080

Figure 61. Estimated flow-duration curve for 1968–98 for site 07149605, Little Sandy Creek near Corwin. Location of site shown in figure 47.



Percentage duration	Streamflow (ft³/s)/mi²
1	3.00
5	.70
10	.39
15	.27
20	.20
25	.16
30	.13
35	.11
40	.096
45	.085
50	.075
55	.065
60	.050
65	.038
70	.024
75	.013
80	.0040
83	.00055

Figure 62. Estimated flow-duration curve for 1968–98 for site 07151670, Bluff Creek south of Anthony. Location of site shown in figure 47.



Percentage duration	Streamflow (ft³/s)/mi²
1	0.79
5	.15
10	.10
15	.077
20	.067
25	.060
30	.055
35	.049
40	.044
45	.040
50	.037
55	.034
60	.030
65	.028
70	.025
75	.022
80	.019
85	.016
90	.012
95	.0081
99	.0030

Figure 63. Estimated flow-duration curve for 1968–98 for site 07157900, Calvary Creek at Coldwater. Location of site shown in figure 47.

Appendix E. Site descriptions for 16 ungaged sites and 4 historic base-flow measurement sites in the Cimarron and lower Arkansas River Basins in Kansas from a previous study (Studley, 2000).

Description of ungaged site on Peace Creek near Sylvia, Kansas, site 07142650.

LOCATION.—Lat. 38° 04'31", long. 98°26'09", in NW1/4NE1/4SW1/4 sec. 8, T.23 S., R.10 W., Reno County, hydrologic unit 11030010, at bridge on Brownlee Road, 8.5 mi northwest of Sylvia, Kansas, and at mile 17.2.

DRAINAGE AREA.—62.4 mi^2.

Description of low-flow, partial-record site on Peace Creek near Sterling, Kansas, site 07142670.

LOCATION.—Lat. 38°08'43", long. 98°15'13", in NW1/4NW1/4NW1/4 sec. 7, T.22 S., R.8 W., Reno County, hydrologic unit 11030010, at bridge on 95th Avenue, 3.5 mi southwest of Sterling, Kansas.

DRAINAGE AREA.—136 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 07142650, Peace Creek near Sylvia.

Description of ungaged site on Cow Creek near Claflin, Kansas, site 07142860.

LOCATION.—Lat. 38° 31'20", long. 98° 35'00", in NE1/4NW1/4 sec. 6, T.18 S., R.11 W., Barton County, hydrologic unit 11030011, at downstream side of State Highway 4 bridge, 2.5 mi west of Claflin, and at mile 97.8.

DRAINAGE AREA.—43.4 mi^2, from U.S. Army Corps of Engineers data.

Description of ungaged site on Turkey Creek near Buhler, Kansas, site 07143660.

LOCATION.—Lat. 38° 08'42", long. 97° 37'31", in NE1/4NW1/4NW1/4 sec. 14, T.22 S., R.3 W., Harvey County, hydrologic unit 11030012, at Dutch Avenue bridge over Turkey Creek.

DRAINAGE AREA.—180 mi^2.

Description of low-flow, partial-record site on East Emma Creek near Halstead, Kansas, site 07144000.

LOCATION.-Lat. 38°01'40", long. 97°25'40", in NE1/4NE1/4NE1/4 sec. 28, T.23 S., R.1 W., Harvey County, hydrologic unit 11030012, at U.S. Highway 50 bridge over East Emma Creek.

DRAINAGE AREA.—58 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 07144037, Emma Creek 3 miles north and 0.75 mile west of Sedgwick.

Description of ungaged site on Emma Creek 3 miles north and 0.75 mile west of Sedgwick, Kansas, site 07144037.

LOCATION.—Lat. 37° 58'14", long. 97° 26'34", in NE1/4NW1/4NW1/4 sec. 16, T.24 S., R.1 W., Harvey County, hydrologic unit 11030012, at 60th Road bridge over Emma Creek and approximately 0.75 mi west of Ridge Road.

DRAINAGE AREA.—177 mi^2.

Description of ungaged site on Sand Creek 3 miles north and 2 miles east of Sedgwick, Kansas, site 07144080.

LOCATION.—Lat. 37° 58'14", long. 97° 23'25", in NE1/4NE1/4NE1/4 sec. 14, T.24 S., R.1 W., Harvey County, hydrologic unit 11030012, at 60th Road bridge over Sand Creek and approximately 2 mi east of Ridge Road.

DRAINAGE AREA.—86.5 mi^2.

Description of ungaged site on Cowskin Creek near Oatville, Kansas, site 07144545.

LOCATION.—Lat. 37° 36'01", long. 97° 24'25", in NW1/4NW1/4NW1/4 sec. 23, T.28 S., R.1 W., Sedgwick County, hydrologic unit 11030013, at West 55th Street bridge over Cowskin Creek and approximately 1.5 mi south of West 39th Street.

DRAINAGE AREA.—152 mi^2.

Description of ungaged site on Smoots Creek near Murdock, Kansas, site 07145220.

LOCATION.—Lat. 37°38'03", long. 97° 53'58", in NW1/4SW1/4SW1/4 sec. 5, T.28 S., R.5 W., Kingman County, hydrologic unit 11030015, at SE 120th Avenue bridge over Smoots Creek and approximately 1.1 mi north of SE 20th Street and at mile 6.6.

DRAINAGE AREA.—142 mi^2.

Description of ungaged site on Grouse Creek near Dexter, Kansas, site 07148100.

LOCATION.—Lat. 37°13'38", long. 96° 42'44", in NW1/4NW1/4 sec. 31, T.32 S., R.7 E., Cowley County, hydrologic unit 11060001, on right bank at downstream side of bridge on county road 0.25 mi east of State Highway 15, 3.2 mi north of Dexter, and 16.5 mi east of Winfield.

DRAINAGE AREA.—170 mi^2 (revised). Furnished by U.S. Army Corps of Engineers, Dallas, Texas.

Description of ungaged site on Silver Creek at Highway 166 east of Arkansas City, Kansas, site 07148110.

LOCATION.—Lat. 37° 04'42", long. 96° 51'33", in SW1/4SW1/4NW1/4 sec. 23, T.34 S., R.5 E., Cowley County, hydrologic unit 11060001, at U.S. Highway 166 bridge over Silver Creek and approximately 10.25 mi east of Arkansas City.

DRAINAGE AREA.—86.1 mi^2.

Description of ungaged site on Mule Creek near Wilmore, Kansas, site 07148200.

LOCATION.—Lat. 37° 16'52", long. 99° 02'38", in NE1/4NW1/4NE1/4 sec. 10, T.32 S., R.16 W., Comanche County, hydrologic unit 11060002, at U.S. Highway 160 bridge over Mule Creek and approximately 15.5 mi east of U.S. Highway 183.

DRAINAGE AREA.—127 mi^2.

Description of ungaged site on Medicine Lodge River at Sun City, Kansas, site 07148600.

LOCATION.—Lat. 37°22'13", long. 98° 54'53", in SE1/4SW1/4SE1/4 sec. 2, T.31 S., R.15 W., Barber County, hydrologic unit 11060003, at bridge on County Road 1346, 0.5 mi south of Sun City, 0.2 mi downstream from Turkey Creek, at mile 75.8.

DRAINAGE AREA.—335 mi^2.

Description of ungaged site on Elm Creek at Medicine Lodge, Kansas, site 07148900.

LOCATION.—Lat. 37°16'33", long. 98°34'22", in NW1/4NE1/4SE1/4 sec. 12, T.32 S., R.12 W., Comanche County, hydrologic unit 11060003, at U.S. Highway 160 bridge over Elm Creek.

DRAINAGE AREA.—168 mi^2.

Description of ungaged site on Sandy Creek near Waldron, Kansas, site 07149590.

LOCATION.—Lat. 37°00'25", long. 98°12'47", in NE1/4NW1/4NW1/4 sec. 17, T.35 S., R.8 W., Harper County, hydrologic unit 11060004, at SW 100 Road bridge over Sandy Creek.

DRAINAGE AREA.—161 mi^2.

Description of low-flow, partial-record site on Little Sandy Creek near Attica, Kansas, site 07149600.

LOCATION.—Lat. 37°09'00", long. 98°20'46", in SW1/4 sec. 30, T.33 S., R.9 W., Harper County, hydrologic unit 11060004, at bridge on State Highway 14.

DRAINAGE AREA.—103 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 07149605, Little Sandy Creek near Corwin.

Description of low-flow, partial-record site on Little Sandy Creek near Corwin, Kansas, site 07149605.

LOCATION.—Lat. 37°03'55", long. 98°17'03", in NE1/4NE1/4NW1/4 sec. 27, T.34 S., R.9 W., Harper County, hydrologic unit 11060004, at SW 60 Road bridge over Little Sandy Creek.

DRAINAGE AREA.—124 mi^2.

Description of low-flow, partial-record site on Bluff Creek near Caldwell, Kansas, site 07151800.

LOCATION.—Lat. 37°00'51", long. 97°42'35", in NW1/4SW1/4NW1/4 sec. 12, T.35 S., R.4 W., Sumner County, hydrologic unit 11060005, at South Eden Road, 7 mi west of Caldwell.

DRAINAGE AREA.—399 mi^2.

REMARKS.—Historic base-flow measurements used for development of the estimated flow-duration curve for ungaged site 07151670, Bluff Creek south of Anthony.

Description of ungaged site on Bluff Creek south of Anthony, Kansas, site 07151670.

LOCATION.—Lat. 37°06'40", long. 98°02'18", in NW1/4SW1/4SW1/4 sec. 1, T.34 S., R.7 W., Harper County, hydrologic unit 11060005, at State Highway 179 bridge over Bluff Creek.

DRAINAGE AREA.—185 mi^2.

Description of ungaged site on Cavalry Creek at Coldwater, Kansas, site 07157900.

LOCATION.—Lat. 37°16'00", long. 99°20'40", in NE1/4NE1/4 sec.14, T.32 S., R.19W., Comanche County, hydrologic unit 11040008, at county highway bridge, 1.0 mi west of Coldwater and at mile 18.3.

DRAINAGE AREA.—39 mi^2.