REGIONALIZATION OF LOW-FLOW CHARACTERISTICS OF TENNESSEE STREAMS

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 85-4191

Prepared in cooperation with the

TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT,

DIVISION OF WATER MANAGEMENT

Click here to return to USGS Publications

REGIONALIZATION OF LOW-FLOW CHARACTERISTICS OF TENNESSEE STREAMS

R. H. Bingham

U. S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 85-4191

Prepared in cooperation with the

TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT,

DIVISION OF WATER MANAGEMENT

Nashville, Tennessee

1986

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
A-413 Federal Building
U.S. Courthouse
Nashville, Tennessee 37203

Copies of this report can be purchased from:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey
Box 25425, Federal Center
Lakewood, Colorado 80225

CONTENTS

PLATES

ILLUSTRATIONS

CONVERSION FACTORS

Analyses and compilations used in this report are in inch-pound units of measurements. Factors for converting inch-pound units to metric (SI) units are listed below.

Multiply	By	To obtain
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.59	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.0283	cubic meter per second (m^3/s)

REGIONALIZATION OF LOW-FLOW CHARACTERISTICS OF TENNESSEE STREAMS

R. H. Bingham

ABSTRACT

Procedures for estimating 3-day 2-year, 3-day 10-year, 3-day 20-year, and 7-day 10-year low flows at ungaged stream sites in Tennessee are based on surface geology and drainage area size. One set of equations applies to west Tennessee streams, and another set applies to central and east Tennessee streams. The equations do not apply to streams where flow is significantly altered by activities of man. Standard errors of estimate of equations for west Tennessee are 24 to 32 percent and for central and east Tennessee 31 to 35 percent.

Streamflow-recession indexes, in days per log cycle, are used to account for effects of geology of the drainage basin on low flow of streams. The indexes in Tennessee range from 32 days per log cycle for clay and shale to 350 days per log cycle for gravel and sand, indicating different aquifer characteristics of the geologic units that sustain streamflows during periods of no surface runoff. Streamflow-recession rate depends primarily on transmissivity and storage characteristics of the aquifers, and the average distance from stream channels to basin divides. Geology and drainage basin size are the most significant variables affecting low flow in Tennessee streams according to regression analyses.

INTRODUCTION

Low-flow information is essential to surface-water quality and water-supply management. The amount of available water in a stream for dilution and transport of waste is a critical factor in determining the load capacity of the stream and withdrawal rates for water supply. With the current emphasis on water quality, low-flow information is important to regulatory agencies concerned with waste disposal into streams. The permissible rate of waste disposal into Tennessee streams, for example, is based on the 3-day 20-year low flow. Needs for low-flow estimates will increase throughout the State, therefore improved techniques to analyze the available data are needed. Immediate applications of the results of this project are to: (1) update the low-flow characteristics of gaged streams, and (2) derive new methods with improved reliability for estimating low-flow of ungaged stream sites.

In response to the expected increase for low-flow information, the U.S. Geological Survey, in cooperation with the Tennessee Department of Health and

Environment, began a study in 1981 to estimate low flow of streams in Tennessee. The study was divided into two phases. During the first phase, statistical analyses of daily streamflow data for continuous-record gaging stations were performed to calculate low flow for selected recurrence intervals and duration of streamflow. Low-flow for continuous-gaging stations were then used to estimate low flow at partial-record stations by methods of correlation. Descriptions of procedures used in the analyses and results of the first phase of the study are presented in a report by Bingham (1985).

During the second phase of the study, equations were derived by multiple regression techniques to estimate four low-flow characteristics of ungaged streams in Tennessee. The four characteristics are the 3-day 2-year ($3Q_2$), 3-day 10-year ($3Q_{10}$), 3-day 20-year ($3Q_{20}$), and 7-day 10-year ($7Q_{10}$) low flow. The $3Q_2$, $3Q_{10}$, and $3Q_{20}$ are the discharges at 2-, 10-, and 20-year recurrence intervals taken from a frequency curve of annual values of the lowest mean discharge for 3 consecutive days (the 3-day low flow). The $7Q_{10}$ is the discharge at the 10-year recurrence interval taken from a frequency curve of annual values of the lowest mean discharge for 7 consecutive days (the 7-day low flow). In Tennessee, low flow at ungaged stream sites can be estimated by substituting values for drainage area size and mapped streamflow-recession indexes into the regression equations.

This report summarizes results of the second phase of the study and describes methods to estimate low flows in Tennessee streams. The report is based on low-flow data collected as part of programs with the Tennessee Department of Health and Environment and other state and federal agencies. Low-flow data for some streams in the Cumberland River basin were furnished by the U.S. Army Corps of Engineers. Data for some streams in the Tennessee River basin were furnished by the Tennessee Valley Authority.

Five previous reports describe low flow, and flow duration of Tennessee streams: Eaton (1958), Wood and Johnson (1965), May and others (1970), Gold (1981), and Bingham (1985). The report by Bingham is based on streamflow data through 1981.

APPLICATION OF REGIONAL EQUATIONS TO ESTIMATE LOW-FLOW CHARACTERISTICS

The methods for estimating low flows in Tennessee streams consist of two sets of regression equations that are based on an index of streamflow recession and size of the drainage basin. One set of equations can be used to estimate low flow of streams in west Tennessee which have drainage areas between 25 and 1,940 mi^2. The other set of equations can be used to estimate low flow of streams in central and east Tennessee which have drainage areas between 2.68 and 2,557 mi^2. Areas where the separate sets of equations apply are shown on plate 1 (in pocket).

The following four equations can be used for estimating low flows in ungaged streams in west Tennessee.

	Standard error of estimate, in percent
$3Q_2 = 1.17 \times 10^{-4} A^{1.02} (G-30)^{1.43}$	29
$3Q_{10} = 7.83 \times 10^{-6} A^{1.06} (G-30)^{1.86}$	25
$3Q_{20} = 3.28 \times 10^{-6} A^{1.07} (G-30)^{2.00}$	32
$7Q_{10} = 1.16 \times 10^{-5} A^{1.06} (G-30)^{1.79}$	24

The following four equations can be used for estimating low flows in ungaged streams in central and east Tennessee.

	Standard error of estimate, in percent
$3Q_2 = 2.95 \times 10^{-3} A^{0.99} (G-30)^{1.01}$	35
$3Q_{10} = 5.33 \times 10^{-4} A^{1.01} (G-30)^{1.30}$	32
$3Q_{20} = 3.15 \times 10^{-4} A^{1.01} (G-30)^{1.39}$	33
$7Q_{10} = 7.08 \times 10^{-4} A^{1.00} (G-30)^{1.25}$	31

where

$3Q_2$ = estimated 3-day 2-year low flow, in cubic feet per second;
$3Q_{10}$ = estimated 3-day 10-year low flow, in cubic feet per second;
$3Q_{20}$ = estimated 3-day 20-year low flow, in cubic feet per second;
$7Q_{10}$ = estimated 7-day 10-year low flow, in cubic feet per second;
A = contributing drainage area, in square miles; and
G = streamflow-recession index, in days per log cycle of decrease in discharge, determined from plate 1.

Limitations and Accuracy of Equations

Accuracy of the regression equations is expressed as standard error of estimate in percent. Standard error is computed from the difference between estimates of low flow from station data and estimates of low flow from the regression equations. Standard error of estimate is the range of error to be expected about two-thirds of the time. The standard error of estimate listed above is based on regression analyses using a streamflow-recession index determined from mapped values on plate 1.

The regression equations in this report are limited to estimating the $3Q_2$, $3Q_{10}$, $3Q_{20}$, and $7Q_{10}$ low flow in natural flow streams in Tennessee. In deriving the equations, drainage areas ranged from 25 to

1,940 mi^2 for west Tennessee streams, and streamflow-recession indexes ranged from 32 to 350. The following table gives the ranges in low-flow characteristics for stations in west Tennessee.

Low-flow characteristic	Range of flow, in cubic feet per second	
	From	To
$3Q_2$	0.4	357
$3Q_{10}$	.1	261
$3Q_{20}$	.1	241
$7Q_{10}$	.1	266

Drainage areas ranged from 2.68 to 2,557 mi^2 for central and east Tennessee streams, and streamflow-recession indexes ranged from 32 to 175. The following table gives the ranges in low-flow characteristics for stations in central and east Tennessee.

Low-flow characteristic	Range of flow, in cubic feet per second	
	From	To
$3Q_2$	0.2	854
$3Q_{10}$	.1	511
$3Q_{20}$	.1	434
$7Q_{10}$	.2	541

Use of the equations should be limited to the range in low flow, drainage area, and streamflow-recession indexes used to derive the equations.

The regression equations should not be used on streams where the flow is significantly affected by regulation or other activities of man. Caution should be used when applying the equations to streams where a significant amount of the low flow is contributed by springs. Definition of the contributing drainage area, in such cases, is uncertain; some of the spring flow might be from adjacent basins. Caution also should be used in applying the equations to streams where most of the formation at or near land surface is limestone. Solution cavities in the limestone may alter the rate of flow considerably within short reaches of the stream channel. For example, a stream channel in limestone can have low flow of several cubic feet per second at one site and have zero flow at another site downstream. This commonly occurs in Overton, Putnam, White, Warren, Rutherford, and Williamson Counties of central Tennessee, and may occur locally in other counties.

Standard errors of the regression equations were determined using map values (plate 1, in pocket) of streamflow-recession indexes in the analyses. Those errors apply only to the stations used in the regression analyses. The average errors associated with use of the equations to estimate low flows in ungaged streams are unknown, but are probably slightly larger than the standard errors of the equations.

ESTIMATES FOR LOW FLOW AT UNGAGED SITES

The following procedures can be used to estimate the $3Q_2$, $3Q_{10}$, $3Q_{20}$, and $7Q_{10}$ low flows for ungaged sites on streams with natural flow in Tennessee. From topographic maps, determine the size of drainage area upstream from the site. From plate 1, determine the streamflow-recession index for the stream basin. Low flows for the site can be estimated by substituting the values of drainage area size and streamflow-recession index into the appropriate regression equations and performing the indicated mathematical operations or by graphical determination using figures 1 through 8. Low-flow values, computed by the equations or estimated from the graphs, of less than 0.05 ft^3/s for $3Q_{10}$, $3Q_{20}$, and $7Q_{10}$ should be considered zero. Low-flow values less than 0.15 ft^3/s for $3Q_2$ should be considered zero. Examples using the regression equations to estimate low flow in ungaged streams are given in Supplement A of this report.

The estimating methods are modified for a stream basin draining two or more areas of different streamflow recession indexes. Drainage area is determined as described in the preceding paragraph. However, discharge from each of two or more streamflow-recession index areas must be computed separately using the equations, and the results weighted based on an estimate of the percentage of the basin draining each streamflow-recession index area.

VERIFICATION OF REGRESSION EQUATIONS AT PARTIAL-RECORD SITES

The regression equations were used to estimate $3Q_{20}$ for 600 low-flow partial-record stations within the State (plate 2) and the results were compared with low-flow estimates obtained from correlation methods. The 600 stations exclude those used in the regression analyses. Estimated low flows, drainage area, mapped streamflow recession index (plate 1), and identification number for the stations are given in Supplement B for west Tennessee and in Supplement C for central and east Tennessee.

Many of the stations in the supplements represent flow affected by man's activity, and many stations have drainage areas and low-flow values outside the limitations of data used to derive the equations for $3Q_{20}$. Those stations, and stations where large springs are known to occur upstream from the site, were omitted from the computation of the standard error of estimate. Partial-record stations used to compute the standard errors are flagged with an asterisk in supplements B and C.

The standard error of estimate was approximated by assuming the correlation values of low flow to be accurate. Regression equations were used to

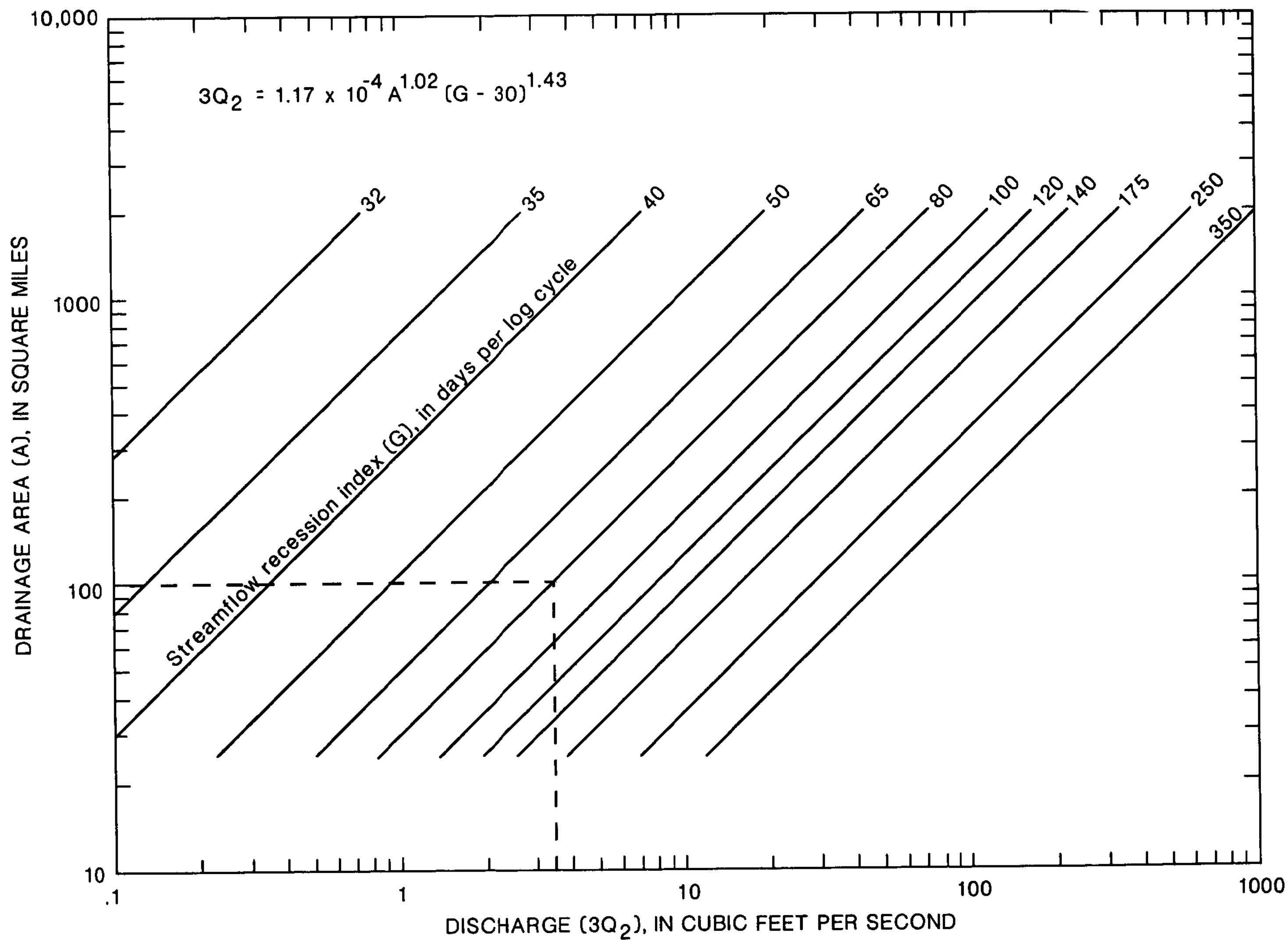

Figure 1.--Graphical solution of 3-day 2-year low-flow equation for west Tennessee.

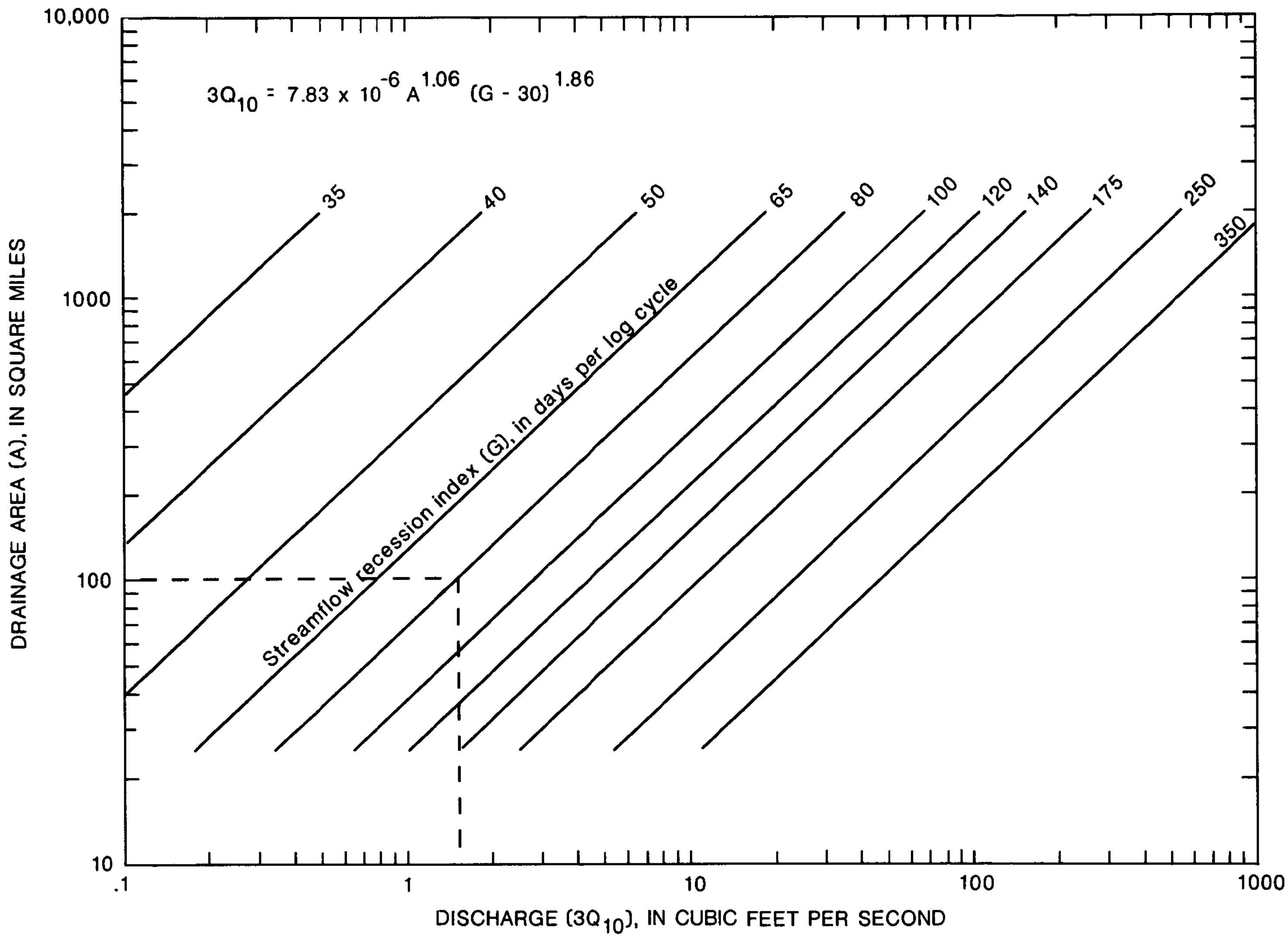

Figure 2.--Graphical solution of 3-day 10-year low-flow equation for west Tennessee.

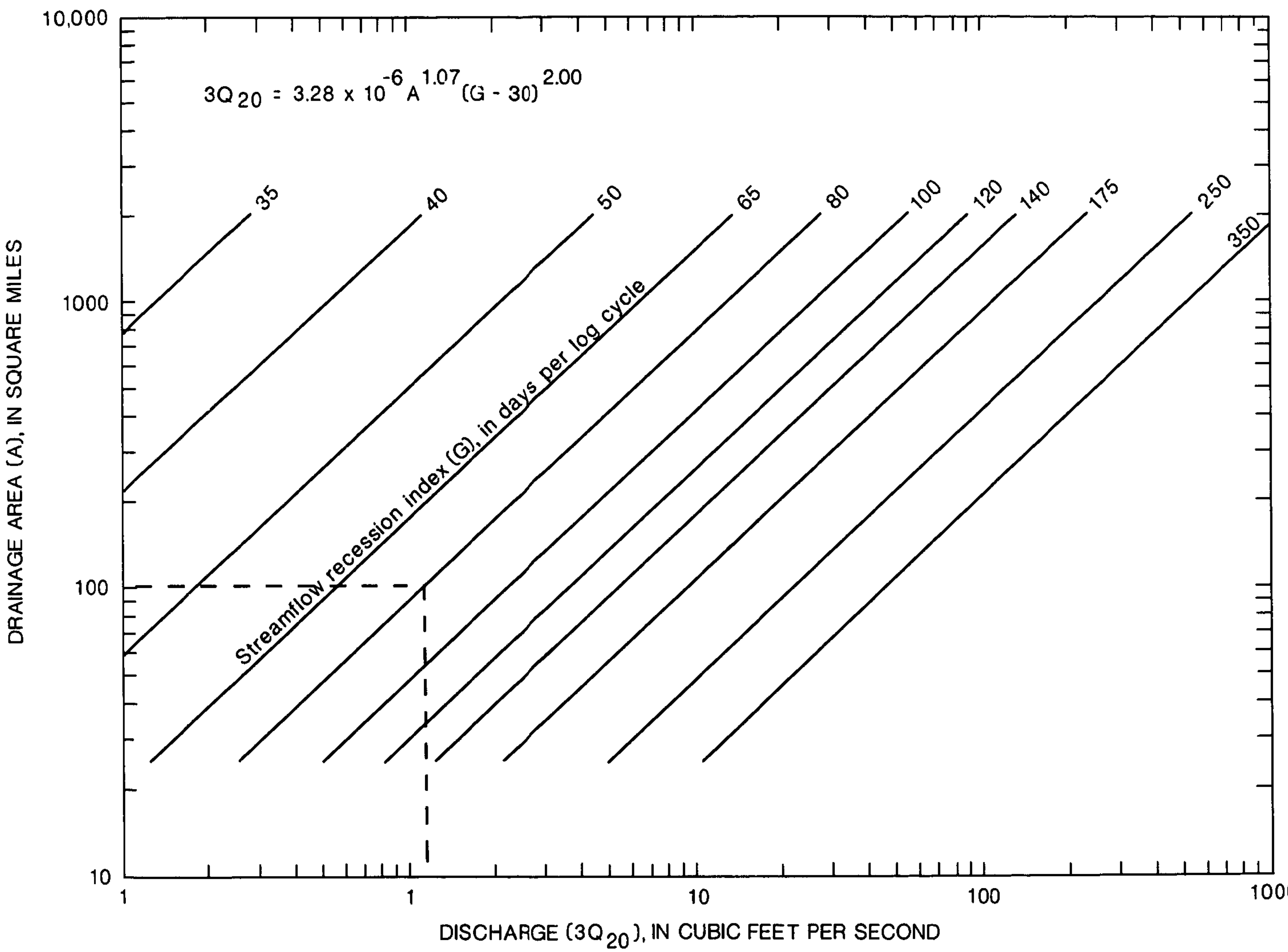

Figure 3.--Graphical solution of 3-day 20-year low-flow equation for west Tennessee.

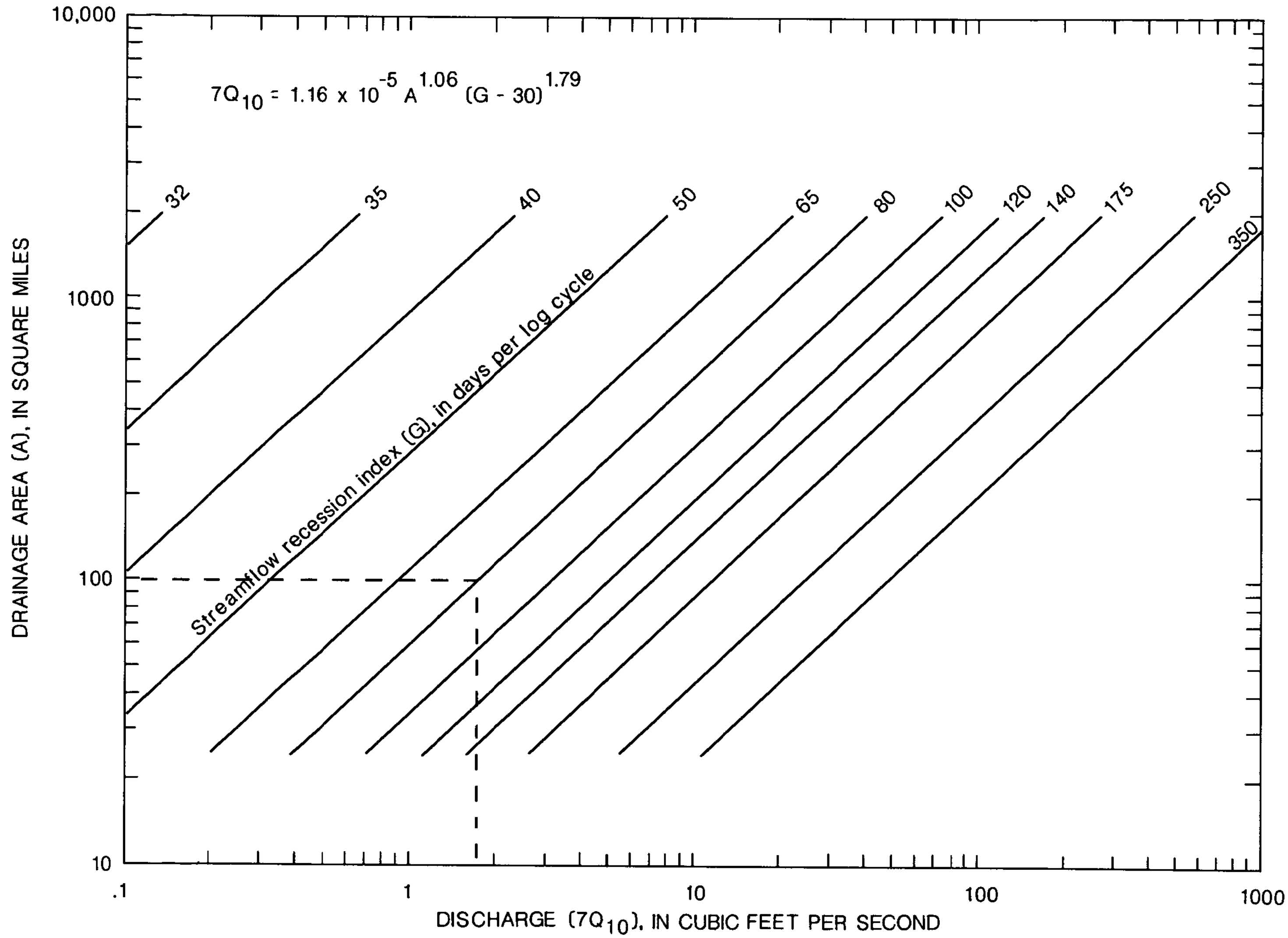

Figure 4.--Graphical solution of 7-day 10-year low-flow equation for west Tennessee.

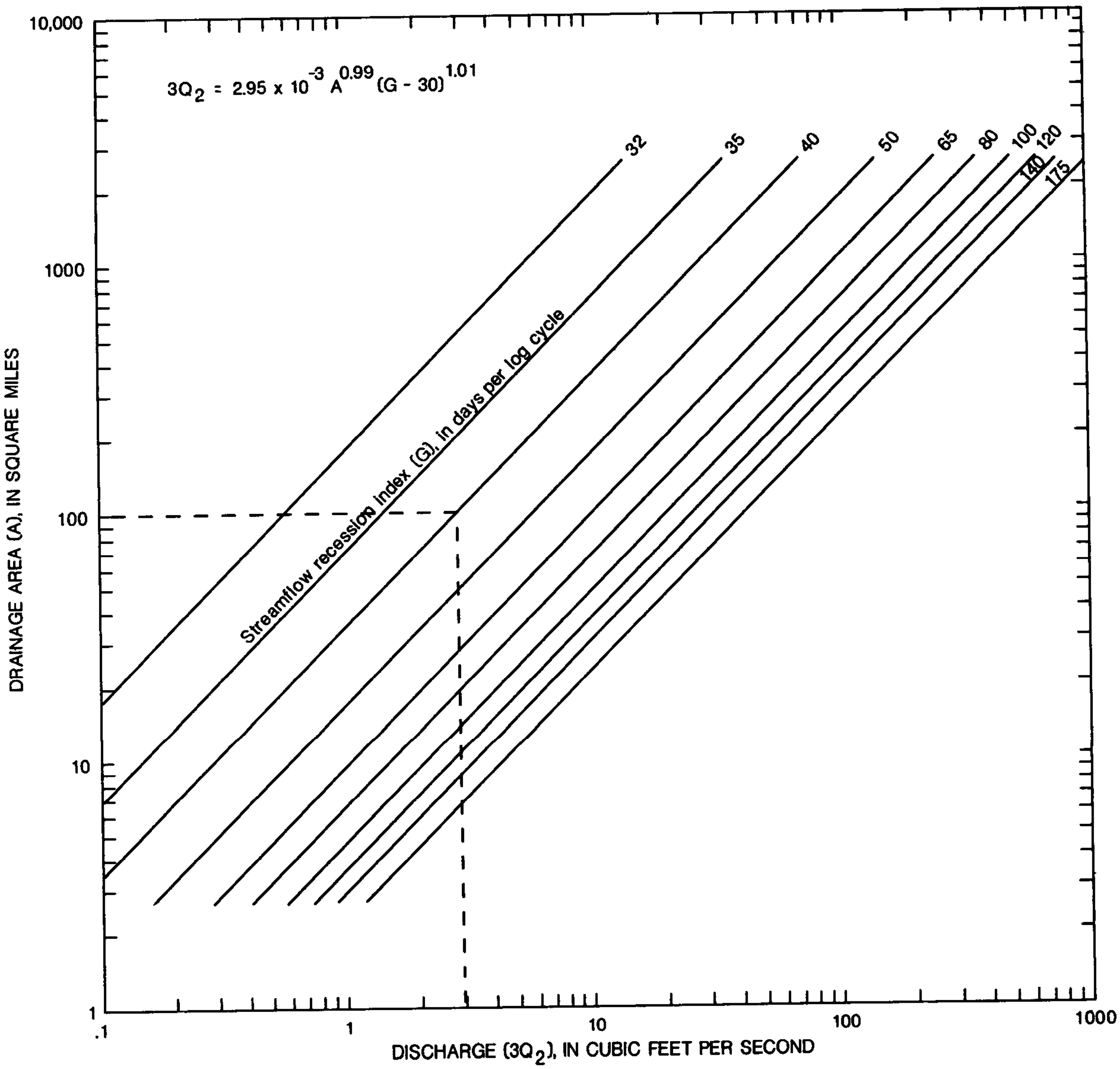

Figure 5.--Graphical solution of 3-day 2-year low-flow equation for central and east Tennessee.

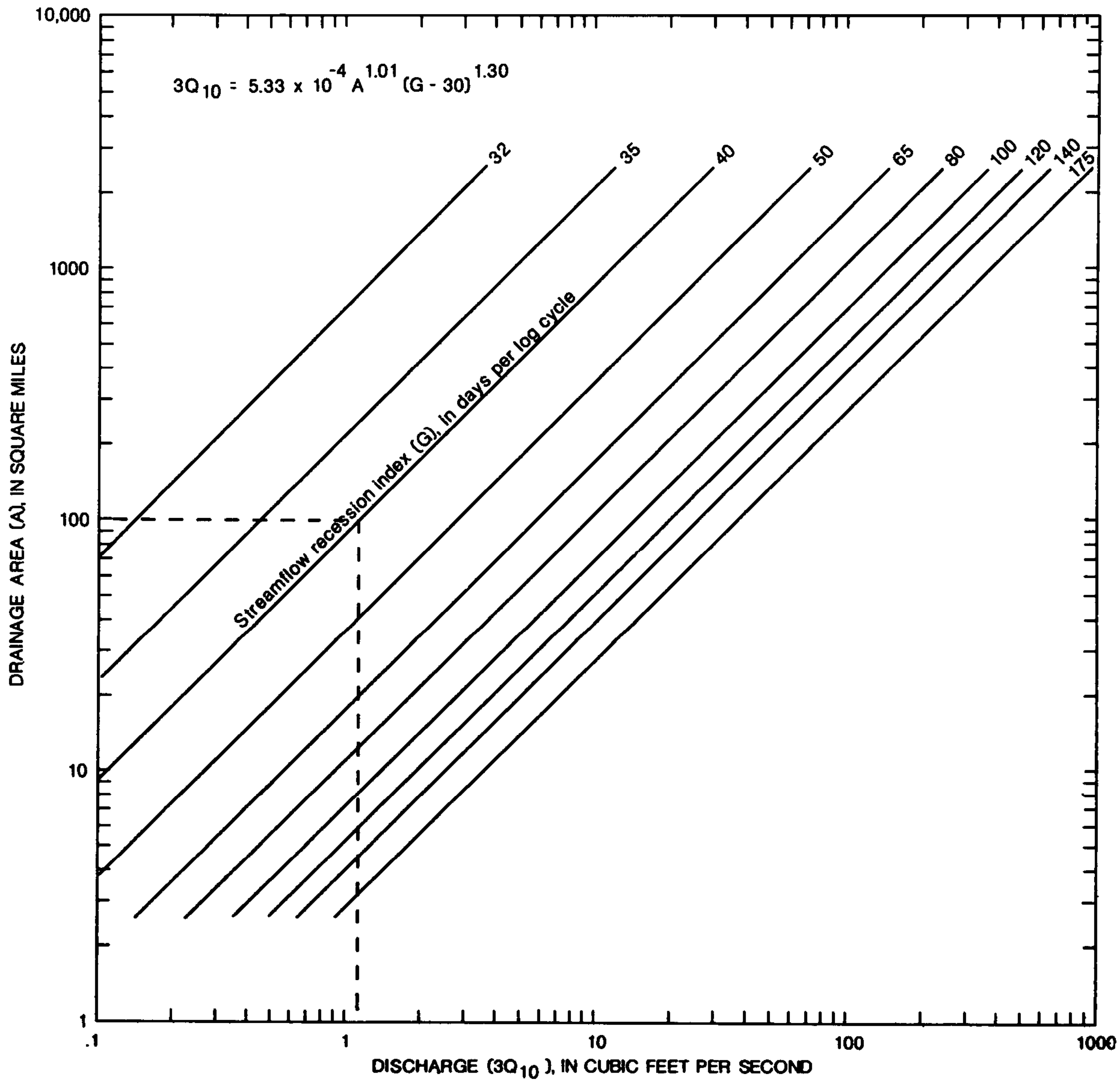

Figure 6.--Graphical solution of 3-day 10-year low-flow equation for central and east Tennessee.

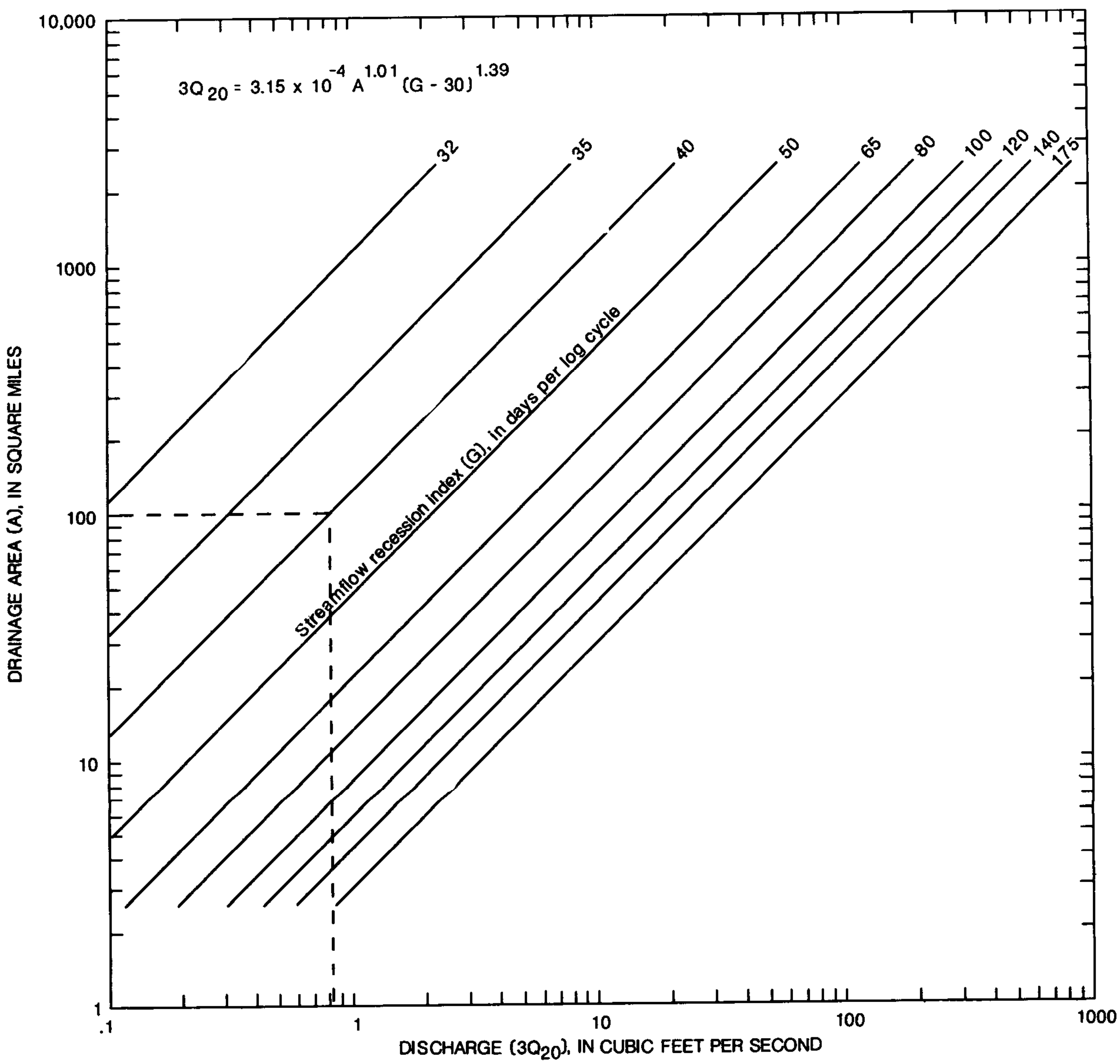

Figure 7.--Graphical solution of 3-day 20-year low-flow equation for central and east Tennessee.

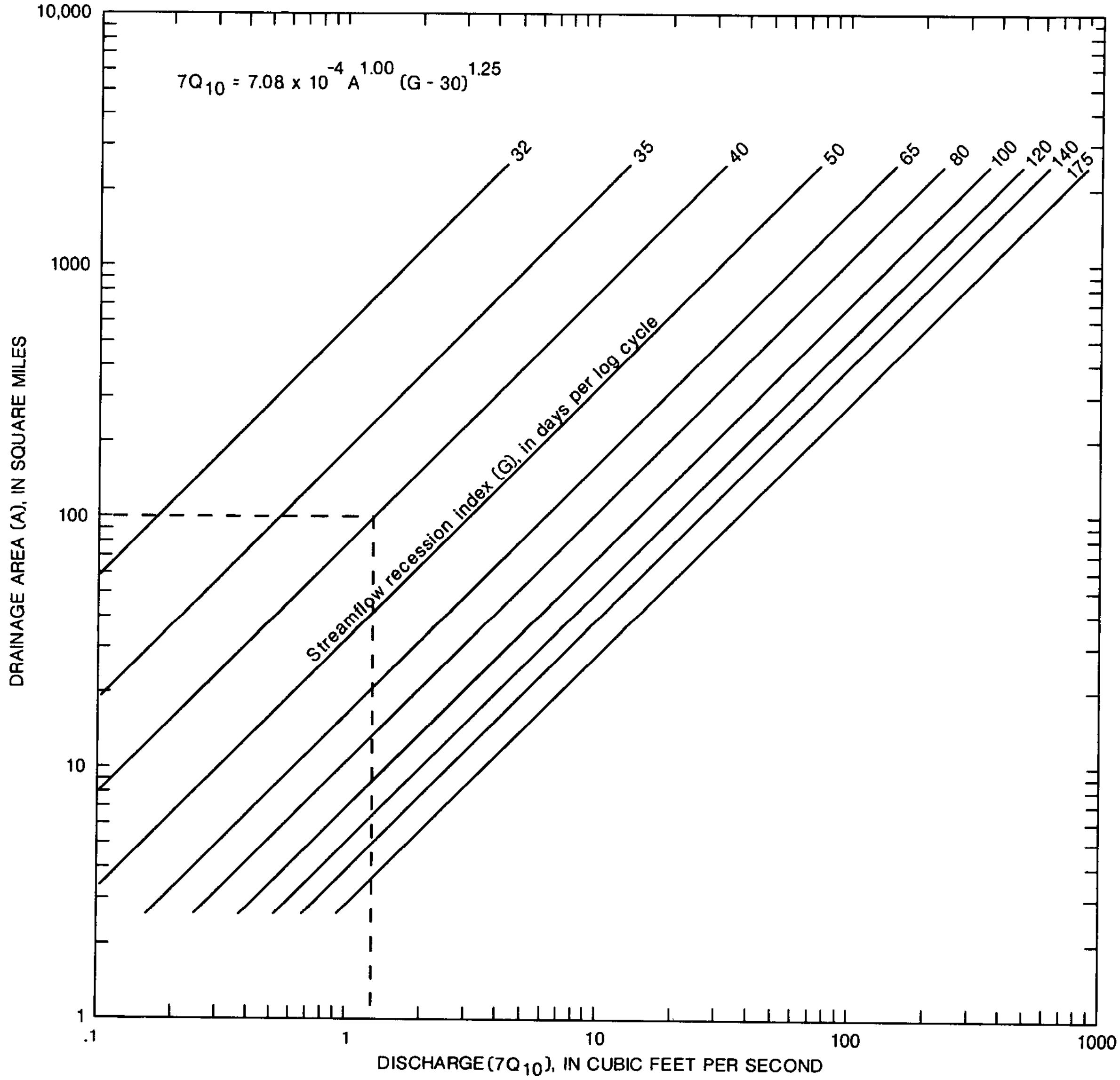

Figure 8.–Graphical solution of 7-day 10-year low-flow equation for central and east Tennessee.

estimate $3Q_{20}$ for partial-record stations and the results compared with estimates obtained from correlation methods. Residuals, in log units, were determined as the difference in logarithms of low flows from regression equations and from correlation methods. The error was computed by the root-mean-square procedure using the equation:

$$RMS = \sqrt{\bar{x}^2 + S^2},$$

where RMS = root mean square, in log units,
$\bar{x}$ = mean of the residuals, and
S = standard deviation of the residuals.

Computed RMS values were transformed to 45 percent for 33 partial-record stations in west Tennessee and to 41 percent for 223 partial-record stations in central and east Tennessee. A two-sided student's t test indicated no bias in low flows determined by the regression equations.

Other comparisons of the low-flow estimates were made with graphical plots. The $3Q_{20}$ low flows from correlation methods for the partial-record stations were plotted against $3Q_{20}$ low flows estimated with the regression equations. Plots of low-flow data for the 33 stations in west Tennessee are illustrated in figure 9. Plots for the 223 stations in central and east Tennessee are illustrated in figure 10. According to visual inspection, the plots indicate no bias, however, the largest errors appear to be associated with the smallest low-flow values used for the comparison. Although these comparisons between low-flow estimates from regression equations and from correlation are not completely independent, they do support confidence in the equations.

PROCEDURES FOR REGIONALIZING LOW-FLOW CHARACTERISTICS

Analyses of basin and climatic characteristics that influence the rate of low flow were performed to regionalize methods of estimating low flow in ungaged streams statewide. The most significant result of these analyses is to relate the effects of geology to the rate of low flow. The relation is defined by streamflow recession indexes for various rock types and combinations of rock types. Streamflow-recession indexes are strongly influenced by aquifers within the geologic framework underlying the stream basin. Thus, the streamflow-recession indexes used in these analyses reflect the effects of geology on the rate of low flow. The recession index area boundaries were delineated based on geologic maps.

Ground Water-Surface Water Relations

Low flow in a stream is usually ground water discharged from the aquifer system to the stream. During the wet period in the spring, most rocks underlying the stream basin are recharged by precipitation in excess of the amount of water that can move through the rocks. After the wet season, water in the rocks drains slowly into the adjacent stream and provides flow during the summer and fall. Such drainage, in combination with evapotranspiration, causes the ground-water level to decline to a point below the local streambed and

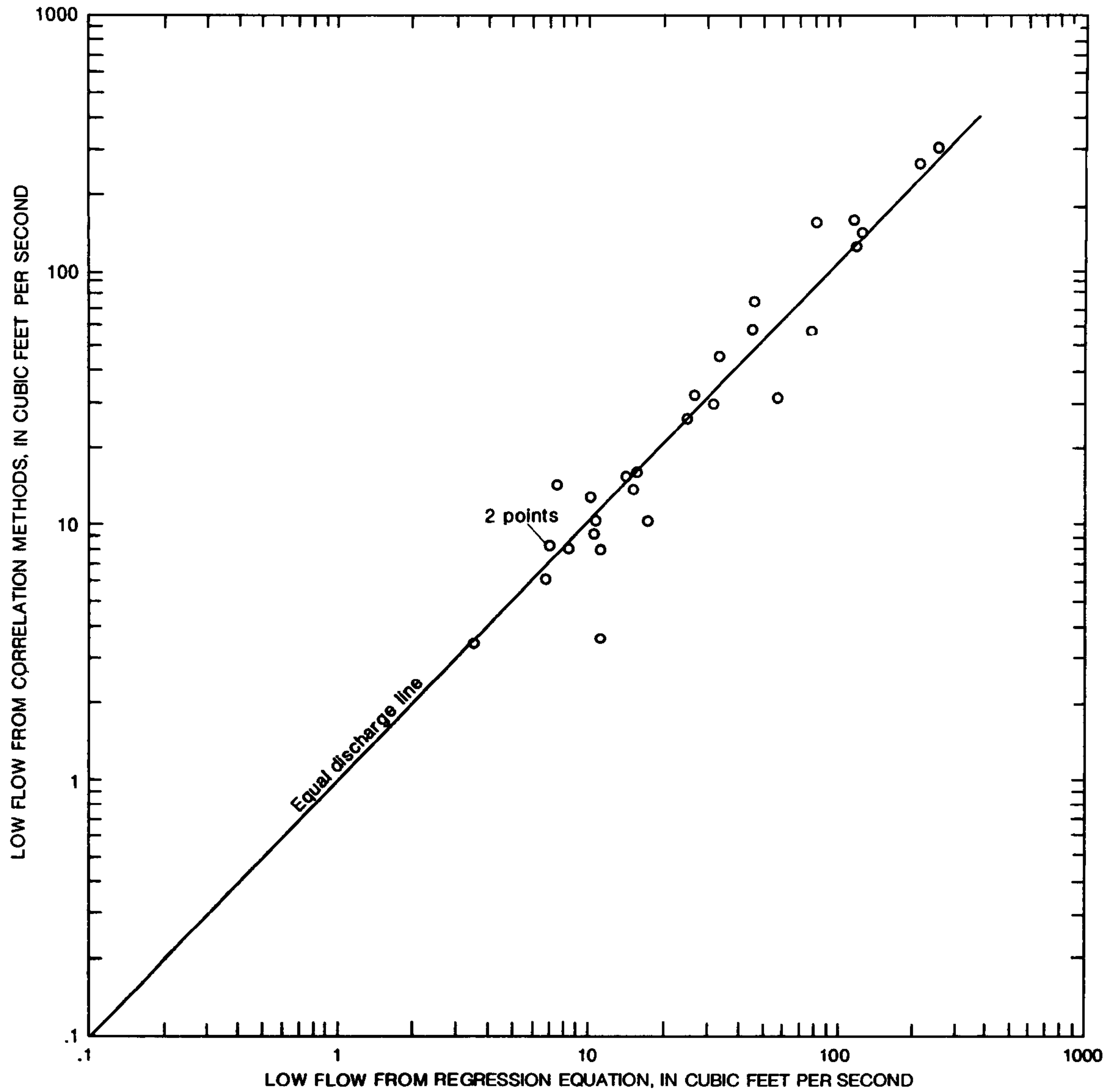

Figure 9.--Plots showing comparison of 3-day 20-year low flow from correlation methods with 3-day 20-year low flow from regression equation for partial-record stations in west Tennessee.

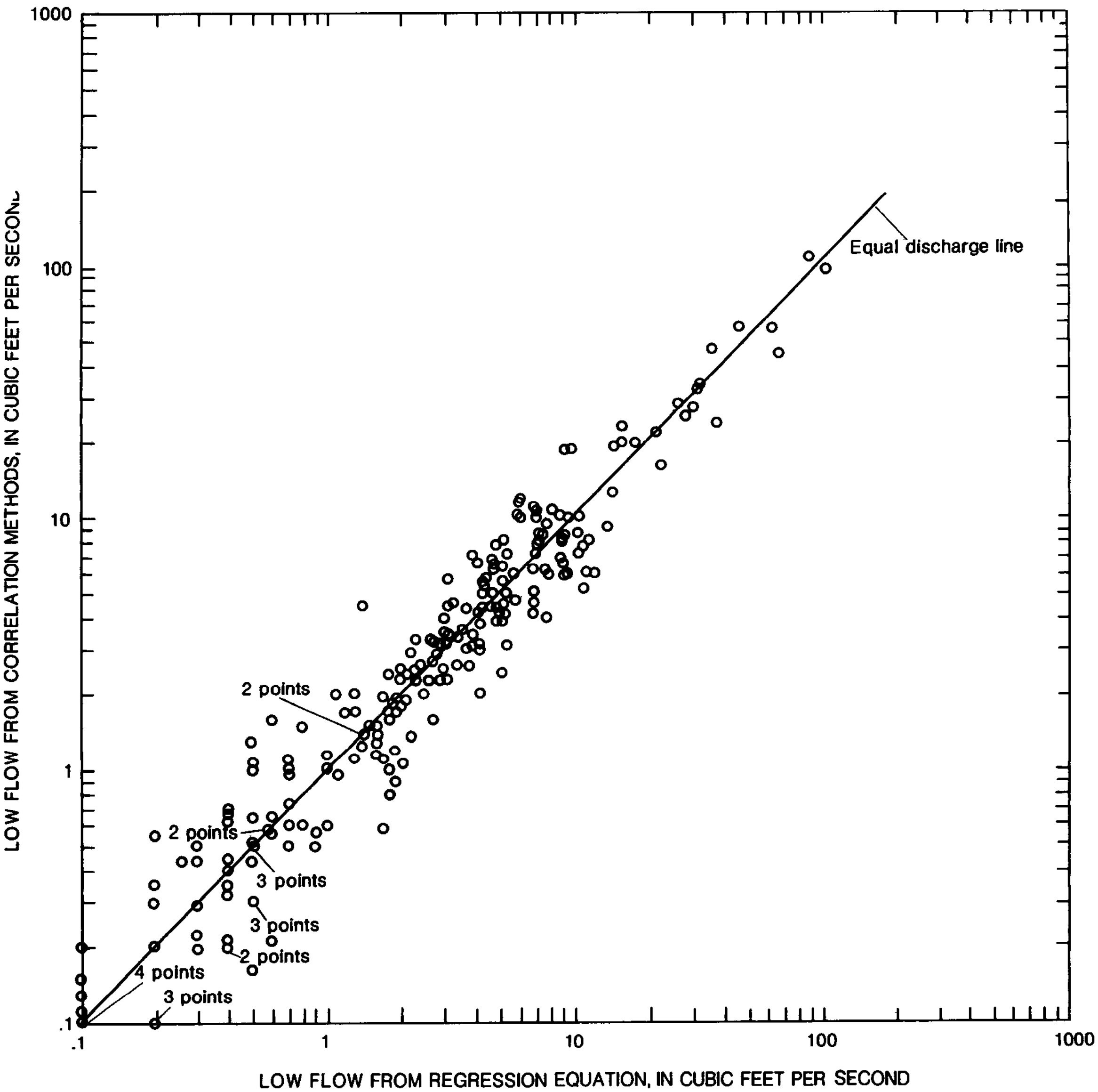

Figure 10.--Plots showing comparison of 3-day 20-year low flow from correlation methods with 3-day 20-year low flow from regression equation for partial-record stations in central and east Tennessee.

water stops flowing into some streams. Consequently, streams in some areas of the State have zero flow for a period during most years. A generalized cross section of a stream basin illustrating the movement of ground water from the aquifer system to the stream is shown in figure 11.

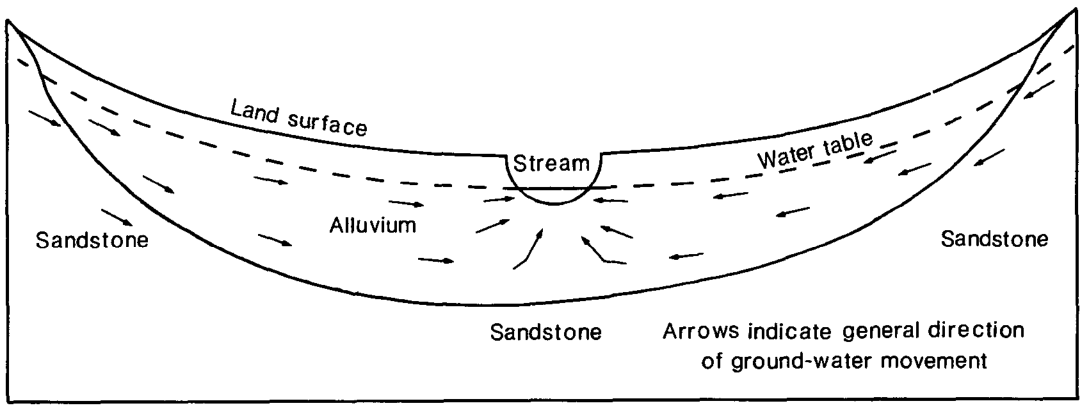

Figure 11.--Generalized cross section of a stream basin showing ground-water movement.

The interactions between the aquifer or groups of aquifers and the streams are extremely complex. The rate of ground-water discharge to a stream is a function of the capacity of the aquifer to store and transmit water, aquifer thickness and areal extent, slope of the water level within the aquifer, amount of precipitation to recharge the aquifer, size of the stream basin, and time. Most streams used in these analyses receive water from two or more rock types or geologic units each having different effects on low flow of the streams. For example, sand yields more water to a stream than does clay, and sandstone yields more water to a stream than does shale. Areal and vertical differences can also occur in aquifer characteristics within a given rock type.

Rorabaugh and others (1966) investigated methods of relating ground water to surface water in the Columbia River basin. In their work, ground-water discharge to selected streams was related to the physical characteristics of the aquifer system as evidenced by the recession pattern of the water level in the aquifer system during a period of no recharge. The report also indicates that streamflow recession for continuous-record gaging stations on unregulated streams can be used to estimate streamflow characteristics.

Trainer and Watkins (1975) used streamflow-recession indexes to estimate average values of aquifer transmissivity and storage in the upper Potomac River basin. Their work shows a direct relation between streamflow recession and the transmissivity of the aquifers. For example, stream basins underlain by aquifers with large transmissivity values had higher indexes of streamflow recession than basins underlain by aquifers with small transmissivity values. By applying that relation, Bingham (1982) used streamflow-recession indexes and surface geology to regionalize low-flow characteristics of unregulated streams in Alabama. For Tennessee, the same relation was used along with information on surface geology to regionalize low flow for selected frequencies statewide.

Streamflow recession

The rate of streamflow recession during base flow is controlled by the hydraulic characteristics of the aquifers. The streamflow-recession index can be estimated by the equation (Rorabaugh and others 1966):

$$t = \frac{a^2S}{T},$$

Where t = time in days per log cycle,
a = distance from the stream to the hydrologic divide,
S = storage coefficient of the aquifer or aquifers, and
T = transmissivity of the aquifer or aquifers.

For this report, these characteristics are not necessary as streamflow data were used to estimate the streamflow-recession indexes graphically. However, according to Trainer and Watkins, (1975, p. 31-32) three factors which affect the streamflow-recession index complicate its definition and interpretation from a graph. Those factors are: (1) the brevity of most recession episodes in a humid region makes the recession curve difficult to establish precisely, (2) losses from ground water and from streamflow through evapotranspiration distort the ideal recession curve during much of the year, and (3) many recession curves are complex because of nonhomogeneity of the aquifers or the presence of multiple aquifers.

Records from approximately 150 continuous-record gaging stations were examined in an attempt to define the streamflow-recession index areas across the State. Streamflow-recession indexes were defined for 109 of those sites. Streamflow at the remaining stations was significantly affected by activities of man, or the record was too short to define the streamflow-recession indexes. For stations where the length of record was adequate, 20 years of streamflow hydrograph plots were examined to determine periods of record to use in estimating the streamflow-recession indexes. Approximately 6 to 10 recessions were plotted for each of the stations to assure consistency in the recession index definition. For some stations, however, only two to three recessions could be used for various reasons to estimate the index. The streamflow recessions, for each station, were plotted on semilog graph paper, daily streamflow on the log scale, and time, in days, on the arithmetic scale. The index of streamflow recession for each station was defined in days per log cycle, that is, the number of days required for the flow to decrease one complete log cycle. The base flow recession of a stream is nearly straight on a semilog plot.

Streamflow records for periods during November through March were generally used for defining the streamflow-recession indexes. During that time, interferences from evaporation and transpiration are least, and the recession probably reflects the geohydrologic control on base runoff and low flow of streams. However, the recession slope is difficult to determine from streamflow in the winter because of interruptions from precipitation. Many of the interruptions are brief, and the recession slope may become nearly straight a few days after the streamflow peak.

The peak discharge during a period of rainfall is used as the first plotting point for the streamflow-recession curve. The plotting of stream discharge for each successive day is continued until the streamflow-recession curve approximates a straight line. The number of days required for the straight-line condition to occur is a function of the basin geometry and the properties of the basin material (Rorabaugh and others, 1966) and is defined as the critical-time factor. The critical-time factor is expressed by the equation:

$$tc = \frac{0.2a^2S}{T}.$$

Each variable is defined on a previous page of this report. The straight-line part of the curve is used to define the index of streamflow recession. The streamflow recession for South Fork Forked Deer River at Jackson, Tennessee (station 221, pl. 1) is illustrated in figure 12. The straight-line part of the curve for South Fork Forked Deer River indicates a recession index of about 235 days per log cycle, and a critical-time factor of 47 days.

Definition of the streamflow-recession index, for numerous stations, can be aided or verified by the critical-time factor. After the days per log cycle have been estimated from the recession plot, multiply the number of days by the critical-time factor (0.2) to determine the number of days for the recession curve to become an apparent straight line. The critical-time procedure works fairly well when the first plotting point on the recession curve represents medium to high discharge. For low to medium discharge, the curves represent increments or additions to the composite of all past events, and, in many cases, the critical-time factor may be as low as 0.1 and may not be conclusive (Daniel, 1976). In many stream basins in Tennessee, the geometry and aquifer characteristics are such that the critical-time factor may represent weeks or months.

Great care is required in estimating the streamflow-recession index from hydrographs because precipitation falls frequently during the winter, and periods of streamflow recession between flood peaks are relatively short. Recession curves that become straight-line segments on semilog plots within 6 to 10 days after flood peaks can be determined readily through inspection of several years of hydrographs for each stream. By contrast, the straight-line segment of a recession curve that would become linear after 50 days or more of uninterrupted recession can be determined only approximately.

Multiple Aquifer Contributions To Streamflow

On a statewide basis, the variation of aquifer hydraulic characteristics and interaction of the aquifers and streamflow is extremely complex. Trainer

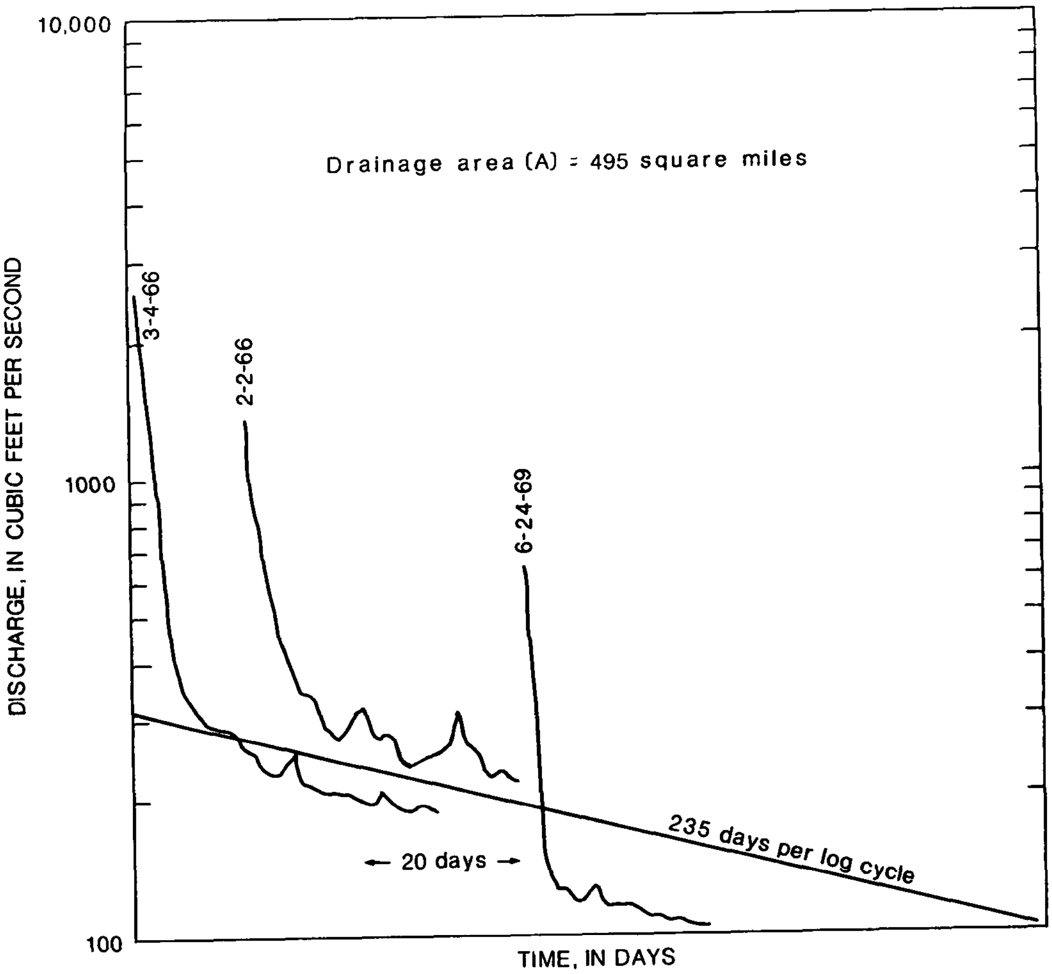

Figure 12.--Base flow recessions for South Fork Forked Deer River which drains mostly sand (station 221 on plate 1).

and Watkins (1975, p. 34) indicate in their report that both areal and vertical differences in hydraulic characteristics of aquifers probably contribute to the complexity of streamflow-recession curves. In many Tennessee streams the flow represents the effects of several aquifers, each having different hydraulic characteristics.

For the purposes of developing the regression equations, no simple method exists for assigning fractions of low flows to parts of a basin draining two or more unlike aquifers. In the case of naturally integrated recessions, such might not be possible while at the same time preserving the statistical validity of the data.

Graphical Computation Method

The streamflow-recession indexes, as determined graphically, for most of the streams in these analyses represent naturally integrated effects of the different aquifers within the basin. For example, flow of Sewee Creek near Decatur, in Meigs County (Station 120 pl. 1), represents naturally integrated effects of two aquifers. One aquifer has a streamflow-recession index of 65 days per log cycle and the other aquifer has a streamflow-recession index of 120 days per log cycle (pl. 1). However, the naturally integrated effects of both aquifers result in a streamflow-recession index of about 85 days per log cycle (fig. 13).

Significantly different streamflow recessions were estimated for several streams used in these analyses by separate straight line segments for different periods on the same streams. Riggs (1964, p. 353-354) describes how runoff from two very unlike aquifers in the same drainage basin might produce two very distinct regions or straight-line segments in the streamflow-recession curve. When two significantly different indexes are observed, it seems reasonable that the flatter one (more days per log cycle) would control longer frequency low flows. For example, a streamflow-recession index of 50 days per log cycle would deplete 99.999 percent of a beginning streamflow during the same period that an index of 250 days per log cycle would deplete only 90 percent of the same beginning streamflow. When different indexes are observed in a single basin, the resulting streamflow is the sum of the contributions from each part of the drainage area and the separate effects are relatively easily distinguished. The streamflow recessions for Sequatchie River near Whitwell, in Marion County (station 145, plate 1), illustrate two indexes representing two unlike aquifers (fig. 14). The recessions also indicate that the naturally integrated effects of the two unlike aquifers (32 and 100 days per log cycle) result in a streamflow-recession index of about 85 days per log cycle. However, for some streams where two or more only slightly different indexes might be expected on the basis of geologic formations, a single observed index can be a naturally integrated effect, and the separate effects from each part of the drainage area may be indistinguishable.

Weighted-Average Method

The weighted-average streamflow-recession index procedure was applied in mapping the index areas as shown on plate 1; thus the values shown may differ slightly from values obtained by the graphical computation method for the same

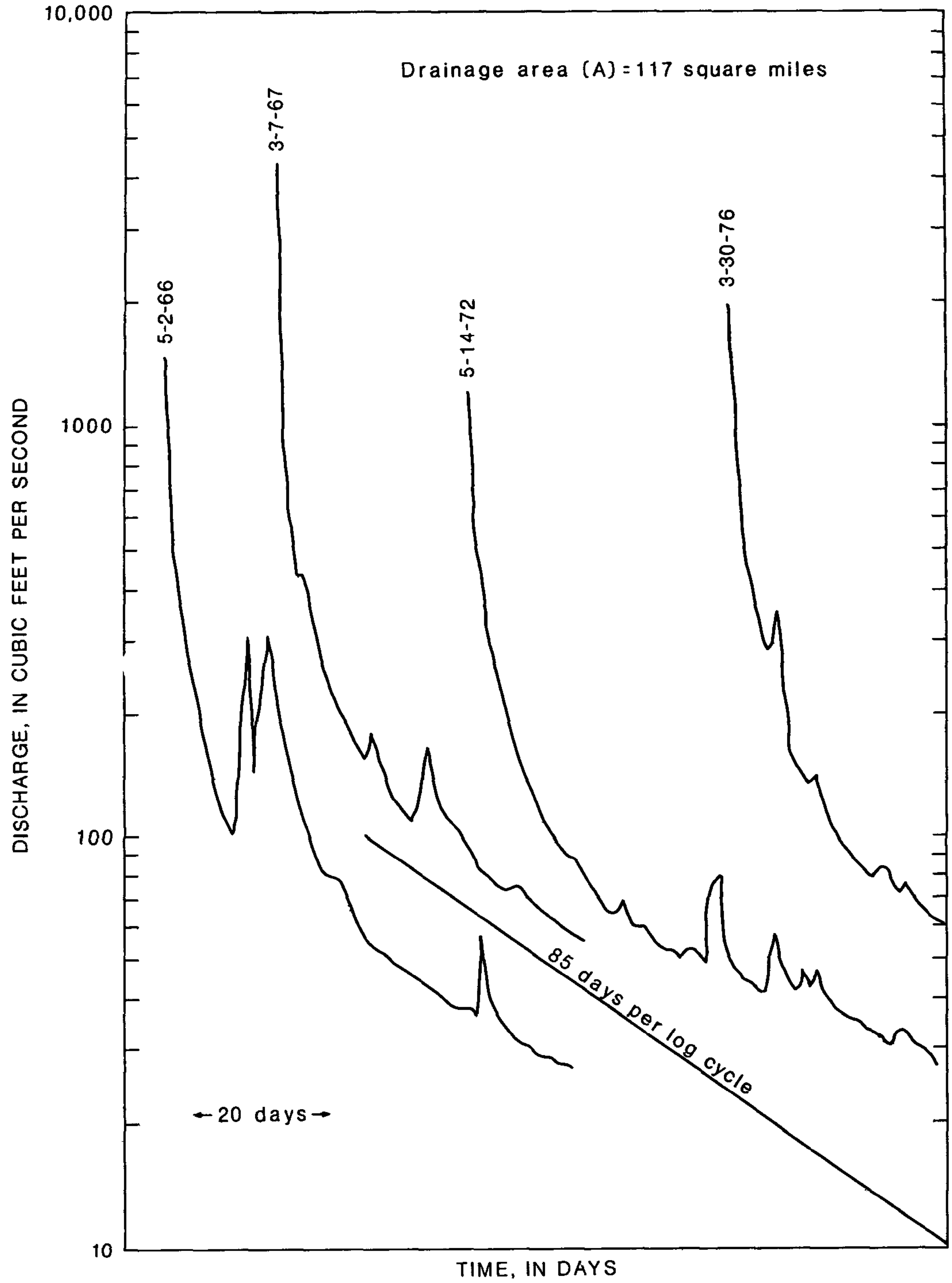

Figure 13.--Base flow recessions for Sewee Creek which drains mostly limestone and dolomite (station 120 on plate 1).

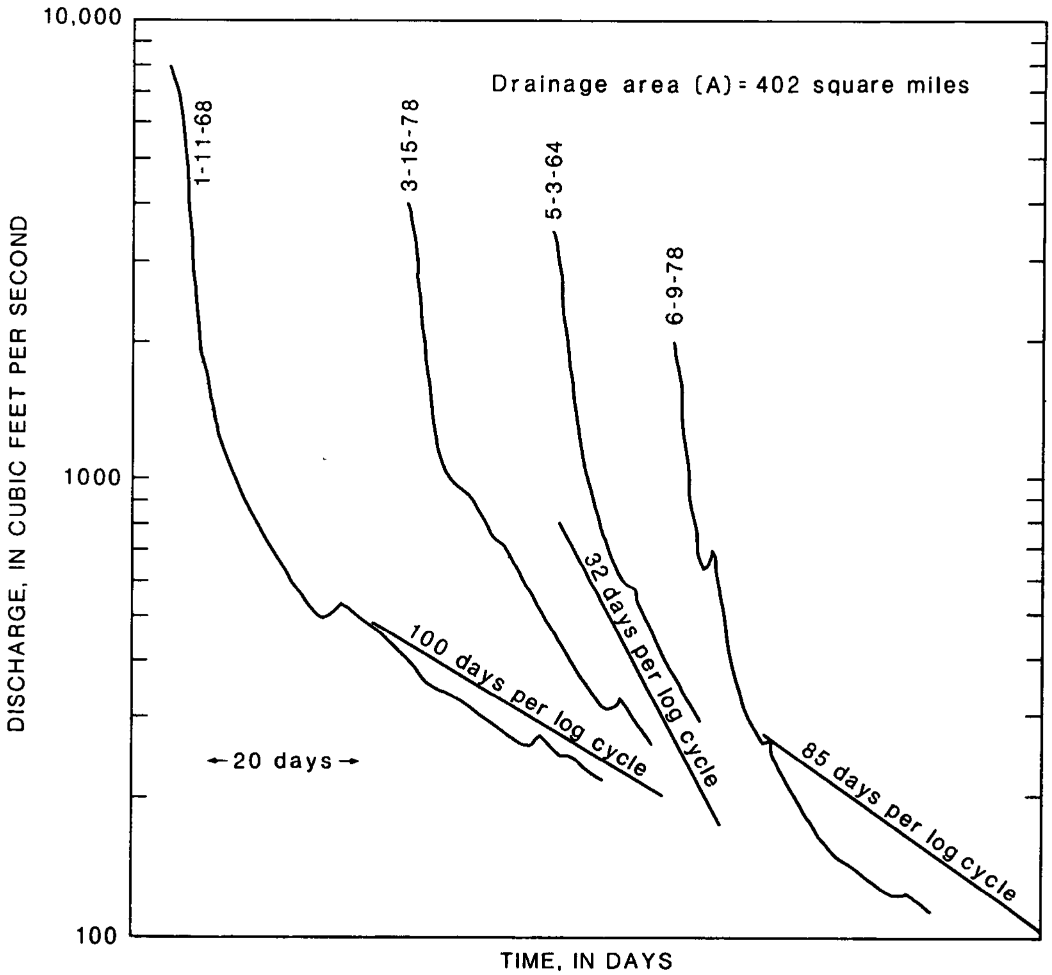

Figure 14.--Three rates of base flow recessions for Sequatchie River which drains mostly limestone and dolomite (station 145 on plate 1)

stations. For the purposes of application of the regressions, however, the effect of contributions from different parts of a basin can be accounted for by the procedure described in Supplement A of this report.

The weighted-average procedure was based on an estimate of the percentage of a stream basin draining each of two or more different aquifers. Sequatchie River at station 145 on plate 1 provides an example of the averaging procedure. A generalized sketch of Sequatchie River basin is shown in figure 15. Approximately 75 percent of the basin drains a limestone and dolomite aquifer which has a streamflow-recession index of 100 days per log cycle (fig. 14). Twenty-five percent of the basin drains the overlying shale and sandstone aquifer which has a streamflow-recession index of 32 days per log cycle. The weighted-average streamflow-recession index is computed by summing 75 percent of 100 days per log cycle and 25 percent of 32 days per log cycle. Thus, the weighted-average streamflow-recession index of the two aquifers is 83 days per log cycle for Sequatchie River at station 145 (pl. 1) near Whitwell. The weighted-average streamflow-recession index is the best estimate of the combined effects of the two aquifers on low flow of Sequatchie River at station 145.

Mapping Streamflow-Recession Indexes

Streamflow-recession index areas (plate 1) were delineated based on streamflow hydrographs, contacts between geologic formations, and the types of geologic formations at land surface in the basin. The types of formations include gravel, sand, clay, and silt in west Tennessee and limestone, chert, shale, sandstone, dolomite, and conglomerate in Central and east Tennessee. In the mountainous areas of extreme east Tennessee, the surface formations also include siltstone, quartzite, and slate. Streamflow data have not been obtained for all the formations contributing water to streamflow within the State. However, the entire State was mapped based on the assumption that similar types of formations contribute similar amounts of water to streamflow, and that ground-water divides on the shallow aquifers correspond to topographic divides.

Boundaries between areas of streamflow-recession indexes on plate 1 follow the same general pattern as the contact lines between formations or groups of formations with major differences in rock type and water-bearing properties. However, the quantitative significance of the several geologic factors that influence low flow in streams cannot be determined precisely.

The streamflow-recession indexes defined for each of the 109 continuous gaging stations were used to represent the relative effects of surface formations on low flow. Effects of the formations on low-flow characteristics were evaluated by plotting gaging station locations and listing their respective streamflow-recession indexes on a map of the State (pl. 1). The data on plate 1 were compared with that on a geologic map of the State (Hardeman and others, 1966) to delineate areas where formation effects on low flow are similar.

Adequate descriptions of the surface formations are essential in determining the position of streamflow-recession index boundaries. In many separate areas, several formations with similar rock types and water-bearing properties were grouped together in a single streamflow-recession area (pl. 1).

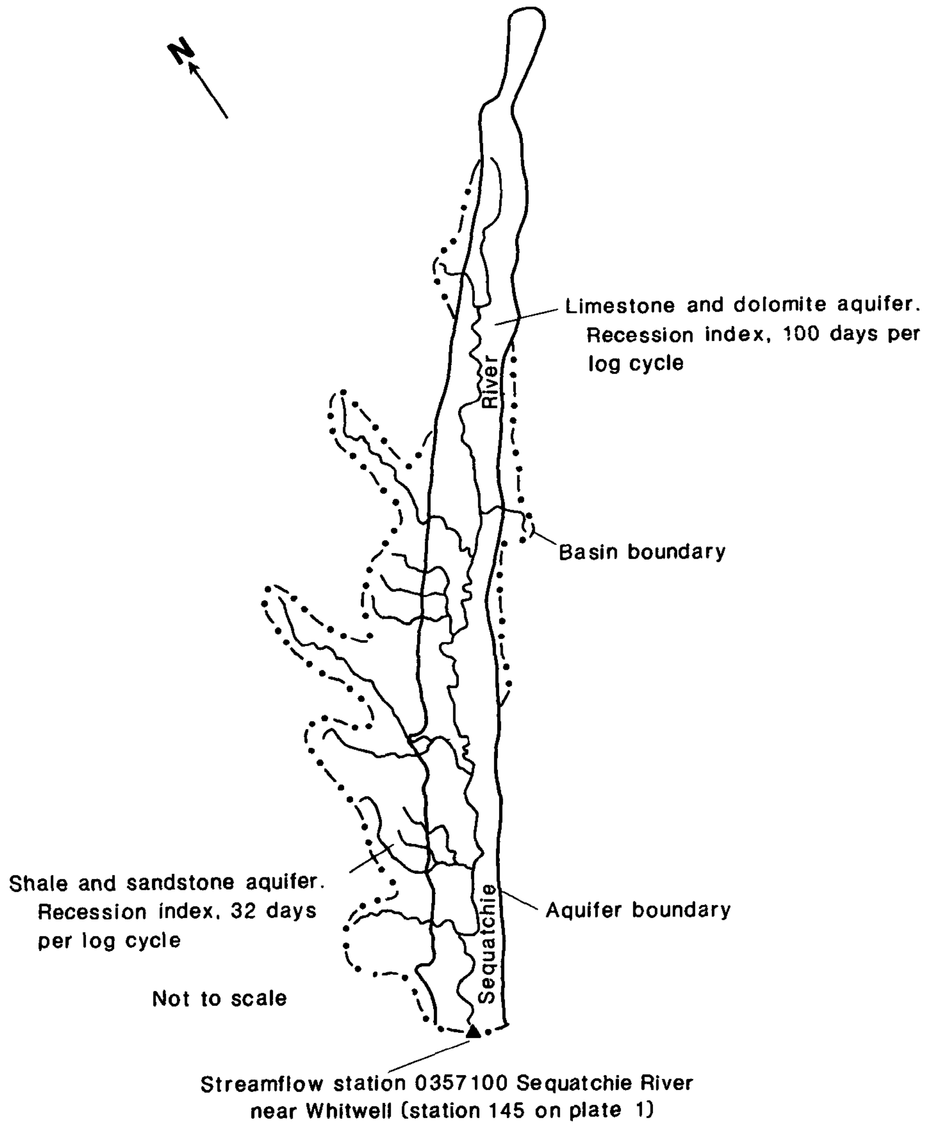

Figure 15.--Generalized sketch of Sequatchie River basin and aquifer boundaries.

For example, in the Sequatchie River Valley near Chattanooga several dolomite and limestone formations are at the surface along the floor and walls of the valley. Those formations have similar rock types and were assumed to have similar water-bearing properties within the Sequatchie Valley, consequently, they were mapped together in a single streamflow-recession index area for the entire length of the valley. Similarly, sand formations in west Tennessee which have essentially the same descriptions were assumed to have the same water-bearing properties and mapped together in a single streamflow-recession index area.

Formations with contrasting rock types and water-bearing properties were separated on plate 1 by streamflow-recession index boundaries. Formations consisting primarily of clay were separated from formations consisting primarily of sand and other geologic units. Formations consisting primarily of shale were separated from formations consisting primarily of sandstone and other geologic units. The streamflow-recession index areas on plate 1 represent the relative capacity of the formations to release water to streams during low flow. A large number of days per log cycle represent slower depletion of water from the formations and a large capacity of the formations to release water, whereas, a small number of days per log cycle represent faster depletion of water from the formations and a small capacity to release water.

The State geologic map (Hardeman and others, 1966) was inadequate in many areas to delineate streamflow-recession index boundaries. In those areas, 7½-minute geologic map quadrangles were used as an aid in delineating the boundaries. For example, the boundaries for Crooked Creek basin and for Beaver Creek basin (station number 212, pl. 1) near Huntingdon, in Carroll County were based on a geologic map of the Huntingdon quadrangle (Ferguson, 1970) and the Palmer Shelter quadrangle (Parks, 1974). The maps were used to define areas of fluvial deposits in the Crooked Creek and Beaver Creek basins. Because of higher-yielding fluvial deposits, the streamflow-recession index area of 350 days per log cycle was extended to include those stream basins. The fluvial deposits are not apparent on the state geologic map.

For three areas in west Tennessee, a mineral resources map of the Tennessee Valley Region (TVA, 1970) was used to delineate streamflow-recession index boundaries for local clay deposits near Lexington, Henderson, and Bolivar. The clay in these three areas have an effect on low flow. The capacity of the clay to release water to streams is much smaller than the surrounding sand formation. Perhaps the effects of other clay deposits on low flow of west Tennessee streams should be accounted for, but streamflow records are not available to determine such effects.

The boundary between streamflow-recession index areas of 100 days and 175 days per log cycle in Polk, Monroe, Blount, and Sevier Counties in east Tennessee was delineated based on reports by McMaster and Hubbard (1970) and King (1964).

Although descriptions of formations are some of the criteria used in delineating streamflow-recession index areas on plate 1, local variations in rock type may result in indexes considerably different than the areas indicate. The areas on plate 1 represent approximately average streamflow-recession indexes; the index may vary slightly from stream to stream within each area. The map is limited to 10 categories of index areas for practical application in estimating low flows. Approximately 15 to 20 categories could be delineated, but the map would be too cumbersome and difficult to use. The procedures used to delineate streamflow-recession index areas on plate 1 are highly subjective to interpretation of formation descriptions and to a lack of adequate information for precise positioning of the index boundaries.

Regression Analyses

Low flows at gaging stations were related to various basin and climatic characteristics by using regression techniques. Low-flow data used in the final regression analyses are tabulated in Supplement D. Characteristics tested were streamflow-recession index, drainage area, main channel slope, length of main channel, mean basin elevation, percent forest cover within the basin, and mean annual precipitation. Streamflow-recession index and drainage area were the only characteristics significant at the 5 percent level of significance.

In Tennessee the most widely used low-flow data are the $3Q_{20}$. Thus, the first regression analyses were performed for the $3Q_{20}$ low flow. Analyses for the $3Q_2$, $3Q_{10}$, and $7Q_{10}$ were performed after completion of the analyses for $3Q_{20}$. Low-flow values for the respective frequencies were substituted into the analyses. Estimating equations derived from the regression analyses are of the same general form for $3Q_2$, $3Q_{10}$, $3Q_{20}$, and $7Q_{10}$ low flows.

The first several regression attempts used streamflow-recession index determined from streamflow hydrographs. The regressions included 109 continuous-record gaging stations randomly located across the State. Those stations appear to represent low flows without significant effects from activities of man. Attempts were made to derive one set of equations to apply statewide. However, because of differences in the hydraulic characteristics of aquifers in west Tennessee and aquifers in the rest of the State, the standard error of estimate of the regression was about 73 percent for $3Q_{20}$ low flow. The equation over estimated $3Q_{20}$ for all continuous-record stations in west Tennessee. For subsequent regressions the State was separated into (1) west Tennessee and (2) central and east Tennessee.

The separation was based primarily on geology and topography. In west Tennessee the aquifers that yield significant amounts of water to streams are in unconsolidated sand and gravel; aquifers in central and east Tennessee are mostly in sandstone, limestone, and dolomite. The land surface in west Tennessee slopes gently, and consequently, the surface of the water table also slopes gently. The gently sloping water table surface in west Tennessee has less hydraulic head than the steeper sloping water table in aquifers in central and east Tennessee. Because of the contrasting difference in water-table slopes, the amount of water contributed to low flow in west Tennessee streams is less per unit area of aquifer. This is probably the principal reason the statewide $3Q_{20}$ equation overestimated low flow in west Tennessee streams.

In subsequent regression analyses for west Tennessee streams, 22 continuous-record stations were used to derive an equation to estimate $3Q_{20}$ low flow. Variables used in the equation were drainage area and streamflow-recession index determined from station hydrographs. Standard error of estimate for the regression was about 33 percent. The next regression used mapped streamflow-recession index values estimated from plate 1 for each of the 22 continuous-record stations. Standard error of estimate for that regression was about 32 percent. In the final regression analyses to derive an equation to estimate $3Q_{20}$ low flow for west Tennessee streams, information for 15 low-flow partial-record stations was added to the data set. The partial-record stations were selected randomly for geographic and geologic distribution. The final regression analysis using 22 continuous-record stations and 15 partial-record stations has a standard error of estimate of about 32 percent.

Additional regression analyses were performed for west Tennessee streams to derive equations to estimate $3Q_2$, $3Q_{10}$, and $7Q_{10}$ low flows. The standard error of estimates for those equations are 29, 25, and 24 percent, respectively. All the equations for west Tennessee streams are of the same format; the regression constant and variable exponents are different.

In regression analyses for central and east Tennessee streams, 59 continuous-record stations were used to derive an equation to estimate $3Q_{20}$ low flow. Variables used in the equation were drainage area and streamflow-recession index determined from station hydrographs. Standard error of estimate for the regression was about 28 percent. The next regression used streamflow-recession indexes estimated from plate 1 for each of the 59 continuous-record stations. Standard error of estimate for that regression was about 32 percent. In the final regression analyses for central and east Tennessee streams, streamflow-recession indexes were estimated from plate 1 for 28 additional continuous-record stations and for 116 low-flow partial-record stations. Information for those stations was added to the data set and the regression rerun. The partial-record stations were selected randomly for geographic and geologic distribution. The final regression using 87 continuous-record stations and 116 partial-record stations has a standard error of estimate of about 33 percent.

Additional regression analyses were performed for streams in central and east Tennessee to derive equations to estimate $3Q_2$, $3Q_{10}$, and $7Q_{10}$ low flows. Standard error of estimates for those equations are 35, 32, and 31 percent, respectively. All the equations for central and east Tennessee streams are of the same format; the regression constant and variable exponents are different.

Equations were derived to estimate low flows based on drainage area size as the only independent variable. Those equations are unacceptable because the standard errors of estimate associated with the equations are too large. For west Tennessee streams, the errors ranged from 100 percent for $3Q_2$ to 153 percent for $3Q_{20}$. For central and east Tennessee streams, the errors ranged from 108 percent for $3Q_2$ to 158 percent for $3Q_{20}$. These large errors indicate the importance of geologic effects on low flow. Geologic effects are accounted for, to some degree, by the mapped index of streamflow recession. After adding the streamflow-recession index variable to the equation for estimating $3Q_{20}$ in west Tennessee streams, the standard error of estimate was decreased from 153 to 32 percent. For central and east Tennessee streams, the standard error of estimate was decreased from 158 to 33 percent.

During the regression analyses a value of 30 was subtracted from the streamflow-recession index to increase the equation constant and to reduce exponents of the variables. In addition, the value of 30 is related to the streamflow-recession rate of zero low-flow areas. The streamflow-recession index for the zero low-flow areas is 32 days per log cycle. Thus, a value of 30 is the feasible maximum value that can be subtracted from the index because of logarithmic transformations used in the regression analyses. However, subtracting a large value from one of the variables in regression equations can affect the linearity of those equations.

The linearity of the low-flow equations in this report was checked with graphical plots. The graphs include plots of regression residuals versus log of the streamflow-recession index, and residuals versus log of drainage area. According to visual inspection, the group of plotting points on each graph forms a straight line. In addition, the $3Q_{20}$ low flows from observed streamflow data for gaging stations were plotted against predicted $3Q_{20}$ low flows estimated with the regression equations. Plots for stations used to derive the $3Q_{20}$ low flow equation for west Tennessee streams are illustrated in figure 16. Plots for stations used to derive the $3Q_{20}$ low-flow equation for central and east Tennessee streams are illustrated in figure 17.

Drainage areas for gaging stations used in the regression analyses for west Tennessee streams ranged from 25.0 to 1,940 mi^2. However, the distribution of drainage areas vary considerably within that range. For example, only four stations have a drainage area larger than 1,000 mi^2, and only two stations have a drainage area larger than 1,500 mi^2. The following table summarizes the distribution of drainage areas used in the regression analyses for west Tennessee streams.

Range in drainage area, (mi^2)	Number of stations in analyses
25-50	9
50-100	9
100-250	5
250-500	5
500-1,000	5
1,000-1,500	2
1,500-1,940	2
Total stations	37

The streamflow-recession indexes used in the regression analyses for west Tennessee streams ranged from 65 to 350 days per log cycle. The following table summarizes distribution of indexes for gaging stations used in the regression analyses.

Range in streamflow-recession indexes	Number of stations in analyses
60-100	5
101-150	6
151-200	11
201-250	12
251-300	2
301-350	1
Total stations	37

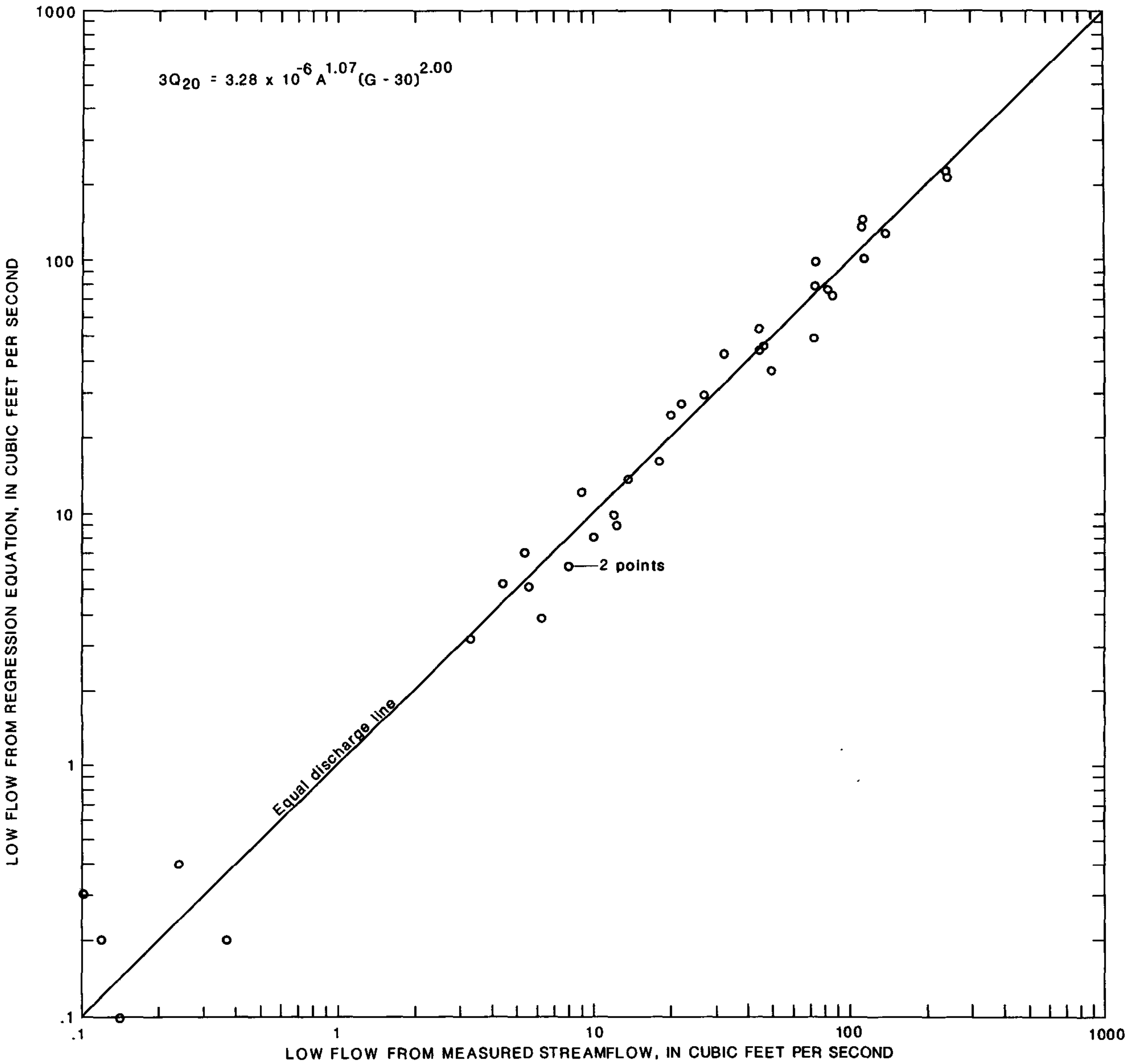

Figure 16.--Plots showing comparison of 3-day 20-year low flow from measured streamflow with 3-day 20-year low flow from regression equation for gaging stations in west Tennessee.

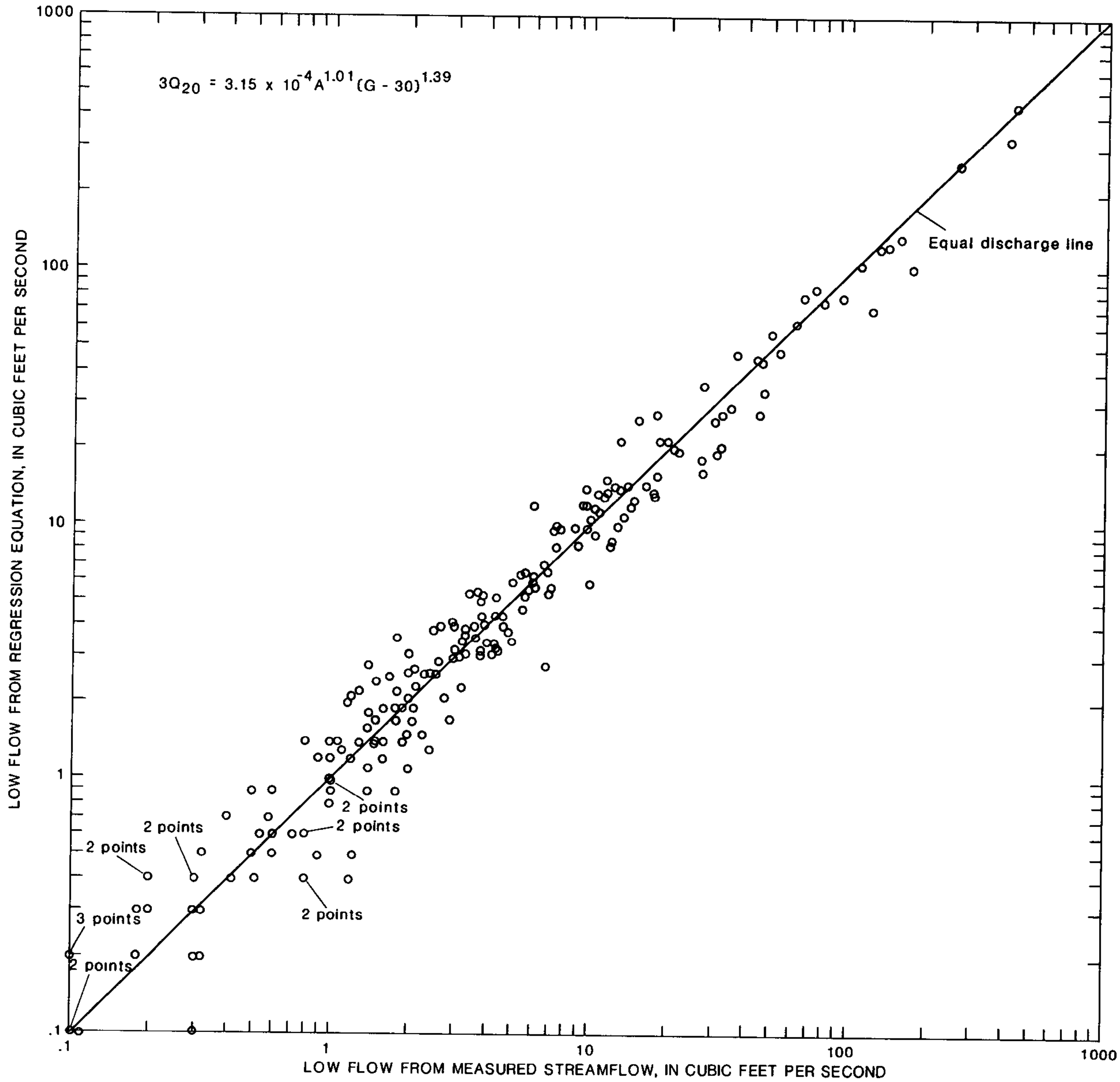

Figure 17.--Plots showing comparison of 3-day 20-year low flow from measured streamflow with 3-day 20-year low flow from regression equation for gaging stations in central and east Tennessee.

Drainage areas for gaging stations used in the regression analyses for central and east Tennessee streams ranged from 2.68 to 2,557 mi^2. The following table summarizes the distribution of drainage areas used in the regression analyses.

Range in drainage area (mi^2)	Number of stations in analyses
2.68-10	11
10-25	53
25-50	37
50-100	36
100-250	32
250-500	11
500-1,000	17
1,000-2,000	5
2,000-2,557	1
Total stations	203

Streamflow-recession indexes used in the regression analyses for central and east Tennessee streams ranged from 32 to 240 days per log cycle. The following table summarizes distribution of indexes for gaging stations used in the regression analyses.

Range in streamflow-recession indexes	Number of stations in analyses
32-40	12
41-50	26
51-65	33
66-80	32
81-100	38
101-120	31
121-140	28
141-175	3
Total stations	203

A partial analysis of the sensitivity of the regression equations to the streamflow-recession index G was performed for one set of conditions for the variable G. Results of sensitivity of the equations for west Tennessee streams for G equal 50, 100, and 200 are as follows:

A = 100 mi^2, and
G = 50, then a 10 percent error in G results in about 34 to 38 percent difference in $3Q_2$, 40 to 50 percent for $3Q_{10}$, 44 to 55 percent for $3Q_{20}$, and 40 to 49 percent for $7Q_{10}$;
for G=100, then a 10 percent error in G results in about 20 to 21 percent difference in $3Q_2$, 25 to 28 percent for $3Q_{10}$, 27 to 31 percent for $3Q_{20}$, and 24 to 27 percent for $7Q_{10}$; and
for G=200, then a 10 percent error in G results in about 16 to 17 percent difference in $3Q_2$, 21 to 23 percent for $3Q_{10}$, 22 to 25 percent for $3Q_{20}$, and 20 to 22 percent for $7Q_{10}$.

Results for sensitivity of the equations for central and east Tennessee streams for G = 50, 100, and 200 are as follows:

A = 100 mi^2, and
G = 50, then a 10 percent error in G results in about 14 percent difference in $3Q_2$, 31 to 34 percent for $3Q_{10}$, 33 to 36 percent for $3Q_{20}$, and 30 to 32 percent for $7Q_{10}$;
for G=100, then a 10 percent error in G results in about 14 percent difference in $3Q_2$, 18 to 19 percent for $3Q_{10}$, 19 to 20 percent for $3Q_{20}$, and 18 percent for $7Q_{10}$; and
for G=200, then a 10 percent error in G results in about 12 percent difference in $3Q_2$, 15 to 16 percent for $3Q_{10}$, 16 to 17 percent for $3Q_{20}$, and 14 to 15 percent for $7Q_{10}$.

The sensitivity analyses indicate that the sensitivity of the variable G in each equation decreases as the value of G increases.

SUMMARY

The permissible rate of waste disposal into Tennessee streams is based on the 3-day 20-year low flow. Thus, estimates of low flow are very important for waste-disposal regulation, and for determining withdrawal rates for water supply.

Regression equations derived from observed streamflow data at 241 gaging stations can be used with streamflow-recession index and drainage area to estimate 3-day 2-year, 3-day 10-year, 3-day 20-year, and 7-day 10-year low flow in ungaged streams in Tennessee. One set of equations apply to streams in west Tennessee, and one set applies to streams in central and east Tennessee. Standard errors of the regression estimates ranged from 24 to 32 percent for west Tennessee, and from 31 to 35 percent for central and east Tennessee. The standard errors apply only to the 241 stations used in the regression analyses.

The relative effects of different rock types and geologic units on low flow were accounted for by a streamflow-recession index expressed in days per log cycle. Streamflow recession is controlled by the hydraulic characteristics of aquifers within the stream basin. The streamflow-recession index is defined as the number of days required for base flow of the stream to recede one complete log cycle. These indexes for gaging stations are related to the geology of the State. Areal distribution of the indexes is shown on plate 1.

REFERENCES CITED

Bingham, R. H., 1982, Low-flow characteristics of Alabama streams: U.S. Geological Survey Water-Supply Paper 2083, 27 p.

______ 1985, Low flows and flow duration of Tennessee streams through 1981: U.S. Geological Survey Water Resources Investigations Report 84-4347, 325 p.

Cragwall, J. S., Jr., 1966, Low-flow analysis of streamflow data: Vanderbilt University Department of Civil Engineering, Technical Report no. 9, 242 p.

Daniel, J. F., 1976, Estimating ground-water evapotranspiration from streamflow records: Water Resources Research, v. 12, no. 3, p. 360-364.

Eaton, W. R., 1958, Summary of flow duration and low flow at stream gaging stations in Tennessee: U.S. Geological Survey open-file report, 137 p.

Ferguson, C. C., 1970, Geologic map of the Huntingdon quadrangle, Tennessee: Tennessee Department of Conservation, Division of Geology, Map GM 9-SW, scale 1:24,000.

Gold, R. L., 1981, Low-flow frequency and flow duration of Tennessee streams: U.S. Geological Survey Open-File Report 78-807, 361 p.

Hardeman, W. D., Miller, R. A., and Swingle G. D., compilers, 1966, Geologic map of Tennessee: Tennessee Department of Conservation, Division of Geology, 4 sheets, scale 1:250,000.

King, Philip B., 1964, Geology of the Central Great Smoky Mountains Tennessee: U.S. Geological Survey Professional Paper 349-C, 148 p., 13 Plates.

May, V. J., Wood, G. H., and Rima, D. R., 1970, A proposed streamflow data program for Tennessee: U.S. Geological Survey open-file report, 108 p.

McMaster, W. M., and Hubbard, E.F., 1970, Water resources of the Great Smoky Mountains National Park, Tennessee and North Carolina: U.S. Geological Survey Hydrologic Investigations Atlas, HA-420, 2 sheets, Scale 1:125,000.

Parks, W. S., 1974, Geologic map of the Palmer Shelter quadrangle, Tennessee: Tennessee Department of Conservation, Division of Geology, Map GM 10-NW, scale 1:24,000.

Riggs, H. C., 1964, The base-flow recession curve as an indicator of ground water: International Association of Scientific Hydrology Publication 63, p. 352-363.

Rorabaugh, M. I., Simons, W. D., Garrett, A. A., and McMurtrey, R. G., 1966, Exploration of methods of relating ground water to surface water-Columbia River basin first phase, with a section on Direct computation of ground-water outflow by electric analog by B. H. Bermes: U.S. Geological Survey open-file report, 124 p.

Tennessee Valley Authority, 1970, Mineral resources of the Tennessee Valley Region: Tennessee Valley Authority, Division of Water Control Planning, Geologic Branch, map report.

Trainer, F. W., and Watkins, F. A., Jr., 1975, Geohydrologic reconnaissance of the upper Potomac River basin: U.S. Geological Survey Water-Supply Paper 2035, 68 p.

Wood, G. H., and Johnson, A. M. F., 1965, Flow characteristics of Tennessee streams, part A, Summaries of flow duration and of low and high flows at gaging stations in Tennessee: Tennessee Division of Water Resources, 326 p.

SUPPLEMENT A

Examples of Estimating Low Flow for Ungaged Streams

The following computations demonstrate the application of regression equations for estimating low flow in ungaged streams in Tennessee. For the first example, assume a stream site is in west Tennessee and that the entire basin has a single streamflow recession index. Assume a 30 mi^2 basin lying within a region having a streamflow-recession index (plate 1) of 140. Estimates of low flows for the site are computed in the following manner.

$$3Q_2 = 1.17 \times 10^{-4} A^{1.02} (G-30)^{1.43}$$

$$3Q_2 = .000117 (30)^{1.02} (140-30)^{1.43}$$

$$3Q_2 = .000117 (32.1) (830)$$

$$3Q_2 = 3.1 \text{ ft}^3/\text{s}$$

$$3Q_{10} = 7.83 \times 10^{-6} A^{1.06} (G-30)^{1.86}$$

$$3Q_{10} = .00000783 (30)^{1.06} (140-30)^{1.86}$$

$$3Q_{10} = .00000783 (36.8) (6{,}266)$$

$$3Q_{10} = 1.8 \text{ ft}^3/\text{s}$$

$$3Q_{20} = 3.28 \times 10^{-6} A^{1.07} (G-30)^{2.00}$$

$$3Q_{20} = .00000328 (30)^{1.07} (140-30)^{2.00}$$

$$3Q_{20} = .00000328 (38.1) (12{,}100)$$

$$3Q_{20} = 1.5 \text{ ft}^3/\text{s}$$

$$7Q_{10} = 1.16 \times 10^{-5} A^{1.06} (G-30)^{1.79}$$

$$7Q_{10} = .0000116 (30)^{1.06} (140-30)^{1.79}$$

$$7Q_{10} = .0000116 (36.8) (4{,}509)$$

$$7Q_{10} = 1.9 \text{ ft}^3/\text{s}$$

For the second example, assume a stream site in central Tennessee is draining a basin having two streamflow-recession index areas. Seventy percent of the basin is in an area with an index of 50, and 30 percent of the basin has an index of 140. The entire basin has a drainage area of 80 mi^2. The estimating equations are used for the entire basin using each of the two streamflow-recession indexes, then a weighted average low flow is computed based on the percentage of the basin draining each streamflow-recession index area on plate 1. Estimates of low flows are computed with the regression equations in the following manner. First, assume the entire basin is draining an area having a streamflow recession index of 50.

$$3Q_2 = 2.95 \times 10^{-3} A^{0.99} (G-30)^{1.01}$$

$$3Q_2 = .00295 (80)^{0.99} (50-30)^{1.01}$$

$$3Q_2 = .00295 (76.6) (20.6)$$

$$3Q_2 = 4.7 \text{ ft}^3/\text{s}$$

Then assume the entire basin is draining an area having a streamflow-recession index of 140.

$$3Q_2 = 2.95 \times 10^{-3} A^{0.99} (G-30)^{1.01}$$

$$3Q_2 = .00295 (80)^{0.99} (140-30)^{1.01}$$

$$3Q_2 = .00295 (76.6) (115.3)$$

$$3Q_2 = 26 \text{ ft}^3/\text{s}$$

The estimated low flows of 4.7 ft^3/s and 26 ft^3/s for $3Q_2$ are weighted based on the 70 and 30 percent of the basin draining areas of each streamflow-recession index.

$$4.7 \text{ ft}^3/\text{s} (0.7) = 3.3 \text{ ft}^3/\text{s}$$

$$26 \text{ ft}^3/\text{s} (0.3) = \underline{7.8} \text{ ft}^3/\text{s}$$

$$\text{weighted average low flow} = 11.1 \text{ ft}^3/\text{s}$$

The 11.1 ft^3/s is rounded to the nearest whole number, thus, 11 ft^3/s is the estimated $3Q_2$ for the stream site in the second example.

The same procedure applies for estimating the $3Q_{10}$ low flow. First assume the entire basin is draining an area having a streamflow-recession index of 50.

$$3Q_{10} = 5.33 \times 10^{-4} A^{1.01} (G-30)^{1.30}$$

$$3Q_{10} = .000533 (80)^{1.01} (50-30)^{1.30}$$

$$3Q_{10} = .000533 (83.6) (49.1)$$

$$3Q_{10} = 2.2 \text{ ft}^3/\text{s}$$

Then assume the entire basin is draining an area having a streamflow-recession index of 140.

$$3Q_{10} = 5.33 \times 10^{-4} A^{1.01} (G-30)^{1.30}$$

$$3Q_{10} = .000533 (80)^{1.01} (140-30)^{1.30}$$

$$3Q_{10} = .000533 (83.6) (450.6)$$

$$3Q_{10} = 20 \text{ ft}^3/\text{s}$$

The estimated low flows of 2.2 ft^3/s and 20 ft^3/s for $3Q_{10}$ are weighted based on the 70 and 30 percent of the basin draining areas of each streamflow-recession index.

$$2.2 \text{ ft}^3/\text{s} (0.7) = 1.5 \text{ ft}^3/\text{s}$$

$$20 \text{ ft}^3/\text{s} (0.3) = \underline{6.0} \text{ ft}^3/\text{s}$$

$$\text{weighted average low flow} = 7.5 \text{ ft}^3/\text{s}$$

The 7.5 ft^3/s is the estimated $3Q_{10}$ low flow for the stream site in the second example.

The same procedure applies for estimating $3Q_{20}$ and $7Q_{10}$ low flows for the stream site in the second example. The appropriate equation for estimating $3Q_{20}$ and for estimating $7Q_{10}$ is used for each index area and a weighted average low flow is computed based on the percent of the basin draining each index area. The estimated $3Q_{20}$ low flow for the stream site in the second example is 6.6 ft^3/s. The estimated $7Q_{10}$ low flow for the stream in the second example is 7.7 ft^3/s.

For the third example, assume a stream site in east Tennessee. Assume the stream is draining a basin having three streamflow-recession index areas and 50 percent of the basin has an index of 65, 30 percent has an index of 100, and 20 percent has an index of 50. Drainage area of the basin is 125 mi^2. The estimating equations are used by applying each of the three streamflow-recession indexes to the entire basin, then a weighted average low flow is computed based on the percent of the basin in each index area. Estimates of low flows for this example are computed in the following manner. First, assume the entire basin has a streamflow recession index of 65.

$$3Q_2 = 2.95 \times 10^{-3} A^{0.99} (G-30)^{1.01}$$

$$3Q_2 = .00295 (125)^{0.99} (65-30)^{1.01}$$

$$3Q_2 = .00295 (119.1) (36.27)$$

$$3Q_2 = 13 \text{ ft}^3/\text{s}$$

Next, assume the entire basin has a streamflow-recession index of 100.

$$3Q_2 = 2.95 \times 10^{-3} A^{0.99} (G-30)^{1.01}$$

$$3Q_2 = .00295 (125)^{0.99} (100-30)^{1.01}$$

$$3Q_2 = .00295 (119.1) (73.04)$$

$$3Q_2 = 26 \text{ ft}^3/\text{s}$$

Finally, assume the entire basin has a streamflow-recession index of 50.

$$3Q_2 = 2.95 \times 10^{-3} A^{0.99} (G-30)^{1.01}$$

$$3Q_2 = .00295 (125)^{0.99} (50-30)^{1.01}$$

$$3Q_2 = .00295 (119.1) (20.61)$$

$$3Q_2 = 7.2 \text{ ft}^3/\text{s}$$

The estimated low flows of 13 ft^3/s, 26 ft^3/s, and 7.2 ft^3/s are weighted based on 50, 30, and 20 percent of the basin draining areas of each streamflow-recession index.

$$13 \text{ ft}^3/\text{s} (0.5) = 6.5 \text{ ft}^3/\text{s}$$

$$26 \text{ ft}^3/\text{s} (0.3) = 7.8 \text{ ft}^3/\text{s}$$

$$7.2 \text{ ft}^3/\text{s} (0.2) = \underline{1.4} \text{ ft}^3/\text{s}$$

$$\text{weighted average low flow} = 15.7 \text{ ft}^3/\text{s}$$

The 15.7 ft^3/s is rounded to the nearest whole number, thus, 16 ft^3/s is the estimated $3Q_2$ for the stream site in the third example.

The same procedure applies for estimating $3Q_{10}$, $3Q_{20}$, and $7Q_{10}$ for the stream site in the third example. The appropriate equation for estimating $3Q_{10}$, $3Q_{20}$, and $7Q_{10}$ is used for each index area and a weighted average low flow computed based on the percent of the basin draining each area. For the stream site in the third example, the $3Q_{10}$ is 9.7 ft^3/s, $3Q_{20}$ is 7.9 ft^3/s, and $7Q_{10}$ is 9.9 ft^3/s.

The weighted average low flow procedure should be used for all ungaged stream sites within the State where the basin is draining more than one streamflow recession index area.

Graphical solutions for the equations for estimating low flows in Tennessee streams are presented in figures 1 through 8. The dashed line and arrows on figures 1 through 4 indicate the procedure to follow for the following example.

$$A = 100 \text{ mi}^2$$

$G = 80$, determined from plate 1

Enter the figures with drainage area (100 mi^2) along the vertical scale. Move horizontally to the line for a streamflow-recession index of 80, then move down to the discharge scale. The following results for west Tennessee streams were obtained from figures 1 through 4 for this example:

from figure 1, $3Q_2 = 3.4\ ft^3/s$,

from figure 2, $3Q_{10} = 1.5\ ft^3/s$,

from figure 3, $3Q_{20} = 1.1\ ft^3/s$, and

from figure 4, $7Q_{10} = 1.7\ ft^3/s$.

The following results for central and east Tennessee streams were obtained using the same methods as described above except figures 5 through 8 were used for the following example:

$$A = 100\ mi^2$$

$$G = 40$$

from figure 5, $3Q_2 = 2.9\ ft^3/s$,

from figure 6, $3Q_{10} = 1.1\ ft^3/s$,

from figure 7, $3Q_{20} = 0.8\ ft^3/s$, and

from figure 8, $7Q_{10} = 1.3\ ft^3/s$.

SUPPLEMENT B

Comparison of Low-Flow Estimates for Low-Flow Partial-Record Stations in West Tennessee

[OBS = map index numbers which correspond to those on plate 2; STAN = downstream order station number; DA = drainage area, in square miles; INDEX = mapped (plate 1) streamflow recession index number, in days per log cycle (index value is a weighted average for basin where the basin lies in multiple streamflow-recession index areas); COR3Q20 = estimated 3-day, 20-year low flow, in cubic feet per second, from correlation method; and COM3Q20 = estimated 3-day, 20-year low flow, in cubic feet per second, from regression equation; * = stations used to compute standard error of estimate of the equation for partial-record stations assuming low-flow values from the correlation method are accurate]

SUPPLEMENT B

Comparison of Low-Flow Estimates for Low-Flow Partial-Record Stations in West Tennessee

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
373	03593295	10.8	65	0	0.1
374	03593520	3.06	65	0	0
376	03594122	7.17	65	0	0
377	03594123	10.5	65	0	0
381*	03594422	49.5	250	12.4	10.3
382	03594424	2.50	250	.10	.4
383	03594453	7.96	65	0	0
384	03594467	1.91	65	0	0
385	03594479	1.22	50	0	0
387	03594560	20.2	70	0	.2
493	03605060	17.6	65	0	.1
494	03605062	18.1	65	0	.1
495	03605067	4.13	65	0	0
496	03605070	5.63	65	0	0
497	03605073	2.49	65	0	0
498	03605076	27.3	65	0	.1
499	03606230	8.76	195	0	.9
500	03606250	10.4	250	1.62	1.9
501*	03606300	88.2	230	15.6	15.8
502	03606305	11.3	250	2.40	2.1
503	03606502	13.2	250	1.27	2.5
504	03606530	9.10	245	0	1.6
505	03606535	6.67	175	0	.5
506	03606537	9.46	75	0	.1
507	03606542	4.03	250	0	.7
508	03607265	14.3	265	6.60	3.1
509	07024182	1.43	350	0	.5
510*	07024200	26.5	350	7.80	11.2
511	07024330	9.99	300	1.00	2.8
512*	07024350	204	315	55.0	78.9
513*	07024400	55.7	275	3.50	14.5
514	07024600	6.37	340	0	2.3
515*	07024700	67.6	320	25.0	25.0
516	07024710	18.6	140	0	.9
517*	07024730	156	245	44.0	33.7
518*	07024750	34.2	300	9.00	10.5
519*	07024760	93.4	190	10.0	10.8
520*	07024770	286	210	56.0	45.2
521*	07024800	752	175	145	82.4
522*	07024900	110	215	10.0	17.2

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
523	07024910	23.3	140	0	1.2
524	07024920	24.0	140	0	1.2
525*	07025050	238	145	13.5	15.1
526*	07025100	268	135	15.0	14.3
527	07025180	8.44	35	0	0
528	07025190	45.6	35	0	0
529	07025200	73.8	35	.90	0
530	07025219	4.98	32	0	0
531	07025220	6.79	32	0	0
532	07025222	3.77	32	0	0
533	07025460	9.27	32	0	0
534	07025640	.14	32	0	0
535	07025642	.12	32	0	0
536*	07025900	1736	180	248	216
537	07026030	17.7	32	.52	0
538	07026380	62.5	32	0	0
539	07026400	38.6	32	0	0
540	07027100	14.8	32	.25	0
541*	07027290	39.9	70	.10	.3
542	07027352	19.8	140	.60	1.0
543	07027400	21.5	250	9.40	4.2
544	07027495	4.85	350	.92	1.8
545	07027600	32.3	180	.40	3.0
546*	07027680	687	220	132	128.5
547	07027900	27.3	32	0	0
548	07027970	11.0	32	0	0
549	07027971	13.6	32	0	0
550	07027980	28.5	32	0	0
551	07028010	1.24	32	0	0
552*	07028200	1048	175	118	117.6
553	07028600	.95	32	0	0
554	07028710	16.6	55	0	0
555*	07028920	173	210	31.0	26.4
556	07028950	13.3	140	0	.6
557	07029050	7.23	32	0	0
558	07029070	53.9	32	0	0
559	07029090	25.5	32	0	0
560	07029200	16.3	32	.28	0
561*	07029275	310	175	28.5	31.9
562*	07029350	329	90	6.00	5.8

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
563*	07029370	44.1	240	8.00	8.3
564*	07029373	55.9	200	8.00	7.0
565*	07029374	56.0	200	8.00	7.0
566	07029390	48.3	65	0	.3
567*	07029480	121	350	30.0	56.9
568*	07029490	122	350	30.0	57.4
569	07029600	24.7	335	12.0	9.4
570*	07029675	51.4	155	3.30	3.5
571	07029680	1.95	350	.60	.7
572	07029685	4.20	350	.80	1.6
573	07029950	2.16	140	0	.1
574	07029960	3.24	140	0	.1
575	07030030	39.4	32	0	0
576*	07030050	2308	170	285	255.1
577	07030100	33.9	32	.10	0
578	07030110	10.1	32	0	0
579	07030140	83.8	32	0	0
580	07030145	9.04	32	0	0
581*	07030210	78.7	165	14.0	6.4
582*	07030212	80.6	165	14.0	6.6
583	07030220	15.5	140	0	.7
584	07030260	34.7	32	0	0
585	07030350	18.2	32	0	0
586	07030352	91.0	32	2.90	0
587	07030355	153	32	3.50	0
588*	07030357	726	140	72.0	45.7
589	07030375	24.0	350	11.3	10.1
590*	07030600	597	225	150	116.5
591	07030900	7.79	32	0	0
592	07030910	11.8	32	0	0
593	07031100	1.68	32	0	0
594*	07031650	699	215	135	124.1
595	07032185	.90	32	0	0
596	07032210	75.7	35	0	0
597	07032222	9.47	32	0	0
598	07032232	116	32	0	0
599	07032250	182	32	0	0
600	07032310	49.4	32	.50	0

SUPPLEMENT C

Comparison of Low-Flow Estimates for Low-Flow Partial-Record Stations in Central and East Tennessee

[OBS = map index numbers which correspond to those on plate 2; STAN = down-stream order station number; DA = drainage area, in square miles; INDEX = mapped (plate 1) streamflow recession index number, in days per log cycle (index value is a weighted average for basin where the basin lies in multiple streamflow recession-index areas); COR3Q20 = estimated 3-day, 20-year low flow, in cubic feet per second, from correlation method; and COM3Q20 = estimated 3-day, 20-year low flow, in cubic feet per second, from regression equation; * = stations used to compute standard error of estimate of the equation for partial-record stations assuming low-flow values from the correlation method are accurate]

SUPPLEMENT C

Comparison of Low-Flow Estimates for Low-Flow Partial-Record Stations in Central and East Tennessee

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
1	03312300	1.85	50	0.54	0
2	03313820	.59	50	0	0
3	03313871	.92	50	0	0
4*	03403750	240	32	.10	.2
5	03403800	51.1	32	.10	0
6	03407879	32.8	32	0	0
7	03407990	300	32	.10	.3
8	03410000	1.21	32	0	0
9	03410010	5.27	32	0	0
10*	03410050	712	35	2.90	2.2
11	03414340	34.6	33	0	.1
12	03414350	33.7	32	0	0
13	03414470	23.4	50	0	.5
14*	03414680	70.8	50	1.50	1.5
15*	03417695	15.3	65	1.10	.7
16*	03417850	40.3	65	.80	1.8
17*	03418030	13.8	65	1.60	.6
18	03418060	74.2	60	0	2.8
19	03418189	11.2	45	0	.2
20	03418520	14.8	32	0	0
21	03419000	101	32	0	.1
22	03419140	9.80	70	0	.5
23	03419170	3.09	32	0	0
24	03419178	2.29	32	0	0
25	03419182	6.67	32	0	0
26*	03419270	37.7	60	4.50	1.4
27*	03420125	29.0	35	.10	.1
28	03420165	6.52	32	0	0
29	03420180	.20	50	0	0
30	03420185	157	32	0	.1
31*	03420880	297	140	44.0	68.1
32*	03421200	31.1	120	5.00	5.3
33*	03422600	30.2	120	4.20	5.1
34	03422610	2.92	120	0	.5
35*	03422620	3.01	120	1.00	.5
36	03422649	2.20	120	0	.4
37*	03422700	18.5	120	5.70	3.1
38*	03422802	5.07	65	.10	.2
39*	03422900	21.1	80	1.30	1.6
40*	03422950	6.36	80	.64	.5

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
41*	03423100	6.96	80	0.44	0.5
42*	03423200	7.37	80	.50	.5
43*	03423250	17.4	80	1.10	1.3
44*	03423400	34.2	65	1.50	1.6
45*	03424520	29.8	60	2.00	1.10
46*	03424600	31.1	35	.13	.1
47	03424620	9.53	35	.17	0
48*	03424640	38.0	42	.70	.4
49	03424650	92.1	35	0	.3
50	03424680	41.2	63	0	1.7
51	03424700	12.9	35	0	0
52*	03424750	227	43	2.7	2.7
53	03424790	10.4	35	0	0
54	03424800	12.0	35	0	0
55	03424850	43.0	35	0	.1
56*	03424900	26.9	35	.10	.1
57	03425060	14.6	32	0	0
58	03425080	50.9	32	0	0
59	03425200	19.1	36	0	.1
60	03425290	64.0	36	0	.3
61	03425300	74.2	36	0	.3
62	03425350	22.3	36	0	.1
63	03425355	25.4	36	0	.1
64	03425360	106	37	0	.5
65	03425580	15.6	32	0	0
66	03425600	11.0	32	0	0
67	03425610	32.4	32	0	0
68	03425618	22.9	40	0	.2
69	03425622	55.8	38	0	.3
70	03425624	97.3	37	0	.5
71	03425645	4.74	35	0	0
72	03425698	2.35	32	0	0
73	03425700	3.32	32	0	0
74	03425775	2.28	32	0	0
75	03425800	.86	32	0	0
76	03425850	32.4	32	0	0
77	03425851	1.39	32	0	0
78	03426000	19.2	46	0	.3
79	03426030	38.1	40	0	.3
80	03426390	31.2	36	0	.1

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
81	03426400	46.0	36	0	0.2
82*	03426700	7.03	55	.35	.2
83	03426840	5.42	42	0	.1
84	03426860	28.5	47	0	.5
85*	03426900	125	51	3.20	2.8
86	03426920	10.9	32	0	0
87	03426950	30.7	33	0	0
88	03426960	48.2	33	0	.1
89	03427000	37.0	32	0	0
90	03427700	10.5	32	0	0
91	03427720	10.3	32	0	0
92	03427800	56.3	32	0	0
93	03427820	12.4	33	0	0
94	03428050	24.5	32	0	0
95	03428100	165	32	0	.1
96	03428190	5.85	32	0	0
97	03428200	177	32	2.10	.2
98	03428400	49.9	32	0	0
99	03428410	51.3	32	0	0
100	03428490	2.58	32	0	0
101	03429050	50.8	32	0	0
102	03429500	69.7	32	0	.1
103	03429900	11.1	32	0	0
104	03430020	35.6	32	0	0
105	03430130	5.23	32	0	0
106	03430145	.53	35	0	0
107	03430150	29.4	33	0	0
108	03430400	12.0	33	0	0
109	03430700	3.86	35	0	0
110	03430900	58.3	33	0	.1
111	03431060	93.4	34	0	.2
112	03431070	101	34	0	.2
113	03431085	107	34	0	.2
114	03431100	1.51	35	0	0
115	03431120	3.30	35	0	0
116	03431200	7.42	35	0	0
117	03431350	14.2	35	0	0
118	03431580	13.3	35	0	0
119	03431599	51.3	35	0	.2
120	03431610	5.29	35	0	0

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
121	03431630	2.21	35	0	0
122	03431640	1.25	35	0	0
123	03431660	1.43	35	0	0
124	03431668	12.0	35	0	0
125	03431680	2.3	35	0	0
126	03431900	11.4	33	0	0
127	03432000	64.6	33	0	.1
128	03432200	25.7	33	0	0
129	03432250	11.4	34	0	0
130	03432300	15.9	34	0	0
131	03432310	6.85	33	0	0
132	03432320	138	33	0	.2
133	03432330	10.2	34	0	0
134	03432335	9.55	34	0	0
135	03432350	191	33	.10	.3
136	03432360	194	33	.10	.3
137	03432400	210	34	.10	.5
138	03432420	3.65	35	0	0
139	03432500	66.9	36	0	.3
140	03432900	17.6	35	0	.1
141	03432950	27.2	35	0	.1
142	03432960	5.06	35	0	0
143*	03433720	80.2	90	4.00	7.8
144*	03433810	27.2	80	2.30	2.0
145*	03433910	66.2	100	6.00	8.0
146*	03434580	727	55	21.2	21.5
147*	03434585	5.05	80	.40	.4
148	03434590	13.3	80	.20	1.0
149*	03434595	13.8	80	.60	1.0
150*	03434640	107	90	7.20	10.5
151*	03434700	843	60	33.0	32.1
152	03435002	27.3	50	.10	.6
153*	03435044	78.4	52	1.90	1.9
154*	03435110	19.7	50	.35	.4
155*	03435120	69.2	53	1.00	1.8
156*	03435300	547	70	27.0	30.9
157	03435580	.43	50	0	0
158	03435602	.48	50	0	0
159	03435604	.17	50	0	0
160	03435705	.83	50	0	0

SUPPLEMENT C--Continued

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
161	03435727	3.09	50	0	0.1
162	03435772	1.65	50	0	0
163	03435791	2.22	50	0	0
164	03435805	1.54	50	0	0
165	03435808	.43	50	0	0
166	03435950	1.32	50	0	0
167*	03436130	20.5	80	1.40	1.5
168*	03436300	69.3	80	5.60	5.2
169*	03436440	179	80	9.10	13.7
170*	03436490	455	77	94.0	104
171*	03436655	52.2	120	10.0	8.9
172*	03436930	55.7	120	6.00	9.5
173	03437060	11.4	120	0	1.9
174	03437080	2.37	120	0	.4
175	03437090	1.95	120	0	.3
176	03437196	2.85	80	0	.2
177*	03454790	32.6	100	3.10	3.9
178*	03461260	5.22	100	.21	.6
179	03461508	12.5	50	1.02	.3
180	03461510	13.5	50	1.05	.3
181	03464915	6.32	100	2.45	.7
182*	03465220	57.3	100	5.0	6.9
183*	03465610	23.1	120	3.40	3.9
184*	03465631	4.21	120	.96	.7
185*	03466234	15.5	120	2.25	2.6
186	03466910	18.7	65	0	.8
187	03467470	9.30	65	0	.4
188*	03467895	9.30	82	.74	.7
189*	03468050	30.8	70	1.95	1.7
190	03468085	1.90	65	0	.1
191*	03468196	3.48	120	.56	.6
192*	03469100	46.1	140	8.60	10.4
193*	03469105	3.74	100	.20	.4
194*	03469119	18.0	100	1.90	2.1
195*	03469130	110	105	12.4	14.7
196*	03469230	20.0	135	3.20	4.2
197*	03469253	31.8	125	4.70	5.8
198*	03469282	7.23	130	1.25	1.4
199	03469290	3.89	100	.11	.5
200*	03469400	59.9	125	7.70	11.0

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
201*	03469620	50.2	65	3.30	2.3
202*	03470330	28.3	80	2.40	2.1
203*	03478550	48.0	120	10.4	8.2
204*	03478590	8.32	115	1.70	1.3
205	03478639	2.98	120	0	.5
206*	03481700	6.77	75	.63	.4
207*	03481800	24.4	75	1.38	1.6
208*	03481815	70.0	75	4.44	4.6
209*	03484200	57.8	105	6.20	7.7
210*	03484797	32.6	100	7.10	3.9
211*	03486230	39.0	100	4.40	4.7
212*	03486488	6.78	70	.32	.4
213	03486660	8.74	120	4.10	1.5
214*	03486860	9.06	120	1.40	1.5
215*	03487100	20.3	120	3.40	3.4
216*	03487548	36.3	110	4.10	5.2
217*	03487562	43.2	100	4.50	5.2
218	03490300	9.22	80	2.50	.7
219*	03491800	32.3	50	.60	.7
220	03491900	2.60	120	.50	.4
221*	03492005	3.13	100	.44	.4
222*	03492995	30.6	80	2.50	2.3
223	03494695	7.91	80	.20	.6
224*	03494800	58.8	50	1.70	1.2
225*	03494955	3.62	80	.50	.3
226*	03497113	6.36	80	1.08	.5
227*	03497200	60.1	165	19.5	18.0
228*	03498715	17.9	120	4.00	3.0
229*	03499000	13.5	120	2.30	2.3
230*	03499053	11.8	120	1.80	2.0
231*	03499055	30.6	120	8.10	5.2
232*	03499062	32.0	120	7.20	5.4
233*	03499110	352	105	66.0	47.5
234	03499160	2.49	80	0	.2
235*	03499290	5.00	120	.60	.8
236*	03499412	10.5	92	1.00	1.0
237*	03518130	60.3	115	9.90	9.5
238*	03518456	59.9	105	9.40	7.9
239*	03518470	21.7	175	8.00	7.1
240*	03518750	25.2	57	1.50	.8

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
241*	03519000	271	105	46.0	36.5
242*	03519600	11.2	120	1.20	1.9
243*	03519660	43.4	120	8.40	7.4
244	03519682	2.62	120	.30	.4
245*	03519700	30.7	110	5.40	4.4
246*	03527700	4.83	50	.11	.1
247*	03528200	21.7	50	.30	.5
248	03528240	8.50	65	1.90	.4
249*	03531700	23.9	105	3.50	3.1
250*	03531800	4.65	65	.30	.2
251*	03534200	39.3	65	2.40	1.8
252	03534400	4.98	65	0	.2
253*	03534500	9.45	67	.30	.5
254*	03534509	11.4	70	.65	.6
255*	03535055	103	87	8.40	9.4
256*	03535183	7.12	82	1.10	.6
257*	03535187	36.4	70	2.50	2.0
258*	03535195	52.5	76	3.60	3.5
259*	03535200	56.1	79	4.20	4.1
260*	03535400	86.8	82	6.20	6.9
261	03538000	6.01	87	0	.5
262	03538200	55.9	46	4.10	.9
263*	03538215	18.4	35	.15	.1
264	03538243	1.78	65	.11	.1
265*	03538244	12.4	70	1.00	.7
266	03538247	2.40	65	.10	.1
267	03538296	13.8	34	0	0
268	03538398	31.2	35	0	.1
269	03538600	12.0	32	0	0
270	03539750	153	32	0	.1
271	03539860	50.3	33	0	.1
272	03540793	19.5	32	0	0
273	03541303	34.3	34	0	.1
274	03541487	19.0	32	0	0
275	03541990	3.48	58	0	.1
276*	03541995	11.8	62	1.85	.5
277*	03542000	108	35	.44	.3
278	03542500	95.9	32	0	.1
279	03542503	6.69	65	.64	.3
280*	03542505	3.03	65	.20	.1

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
281*	03543300	32.3	105	5.60	4.3
282*	03544220	6.48	65	.22	.3
283	03556560	4.39	50	.95	.1
284*	03556700	3.82	57	.10	.1
285*	03557200	9.90	76	.50	.7
286*	03557300	101	90	18.5	9.9
287*	03564920	7.40	110	.96	1.1
288*	03565087	33.5	120	6.00	5.7
289	03565130	2.90	140	0	.6
290	03565405	2.04	120	.30	.3
291*	03565410	24.3	140	3.10	5.4
292*	03565437	22.1	140	7.80	4.9
293*	03565444	26.8	140	10.0	6.0
294*	03565730	69.3	140	19.5	15.7
295*	03566050	15.6	100	1.70	1.9
296*	03566102	21.2	100	2.00	2.5
297*	03566106	25.2	100	2.50	3.0
298*	03566112	35.1	100	3.80	4.2
299*	03566117	2.87	120	.16	.5
300*	03566123	2.81	120	.52	.5
301*	03566128	42.1	120	8.20	7.2
302*	03566137	11.6	120	1.80	1.9
303*	03566235	65.9	120	6.00	11.3
304	03566253	3.12	84	0	.3
305	03566271	5.84	65	0	.3
306	03566292	57.2	32	0	0
307	03566319	17.6	40	0	.1
308	03566400	49.0	35	0	.2
309	03566410	18.1	65	1.75	.8
310*	03566430	10.8	65	.30	.5
311	03566530	62.6	35	0	.2
312	03566533	5.05	65	0	.2
313*	03566550	6.68	65	.29	.3
314*	03566625	108	58	3.01	3.7
315	03566985	2.63	65	.10	.1
316	03566990	4.55	65	0	.2
317	03566996	12.1	66	.23	.6
318*	03567400	153	120	28.0	26.4
319*	03567494	14.2	120	2.60	2.4
320*	03567496	19.3	120	2.65	3.3

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
321*	03567590	12.1	80	0.50	0.9
322	03567940	3.00	120	.10	.5
323*	03568630	63.9	65	3.20	2.9
324*	03568670	70.7	65	4.60	3.3
325	03569016	1.16	65	0	.1
326*	03569193	6.37	65	.15	.3
327	03569245	22.6	32	0	0
328	03570480	20.6	32	0	0
329*	03570560	12.1	100	1.40	1.4
330*	03570602	106	93	5.10	11.1
331	03570650	154	93	9.50	16.2
332	03570800	15.4	32	0	0
333	03570810	66.1	33	0	.1
334*	03570840	5.5	66	.20	.3
335	03570855	15.3	35	0	0
336	03570870	17.9	35	0	.1
337	03571320	6.14	32	0	0
338	03571700	12.9	51	0	.3
339	03571775	16.9	50	0	.4
340*	03571825	117	52	2.85	2.8
341	03571827	4.42	75	0	.3
342	03572030	.42	50	0	0
343*	03572090	78.2	50	.58	1.7
344	03577966	25.7	50	0	.5
345	03577985	22.4	49	0	.4
346*	03578030	21.6	48	.21	.4
347	03578190	18.4	125	0	3.3
348*	03578500	41.3	80	3.20	3.1
349*	03578504	50.5	92	4.00	5.1
350	03579620	12.3	140	.29	2.7
351*	03579700	41.2	140	8.40	9.3
352	03580000	20.2	50	.12	.4
353	03580200	10.3	50	.55	.2
354*	03580500	77.1	60	4.50	2.9
355*	03580700	24.6	95	4.40	2.6
356	03581000	23.1	50	1.90	.5
357	03582532	26.1	35	0	.1
358	03582646	22.5	40	0	.2
359	03583319	52.0	41	0	.5
360*	03583330	28.9	105	2.55	3.8

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
361*	03583400	86.6	70	6.70	4.8
362*	03583480	22.9	50	.50	.5
363*	03584050	8.10	50	.10	.2
364	03584300	35.7	50	0	.7
365	03585200	13.5	140	0	3.0
366	03587270	23.5	140	2.85	5.3
367	03587300	38.8	140	2.90	8.7
368*	03588200	18.6	140	4.40	4.2
369*	03588260	53.6	140	6.00	12.1
370*	03588340	31.5	140	10.5	7.1
371*	03588515	8.58	140	.90	1.9
372*	03588600	46.6	140	10.0	10.5
375*	03593585	21.7	130	6.60	4.2
378*	03594140	84.4	95	6.50	9.2
379	03594163	15.5	51	0	.3
380	03594200	19.0	77	0	1.3
386*	03594484	251	150	55.0	64.9
388	03594900	3.29	140	.15	.7
389	03594920	7.12	140	.17	1.6
390	03595000	55.2	135	4.00	11.7
391*	03595100	13.0	140	2.26	2.9
392	03595200	19.2	135	.75	4.0
393*	03595500	40.4	120	4.60	6.9
394	03595900	8.64	140	.56	1.9
395	03596090	22.8	140	1.00	5.1
396	03596100	28.1	140	2.80	6.3
397*	03596130	30.6	140	11.0	6.9
398	03596200	3.32	140	0	.7
399	03596543	.45	77	1.20	0
400	03596550	5.92	56	2.36	.2
401*	03596700	16.8	50	.20	.4
402	03596900	12.1	45	0	.2
403*	03597200	80.1	51	1.60	1.8
404*	03597220	85.5	50	1.70	1.8
405	03597535	5.97	34	0	0
406	03597600	36.4	35	0	.1
407*	03597787	17.2	52	.68	.4
408	03597800	18.3	51	.90	.4
409*	03597900	49.6	34	.10	.1
410	03598100	30.7	35	0	.1

SUPPLEMENT C--Continued

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
411	03598150	9.32	32	0	0
412	03598180	40	32	0	0
413	03598190	31.5	33	0	0
414	03598250	71.9	32	0	.1
415	03598298	23.7	32	0	0
416	03599100	48.7	33	0	.1
417*	03599250	916	62	23.5	38.2
418	03599300	28.9	32	0	0
419	03599403	41.6	32	0	0
420*	03599418	1028	60	30.0	39.2
421	03599420	9.24	32	0	0
422	03599421	6.21	32	0	0
423*	03599450	74.0	35	.20	.2
424*	03600256	32.8	38	.55	.2
425	03600280	15.1	41	0	.1
426	03600410	6.39	35	0	0
427*	03601080	14.8	95	1.15	1.6
428*	03601100	48.3	74	3.50	3.0
429	03601250	36.7	34	.29	.1
430*	03601500	112	54	2.30	3.1
431*	03601550	45.2	72	4.40	2.7
432*	03601700	99.8	115	23.0	15.8
433	03601855	25.5	140	0	5.7
434*	03601900	154	130	44.0	30.7
435*	03601980	5.69	95	.56	.6
436*	03602110	9.0	95	1.15	1.0
437*	03602192	21.2	140	5.00	4.7
438*	03602200	6.21	80	.50	.5
439*	03602229	6.31	110	.56	.9
440*	03602232	13.7	120	1.05	2.3
441*	03602245	19.8	140	5.80	4.4
442	03602316	12.6	140	0	2.8
443*	03602590	22.9	140	6.40	5.1
444*	03602630	7.64	140	2.10	1.7
445*	03602660	30.8	140	4.15	6.9
446*	03602700	51.2	140	8.10	11.5
447*	03603479	26.9	125	4.90	4.9
448*	03603500	75.1	130	19.0	14.9
449*	03603540	21.4	140	6.30	4.8
450*	03603560	12.1	140	3.30	2.7

OBS	STAN	DA	INDEX	COR3Q20	COM3Q20
451*	03603580	101	140	16.00	22.9
452*	03603586	10.1	140	1.36	2.2
453*	03603590	15.3	140	2.60	3.4
454*	03603600	126	140	25.0	28.7
455*	03603690	19.3	140	5.00	4.3
456*	03603710	6.57	130	2.00	1.3
457	03603713	4.67	140	0	1.0
458*	03603716	20.1	135	3.00	4.2
459*	03603730	24.6	135	4.10	5.2
460*	03603770	56.6	95	11.5	6.1
461	03603780	6.85	105	0	.9
462*	03603850	22.8	140	2.40	5.1
463*	03603860	12.3	140	1.58	2.7
464*	03603900	56.4	115	7.90	8.9
465	03604012	16.2	130	0	3.2
466	03604020	14.3	130	0	2.8
467	03604030	1.68	140	0	.4
468*	03604050	516	120	105	90.0
469	03604120	21.0	55	2.00	.6
470*	03604150	15.2	105	2.30	2.0
471*	03604200	45.1	115	10.0	7.1
472*	03604240	83.6	96	18.1	9.3
473*	03604620	31.3	140	7.30	7.0
474	03604900	2.22	120	0	.4
475	03605200	10.8	120	0	1.8
476	03605500	20.1	120	.58	3.4
477	03605525	27.4	120	1.10	4.6
478	03605580	6.22	120	0	1.0
479*	03605953	24.8	120	2.00	4.2
480*	03605968	54.5	120	6.00	9.3
481	03607585	.78	120	0	.1
482	03607590	.73	120	0	.1
483	03607598	.46	120	0	.1
484	03607800	2.14	120	0	.4
485	03608010	2.04	120	0	.3
486	03608020	4.15	120	0	.7
487	03608022	.59	120	0	.1
488	03608030	1.79	120	0	.3
489	03608035	2.28	120	0	.4
490	03608040	1.29	120	0	.2
491	03608043	1.53	120	0	.3
492	03608046	1.00	120	0	.2

SUPPLEMENT D

Low Flow Values Estimated from Observed Streamflow Records and Regression Equations, and Data Used to Derive the Equations for Tennessee Streams

[Map index numbers correspond to station identification numbers on plate 1; streamflow recession index number from plate 1; *, sites used to derive low-flow equations for streams in west Tennessee; mi^2, square miles; ft^3/s, cubic feet per second]

Map index No.	Station No.	Drainage area (mi^2)	Streamflow recession index	$3Q_{20}$ Observed (ft^3/s)	$3Q_{20}$ Regression (ft^3/s)	$3Q_2$ Observed (ft^3/s)	$3Q_2$ Regression (ft^3/s)	$3Q_{10}$ Observed (ft^3/s)	$3Q_{10}$ Regression (ft^3/s)	$7Q_{10}$ Observed (ft^3/s)	$7Q_{10}$ Regression (ft^3/s)
1	03408500	382	32	0.18	0.3	3.98	2.2	0.39	0.5	0.47	0.7
2	03409500	272	35	.80	1.4	4.54	3.9	1.22	1.2	1.45	1.5
3	03414500	202	47	4.00	3.4	9.06	10.1	4.74	4.5	5.01	5.0
4	03415000	114	48	2.74	2.1	4.28	6.1	2.94	2.7	3.08	3.0
5	03415500	445	53	10.3	11.7	21.4	30.1	12.0	14.7	14.0	16.2
6	03416000	106	60	3.58	4.0	8.23	9.5	4.32	4.9	5.19	5.3
7	03416100	138	62	6.1	5.7	11.0	13.2	6.9	6.9	7.6	7.6
8	03417750	21.2	65	1.0	1.0	1.2	2.2	1.1	1.2	1.1	1.3
9	03417800	15.1	65	.58	.7	1.0	1.6	.66	.8	.69	.9
10	03418000	78.7	65	3.3	3.7	6.2	8.3	3.8	4.4	3.90	4.8
11	03418020	22.5	65	1.0	1.0	2.1	2.4	1.2	1.2	1.25	1.4
12	03418050	50.3	65	3.2	2.3	6.0	5.3	3.6	2.8	3.7	3.1
13	03419300	16.7	75	1.4	1.1	2.3	2.3	1.6	1.3	1.7	1.4
14	03419500	157	75	10.0	10.5	19.0	21.1	11.6	12.3	12.5	13.2
15	03420000	175	76	14.2	12.0	25.5	24.1	16.0	14.1	17.2	15.1
16	03420120	78.8	67	3.0	4.0	5.4	8.7	3.4	4.7	3.8	5.2
17	03420200	174	37	.5	.9	3.8	3.6	.7	1.2	1.0	1.4
18	03420500	126	140	34.4	29.3	45.3	42.0	36.7	31.3	37.1	32.3
19	03420800	132	60	3.8	5.0	11.0	11.8	4.5	6.1	5.6	6.7
20	03420900	303	110	44.0	45.5	70.0	72.8	48.0	50.3	54.0	52.3
21	03421000	642	85	49.8	57.5	88.5	105	57.0	66.0	63.8	69.5
22	03422800	16.8	60	.6	.6	.8	1.5	.7	.8	.7	.8
23	03424660	42.3	50	1.8	.9	3.3	2.5	2.1	1.1	2.2	1.3
24	03424670	137	35	1.2	.4	2.9	1.1	1.4	.6	1.6	.7
25	03426600	25.5	90	1.7	2.5	3.8	4.6	2.1	2.8	2.5	3.0
26	03426800	39.1	104	3.80	5.2	7.60	8.8	4.60	5.7	4.90	6.1
27	03426850	24.5	50	.32	.5	1.0	1.5	.41	0.7	.54	.7
28	03426880	24.0	60	1.4	.9	3.0	2.2	1.6	1.1	2.0	1.2
29	03427500	262	46	2.95	4.1	9.71	12.3	3.85	5.4	5.15	6.0
30	03427900	65.1	34	.18	.2	.7	.8	.34	.2	.38	.3
31	03428070	165	32	.11	.1	.6	.9	.2	.2	.2	.3
32	03429000	571	45	7.33	8.3	16.0	25.1	7.80	10.9	9.95	12.2
33	03430100	892	45	11.2	13.0	20.7	39.1	12.8	17.1	13.4	19.0
34	03431600	51.6	37	.3	.3	1.10	1.1	.40	.4	.41	.4
35	03431700	24.3	35	.1	.1	.60	.4	.2	.1	.3	.1
36	03431800	97.2	100	9.28	12.0	14.0	20.5	9.96	13.4	10.3	14.1
37	03433500	408	32	.42	.4	5.90	2.3	.95	.6	1.0	.7
38	03433700	59.6	130	6.0	12.0	15.0	18.1	10.0	13.0	10.0	13.5
39	03434000	115	100	12.2	14.2	21.0	24.3	13.8	15.9	14.2	16.7
40	03434500	681	56	19.8	21.4	44.4	52.1	23.6	26.5	25.4	29.0

Map index No.	Station No.	Drainage area (mi^2)	Streamflow recession index	$3Q_{20}$ Observed (ft^3/s)	$3Q_{20}$ Regression (ft^3/s)	$3Q_2$ Observed (ft^3/s)	$3Q_2$ Regression (ft^3/s)	$3Q_{10}$ Observed (ft^3/s)	$3Q_{10}$ Regression (ft^3/s)	$7Q_{10}$ Observed (ft^3/s)	$7Q_{10}$ Regression (ft^3/s)
41	03434600	56.2	90	5.8	5.6	9.8	10.2	6.4	6.3	6.5	6.7
42	03435007	11.2	57	.3	.4	.7	.9	.32	.4	.34	.5
43	03435030	15.1	45	.1	.2	.7	.7	.2	.3	.2	.3
44	03435400	98.0	100	9.5	12.0	15.0	20.7	10.4	13.5	10.6	14.3
45	03435790	75.1	50	1.4	1.6	4.0	4.5	1.8	2.0	1.9	2.3
46	03435900	32.0	80	1.5	2.4	2.6	4.8	1.7	2.8	1.8	3.0
47	03436000	186	55	3.66	5.5	10.2	13.8	4.66	6.8	5.0	7.5
48	03436100	935	75	61.3	63.4	98.4	124	65.4	74.4	66.6	78.8
49	03436200	188	80	14.0	14.6	20.0	28.1	15.0	16.9	15.5	18.0
50	03436430	130	80	7.4	10.0	13.0	19.5	8.0	11.6	8.6	12.4
51	03436700	124	120	18.3	21.8	25.1	33.7	19.4	23.7	20.2	24.7
52	03436900	34.5	120	5.0	6.0	7.0	9.5	5.2	6.5	5.4	6.9
53	03436970	11.9	120	1.17	2.0	3.5	3.3	1.5	2.2	1.53	2.4
54	03455000	1,858	140	434	443	854	609	511	475	541	480
55	03461200	10.2	100	1.6	1.2	4.60	2.2	2.1	1.4	2.3	1.5
56	03461300	55.3	94	6.0	6.0	13.0	10.7	7.2	6.7	8.0	7.2
57	03464815	81.0	100	7.6	9.7	17.0	17.1	9.0	11.1	9.9	11.8
58	03465000	15.9	100	2.1	1.9	4.1	3.4	2.4	2.2	2.5	2.3
59	03465500	805	100	173	101	349	168	206	113	224	118
60	03466200	78.1	120	11.6	13.6	17.5	21.3	12.5	14.9	13.0	15.6
61	03466370	14.9	120	2.43	2.6	3.9	4.1	2.65	2.8	2.8	3.0
62	03466700	40.4	50	.6	.9	1.6	2.4	.7	1.1	.8	1.2
63	03466840	78.0	98	10.2	9.2	14.0	16.0	11.0	10.3	11.5	10.9
64	03466885	7.99	50	.1	.2	.24	.5	.1	.2	.2	.2
65	03467000	220	68	10.5	11.6	17.8	24.9	11.9	13.9	12.6	14.9
66	03467490	41.2	65	1.9	1.9	3.2	4.3	2.1	2.3	2.3	2.5
67	03468250	10.4	50	.1	.2	.4	.6	.1	.3	.2	.3
68	03469112	11.2	100	1.5	1.4	3.4	2.4	1.9	1.5	2.0	1.6
69	03469160	64.1	72	3.3	3.9	8.2	8.1	3.9	4.5	4.5	4.9
70	03469238	24.0	111	3.6	3.6	7.5	5.9	4.5	3.9	4.6	4.2
71	03469500	76.2	95	9.0	8.4	22.0	15.0	10.8	9.5	12.4	10.1
72	03470000	353	80	32.1	27.5	71.8	52.6	38.9	31.9	43.2	33.8
73	03476980	18.4	50	.3	.4	.9	1.1	.4	.5	.4	.6
74	03478602	12.9	96	1.6	1:4	2.3	2.6	1.9	1.6	1.9	1.7
75	03481625	12.6	88	1.2	1.2	2.4	2.2	1.4	1.3	1.5	1.4
76	03482000	102	76	6.6	7.0	15.0	14.1	7.9	8.2	8.5	8.8
77	03484420	13.8	100	1.5	1.7	3.5	3.0	1.9	1.9	2.1	2.0
78	03484911	25.5	70	1.3	1.4	3.8	3.1	1.7	1.7	1.9	1.8
79	03485500	137	110	31.9	20.4	57.3	33.1	36.8	22.5	39.1	23.6
80	03486200	28.1	102	1.8	3.6	4.9	6.2	2.2	4.0	2.4	4.2

Map index No.	Station No.	Drainage area (mi^2)	Streamflow recession index	$3Q_{20}$ Observed (ft^3/s)	$3Q_{20}$ Regression (ft^3/s)	$3Q_2$ Observed (ft^3/s)	$3Q_2$ Regression (ft^3/s)	$3Q_{10}$ Observed (ft^3/s)	$3Q_{10}$ Regression (ft^3/s)	$7Q_{10}$ Observed (ft^3/s)	$7Q_{10}$ Regression (ft^3/s)
81	03486500	10.3	50	0.3	0.2	1.5	0.6	0.4	0.3	0.5	0.3
82	03487520	44.5	65	1.2	2.1	2.5	4.7	1.3	2.5	1.4	2.7
83	03487550	36.3	100	4.3	4.4	6.70	7.7	4.7	5.0	4.9	5.3
84	03491000	47.3	70	2.3	2.6	4.4	5.7	2.7	3.1	2.8	3.4
85	03491300	47.0	65	1.3	2.2	2.5	4.9	1.5	2.6	1.6	2.9
86	03494528	18.2	120	4.2	3.1	6.0	5.0	4.5	3.4	4.6	3.6
87	03494740	6.68	50	.1	.1	.8	.4	.11	.2	.13	.2
88	03495000	61.4	65	2.6	2.9	4.8	6.4	2.9	3.4	3.0	3.8
89	03497300	106	145	30	26	48.0	37.0	33.0	27.8	36.0	28.7
90	03498000	192	90	30.2	19.2	54.7	34.6	34.5	21.8	36.3	23.1
91	03498500	269	100	46.8	33.5	80.0	56.5	52.7	37.5	54.8	39.3
92	03499200	13.2	135	5.4	2.81	6.8	4.3	5.6	3.0	5.8	3.2
93	03499300	11.2	120	1.6	1.9	2.9	3.1	1.8	2.1	1.9	2.2
94	03499620	9.62	120	2.1	1.7	3.0	2.7	2.2	1.8	2.2	1.9
95	03518410	67.1	87	5.2	6.2	12.0	11.5	6.1	7.1	6.6	7.5
96	03518500	118	112	26.6	18.2	47.5	29.2	30.1	20.0	31.4	20.9
97	03518800	27.9	100	4.2	3.4	6.6	5.9	4.5	3.8	4.8	4.0
98	03519640	16.0	120	1.4	2.8	3.7	4.4	1.8	3.0	1.9	3.2
99	03519732	47.2	140	13.5	10.9	18.0	15.8	14.3	11.6	14.9	12.1
100	03520043	23.3	120	4.6	4.0	7.0	6.4	5.0	4.4	5.2	4.6
101	03527600	85.8	60	4.4	3.2	8.0	7.7	5.0	3.9	5.2	4.3
102	03528000	1,474	65	121	70.6	208	152	136	85.1	140	91.0
103	03528300	19.0	90	1.8	1.9	2.6	3.5	1.9	2.1	2.1	2.3
104	03528400	2.68	120	.5	.5	.8	.8	.6	.5	.6	.5
105	03531815	19.9	115	3.8	3.2	5.2	5.2	3.9	3.5	4.2	3.7
106	03531900	62.5	75	3.95	4.1	6.2	8.5	4.5	4.8	4.5	5.2
107	03532000	685	100	72.9	86.0	112	143	78.9	96.4	81.1	100
108	03532100	31.2	90	3.3	3.1	5.2	5.7	3.6	3.5	4.00	3.7
109	03532200	24.0	42	.32	.2	.7	.9	.37	.3	.46	.4
110	03534000	24.5	53	.8	.6	1.0	1.7	.85	.8	.86	.9
111	03534980	7.82	82	.54	.6	.8	1.2	.6	.7	.6	.8
112	03535000	68.5	80	4.34	5.2	7.27	10.3	4.77	6.1	5.16	6.5
113	03535050	93.3	75	6.0	6.2	15.0	12.6	8.4	7.3	9.0	7.8
114	03538180	10.2	70	.8	.6	1.3	1.2	.9	.7	.95	.7
115	03538225	82.5	65	4.84	3.8	8.17	8.6	5.25	4.6	5.54	5.0
116	03538275	7.15	65	.2	.3	.6	.8	.3	.4	.4	.4
117	03539600	139	32	.3	.1	1.6	.8	.4	.2	.5	.2
118	03539800	518.0	32	.6	.5	7.0	3.0	1.1	.8	1.3	.9
119	03543200	26.4	53	.4	.7	.9	1.8	.5	.8	.5	1.0
120	03543500	117	84	12.9	10.0	19.9	19.0	14.1	11.5	14.5	12.3

SUPPLEMENT D--Continued

Map index No.	Station No.	Drainage area (mi^2)	Streamflow recession index	$3Q_{20}$ Observed (ft^3/s)	$3Q_{20}$ Regression (ft^3/s)	$3Q_2$ Observed (ft^3/s)	$3Q_2$ Regression (ft^3/s)	$3Q_{10}$ Observed (ft^3/s)	$3Q_{10}$ Regression (ft^3/s)	$7Q_{10}$ Observed (ft^3/s)	$7Q_{10}$ Regression (ft^3/s)
121	03544235	22.2	70	1.0	1.2	1.9	2.7	1.16	1.5	1.23	1.6
123	03557000	1,223	150	410	328	800	439	480	348	490	352
124	03557148	79.4	115	14.7	12.8	20.0	20.4	15.7	14.1	16.8	14.7
125	03561500	447	140	110	105	360	149	130	113	140	115
126	03561905	9.89	175	4.2	3.3	6.8	4.4	4.6	3.4	4.8	3.6
127	03565040	14.8	120	2.0	2.6	3.0	4.1	2.1	2.8	2.2	2.9
128	03565080	8.54	120	1.97	1.5	2.7	2.4	2.07	1.6	2.1	1.7
129	03565120	37.8	120	6.9	6.6	9.4	10.4	7.2	7.1	7.4	7.5
130	03565160	32.7	120	7.1	5.7	9.1	9.0	7.4	6.2	7.5	6.5
131	03565250	114	120	21	20	29	31.0	22.0	21.8	22.0	22.7
132	03565300	31.8	65	2.27	1.5	3.95	3.4	2.55	1.8	2.71	1.9
133	03565500	57.0	140	17.5	13.1	22.4	19.1	18.2	14.0	18.5	14.6
134	03566126	29.3	130	10.0	5.9	13.0	9.0	10.3	6.3	10.3	6.6
135	03566250	88.7	95	9.7	9.8	15.0	17.4	10.3	11.1	11.3	11.8
136	03566260	44.5	90	4.6	4.4	7.0	8.1	5.0	5.0	5.2	5.3
137	03566320	22.7	48	.80	.4	2.5	1.2	1.0	.5	1.15	.6
138	03566420	18.8	80	1.9	1.4	3.2	2.9	2.2	1.6	2.3	1.8
139	03566450	28.3	67	1.0	1.4	4.8	3.2	1.15	1.7	1.20	1.8
140	03566543	13.2	60	.90	.5	1.7	1.2	1.0	.6	1.05	.7
141	03567500	428	120	79.4	76.0	113	116	85.9	83.0	88.3	85.6
142	03570580	23.7	72	1.5	1.4	3.1	3.0	1.8	1.7	1.9	1.8
143	03570600	86.2	80	5.6	6.6	9.8	13.0	6.5	7.7	7.0	8.2
144	03570835	274	80	13.0	21.3	24.0	40.9	17.0	24.7	19.0	26.3
145	03571000	402	83	26.7	35.8	50.7	66.0	30.7	41.1	32.1	43.4
146	03571500	116	65	3.45	5.4	6.90	12.1	4.0	6.5	4.2	7.1
147	03571835	28.2	65	1.13	1.3	2.50	3.0	1.3	1.6	1.4	1.7
148	03578000	65.6	50	1.08	1.4	3.13	3.9	1.36	1.8	1.44	2.0
149	03578500	41.3	80	3.0	3.2	7.5	6.2	3.80	3.6	4.4	3.9
150	03579100	275	90	17.9	27.6	51.3	49.4	28.8	31.4	32.4	33.1
151	03580300	55.9	50	.9	1.2	2.5	3.3	1.0	1.5	1.1	1.7
152	03580800	89.7	115	16.1	14.5	19.0	23.1	16.9	15.9	17.0	16.6
153	03581200	49.4	50	2.0	1.1	4.2	3.0	2.34	1.3	2.5	1.5
154	03582000	827	110	140	125	170	197	140	139	150	143
155	03583300	47.5	37	.2	.4	.6	1.0	.2	.3	.2	.4
156	03583360	20.2	50	.8	.4	1.5	1.2	.8	.5	.9	.6
157	03583500	24.4	100	3.1	3.0	5.3	5.2	3.6	3.3	3.9	3.5
158	03584000	366	60	13.0	14.0	25.3	32.5	14.7	17.1	15.6	18.5
159	03584500	1,784	75	130	122	247	237	152	143	161	151
160	03585250	36.6	140	12.0	8.4	15.0	12.3	12.3	9.0	12.7	9.3

Map index No.	Station No.	Drainage area (mi^2)	Streamflow recession index	$3Q_{20}$ Observed (ft^3/s)	$3Q_{20}$ Regression (ft^3/s)	$3Q_2$ Observed (ft^3/s)	$3Q_2$ Regression (ft^3/s)	$3Q_{10}$ Observed (ft^3/s)	$3Q_{10}$ Regression (ft^3/s)	$7Q_{10}$ Observed (ft^3/s)	$7Q_{10}$ Regression (ft^3/s)
161	03585260	17.4	140	2.65	4.0	3.8	5.9	2.6	4.2	2.9	4.4
162	03587900	15.4	140	5.0	3.5	7.8	5.2	5.3	3.7	5.6	3.9
163	03588400	43.0	140	8.7	9.9	16.0	14.4	9.9	10.6	10.0	11.0
164	03588500	348	138	66.0	79.6	108	113	74.1	85.3	79.0	87.4
165	03590900	42.5	68	1.8	2.2	5.0	4.9	2.2	2.6	2.4	2.9
166 *	03593300	49.4	65	.1	.3	1.47	1.0	.23	.4	.3	.4
167	03593580	26.9	130	6.9	5.4	10.0	8.2	7.6	5.8	7.7	6.1
168	03593600	66.7	130	17.3	13.5	27.5	20.3	19.0	14.5	19.5	15.1
169	03593700	14.9	130	3.0	3.0	5.6	4.6	3.3	3.2	3.5	3.4
170	03593800	104	125	21.5	19.7	35.1	30.0	24.1	21.3	24.5	22.2
171	03594040	53.7	66	2.5	2.6	10.0	5.8	3.0	3.1	3.3	3.4
172 *	03594120	45.5	75	.24	.4	3.31	1.3	.54	.5	.77	.6
173	03594150	25.8	77	1.4	1.8	3.7	3.6	1.7	2.0	1.8	2.2
174	03594160	201	66	8.4	9.8	28.0	21.6	11.0	11.8	11.0	12.8
175	03594180	50.7	64	2.15	2.3	5.4	5.2	2.6	2.7	2.6	3.0
176	03594260	24.7	95	2.1	2.7	3.7	4.9	2.4	3.0	2.5	3.3
177	03594400	16.8	60	.72	.6	1.5	1.5	.82	.8	1.45	.8
178 *	03594445	115.0	205	18.0	16.0	34.0	24.3	20.2	17.4	21.0	18.0
179	03595300	35.3	60	2.4	1.3	4.2	3.2	2.8	1.6	2.9	1.8
180	03596000	107	100	10.7	13.2	18.3	22.6	12.1	14.8	12.7	15.6
181	03596500	208	105	45.0	28.0	61.0	46.9	48.0	31.6	48.0	33.1
182	03597000	66.3	45	1.0	.9	4.0	3.0	1.5	1.2	1.6	1.4
183	03597700	130	44	1.8	1.7	5.6	5.4	2.5	2.2	2.6	2.5
184	03598000	481	90	53.8	48.5	82.7	86.1	59.6	55.2	60.8	58.0
185	03599430	26.9	42	.32	.3	.6	1.0	.4	.4	.42	.4
186	03599500	1,208	50	15.1	26.4	65.2	70.6	22.6	33.7	32.9	36.9
187	03600380	37.5	45	1.22	.5	2.8	1.7	1.4	.7	1.5	.8
188	03600500	17.5	100	2.00	2.1	4.09	3.7	2.41	2.4	2.53	2.5
189	03601695	8.43	130	2.9	1.7	4.5	2.6	3.15	1.8	3.2	1.9
190	03601860	15.3	130	3.8	3.1	7.2	4.7	4.4	3.3	4.6	3.5
191	03601950	5.56	75	.51	.4	1.4	.8	.62	.4	.63	.5
192	03602235	22.7	120	2.5	3.9	4.0	6.2	2.8	4.3	2.8	4.5
193	03602500	202	135	45.6	44.2	68.6	64.1	50.0	47.5	50.5	48.9
194	03602600	74.7	135	27.0	16.2	40.0	23.8	29.0	17.4	29.0	18.0
195	03603000	2,557	90	267	262	406	453	290	299	303	310
196	03603550	60.2	140	9.6	14	16.0	20.2	10.0	14.8	11.0	15.4
197	03603660	37.7	140	12.0	8.7	19.0	12.7	13.4	9.2	14.0	9.6
198	03603720	13.4	140	2.0	3.1	3.4	4.5	2.2	3.3	2.3	3.4
199	03603750	19.1	140	3.8	4.4	6.4	6.4	4.3	4.7	4.5	4.9
200	03604000	447	120	92.6	79.4	147	121	102	86.7	106	89.4

Map index No.	Station No.	Drainage area (mi²)	Streamflow recession index	$3Q_{20}$ Observed (ft³/s)	$3Q_{20}$ Regression (ft³/s)	$3Q_2$ Observed (ft³/s)	$3Q_2$ Regression (ft³/s)	$3Q_{10}$ Observed (ft³/s)	$3Q_{10}$ Regression (ft³/s)	$7Q_{10}$ Observed (ft³/s)	$7Q_{10}$ Regression (ft³/s)
201	03604060	7.34	95	1.0	0.8	1.7	1.5	1.12	0.9	1.15	1.0
202	03604100	10.1	60	.2	.4	1.0	.9	.3	.5	.4	.5
203	03604180	15.2	140	3.2	3.5	5.4	5.1	3.2	3.7	3.6	3.9
204	03604500	707	125	157	136	239	201	171	148	174	152
205	03604600	24.8	135	5.6	5.3	8.6	8.0	6.2	5.7	6.2	6.0
206	03605555	31.9	110	5.5	4.7	9.4	7.8	6.4	5.2	6.8	5.5
207 *	03606280	41.4	230	5.4	7.0	8.4	10.3	5.6	7.5	5.8	7.7
208 *	03606500	205	240	32.1	42.7	48.7	57.0	34.6	45.0	35.5	45.8
209 *	03607000	379	200	44.0	54.0	67.0	79.1	47.0	58.3	49.0	60.2
210 *	03607200	47.9	240	12.1	9.0	16.4	12.9	12.7	9.6	12.9	9.8
211 *	07024250	43.5	200	4.4	5.3	7.6	8.6	4.6	5.9	4.7	6.1
212 *	07024300	55.5	350	20.0	24.6	25.0	27.3	21.0	24.6	22.0	24.4
213 *	07024500	383	235	73.3	79.4	98.1	104	77.5	83.5	79.5	85.0
214 *	07024720	137	300	46.0	45.9	58.0	54.0	47.5	46.8	48.0	46.9
215 *	07025000	203	150	13.5	13.8	20.0	25.4	14.6	15.8	15.7	16.7
216 *	07025300	83.7	300	22.0	27.1	29.0	32.6	23.5	27.7	24.0	27.8
217 *	07025350	36.7	65	.37	.2	.50	.8	.39	.3	.4	.3
218 *	07025500	480	205	85.8	73.6	103	105	88.6	79.8	90.0	81.4
219 *	07026000	1,852	175	241	214	357	320	261	233	266	242
220 *	07027300	160	230	27.0	29.7	37.0	41.2	28.5	31.6	29.0	32.3
221 *	07027500	495	230	73.2	99.4	98.7	131	77.8	105	81.0	107
222 *	07027700	25.0	60	.14	.1	.27	.4	.16	.1	.17	.2
223 *	07028000	1,003	195	112	144	165	205	121	155	125	160
224 *	07028500	73.4	140	6.25	3.9	11.1	7.9	7.25	4.6	7.46	4.9
225 *	07028900	88.2	120	3.30	3.2	7.0	7.2	3.90	3.8	4.00	4.1
226 *	07029000	369	195	72.8	49.4	90.2	73.7	75.7	53.6	77.0	55.5
227 *	07029100	867	160	81.6	76.4	129	126	90.1	85.3	96.2	89.4
228 *	07029380	94.8	140	5.55	5.1	17.7	10.3	6.91	6.0	7.15	6.4
229 *	07029400	837	130	44.4	43.5	84.1	83.3	51.6	50.5	56.1	53.9
230 *	07029410	47.6	250	12.0	9.9	14.7	13.7	12.5	10.4	12.8	10.6
231 *	07029440	40.4	60	.12	.2	.40	.7	.12	.2	.14	.3
232 *	07029500	1,480	160	111	135	188	217	122	150	126	157
233 *	07029700	84.3	210	9.00	12.1	12.6	18.4	9.70	13.2	10.0	13.6
234 *	07030000	1,940	175	238	225	341	335	255	245	258	255
235 *	07030020	92.0	170	10.0	8.1	13.2	14.1	10.6	9.1	10.7	9.5
236 *	07030209	76.9	165	8.00	6.2	11.8	11.1	8.50	7.0	8.6	7.4
237 *	07030280	505	150	49.8	36.5	78.7	64.5	56.2	41.4	57.3	43.7
238 *	07030400	71.9	170	8.00	6.2	11.3	10.9	9.00	7.0	9.1	7.3
239 *	07030500	503	230	114	101	151	133	122	106	124	109
240 *	07031700	770	210	138	129	194	177	149	138	161	141
241	03435500	706	75	36.5	47.8	58.3	94.2	39.6	56.0	42.1	59.4

☆U.S. GOVERNMENT PRINTING OFFICE 1986—631-262/40003