MANUAL FOR ESTIMATING SELECTED STREAMFLOW CHARACTERISTICS OF NATURAL-FLOW STREAMS IN THE COLORADO RIVER BASIN IN UTAH

by R. C. Christensen, E. B. Johnson, and G. G. Plantz

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[Plate is in pocket]

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CONVERSION FACTORS

Values in this report are given in inch-pound units. The conversion factors are shown to obtain metric equivalents to four significant figures.

Multiply	By	To obtain
Cubic foot per second	0.02832	Cubic meter per second
Foot	0.3048	Meter
Foot per mile	0.1894	Meter per kilometer
Inch	25.40	Millimeter
Mile	1.609	Kilometer
Square mile	2.590	Square kilometer

GLOSSARY

Annual maximum n-day mean discharge--The annual maximum mean value from daily discharges for an indicated n consecutive days and recurrence interval, in cubic feet per second.

Average discharge--The arithmetic mean of all yearly discharges of a gaging-station record, in cubic feet per second.

Base runoff--Fair-weather natural runoff, composed mostly of ground water effluent.

Coefficient of determination (R-square)--A measure of how much variation of the dependent variable that is explained by the independent variable(s) in a multiple-regression equation.

Coefficient of variation--A measure of the amount of variation in a set of data. It is obtained by calculating the standard deviation and dividing it by the arithmetic mean of the set of data.

Dependent variable--A streamflow characteristic that is related to basin and climatic characteristics in a multiple-regression analysis.

Elevation--Height of land or water surface, in feet, as related to sea level or the National Geodetic Vertical Datum of 1929 (NGVD of 1929).

Equivalent years of record--The number of years of observed record required to provide an estimate of equal accuracy to that provided by a regression equation.

Gaging station--A particular site on a stream where a continuous record of discharge is obtained.

Independent variable--A basin or climatic characteristic to which a streamflow characteristic is related to in a multiple-regression analysis.

Multiple-regression analysis--A statistical technique whereby an equation is derived between a dependent variable and one or more independent variables.

Natural-flow stream--A term used in this manual to denote a stream on which diversions, regulations, and urbanization have insignificant effect on the streamflow characteristics.

Outliers--Those observations in a statistical sample that depart from the trend of the rest of the data.

Partial-record station--A particular site on a stream where a non-continuous record of discharge is collected systematically during a period of years.

Pearson Type III frequency distribution--A statistical distribution used in discharge-frequency analysis, which is described by three parameters: mean, standard deviation, and coefficient of skewness of the logarithms of the sample observations.

Recurrence interval--The average interval of time, in years, within which a given streamflow characteristic will be exceeded once.

Residual--The difference between the measured value of an observation and the corresponding fitted value obtained by use of the fitted regression equation.

Seepage run--Discharge measurements made at intervals along a stream channel during a period of base runoff to identify significant gains or losses in streamflow.

Skewness--A numerical measure or index of asymmetry of a frequency distribution. From a practical standpoint, the term indicates positive or negative curvature of a discharge-frequency relation.

Standard deviation--A measure of the dispersion of a set of data about the arithmetic mean of that data. It is the square root of the sum of squares of the deviations from the arithmetic mean divided by the number of values minus one.

Standard error of estimate (in percent)--A measurement of how well the observed data agree with estimates from the regression equation. It is a range of error in percent, such that the value estimated by the regression equation is within this range at about two of three sites and is within twice this range at about 19 of 20 sites.

Standard error of prediction--A measure of the difference between estimated and true values of a characteristic. It is the standard error of estimate or scatter about the equation plus the error in the regression equation.

Water year--The 12-month period ending September 30 that is designated by the calendar year in which it ends.

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ABSTRACT

Methods are presented for estimating 10 streamflow characteristics at three types of sites on natural-flow streams in the Colorado River Basin in Utah. The streamflow characteristics include average discharge and annual maximum 1-, 7-, and 15-day mean discharges for recurrence intervals of 10, 50, and 100 years. At or near gaged sites, two methods weight gaging-station data with regression-equation values to estimate streamflow characteristics. At sites on ungaged streams, a method estimates streamflow characteristics using regression equations.

The regression equations relate the streamflow characteristics to the following basin and climatic characteristics: contributing drainage area, mean basin elevation, mean annual precipitation, main-channel slope, and forested area. Separate regression equations were developed for four hydrologically distinct regions in the study area. The standard error of estimate for the 10 streamflow characteristics ranges from 13 to 87 percent.

Basin, climatic, and streamflow characteristics, available as of September 30, 1981, are presented for 135 gaging stations in Utah, Arizona, Colorado, and Wyoming. In addition, weighted estimates of the streamflow characteristics based on station data and the regression-equation estimates are provided for most gaging stations.

INTRODUCTION

This manual provides methods for calculating 10 streamflow characteristics at three types of sites on natural-flow streams (those which are not significantly affected by regulation, diversion, or urbanization) in the Colorado River Basin in Utah (pl. 1). The methods are presented for estimating average discharge and annual maximum 1-, 7-, and 15-day mean discharges for recurrence intervals of 10, 50, and 100 years at sites on such streams. This manual is intended to aid planners, engineers, officials of Federal, State, county, and municipal agencies, and private firms in developing and managing the surface-water resources in the Colorado River Basin. The information can be used to determine natural streamflow conditions, identify the effects of man's activities on streamflow, establish water-quality standards for streams, and design water-control structures.

The methods for estimating streamflow characteristics at gaged sites, near gaged sites on the same stream, and at ungaged sites are described first, and the regression equations developed for computing streamflow characteristics at ungaged sites are listed in tables 1-4. The limitations of the methods then are discussed in terms of their range of applicability. The range of basin and climatic characteristics used in the regression equations is listed in table 5.

Application of the methods is presented in a step-by-step procedure using several examples. Next, the analytical development of the regression equations is described. Attention is briefly given to the need for developing methods that could be used for transferring low-flow characteristics from gaged to ungaged sites in the Colorado River Basin in Utah. Finally, streamflow characteristics and basin and climatic characteristics used to develop the equations are listed in table 6 at the back of the manual.

Mean annual streamflow (average discharge) and high streamflow in the Colorado River Basin in Utah have been the subject of at least five reports during the past 15 years. Whitaker (1971) evaluated the accuracy of estimates of mean annual streamflow and 7-day high streamflow at recurrence intervals of 2, 10, and 50 years by regionalization of the streamflow data available through the 1970 water year. Cruff (1975) estimated the monthly, annual, and mean annual streamflows for streams in the Duchesne River basin based on the method of monthly-discharge measurements described by Riggs (1969). Fields and Adams (1975) estimated mean annual streamflow in northeastern Utah based on drainage area and mean annual precipitation by using multiple-regression techniques and data based on the common-time period of 1941-70. Fields (1975) developed relations between mean annual streamflow and width of channel-bar cross section for emphemeral and perennial streams. Thomas and Lindskov (1983) developed equations for estimating 2-, 5-, 10-, 25-, 50-, and 100-year annual peak discharges using multiple-regression techniques, and they also presented ratios of 500- to 100-year values.

This manual was prepared by the U.S. Geological Survey in cooperation with the U.S. Bureau of Land Management. Increasing development of energy resources on lands administered by the Bureau of Land Management in the Colorado River Basin in Utah has created a need for a uniform methodology to estimate streamflow characteristics.

DESCRIPTION OF METHODS FOR ESTIMATING STREAMFLOW CHARACTERISTICS

The three methods described here can be used to estimate streamflow characteristics of natural-flow streams in the Colorado River Basin in Utah. The first two methods require daily-discharge records at or near the stream site. The third method, which is used at sites on ungaged streams, consists of regression equations to relate streamflow characteristics to basin and climatic characteristics. At sites near a state line on streams entering Utah, the streamflow characteristics estimated by these methods should be coordinated with the office of the Geological Survey in the adjacent state.

Streamflow Information at Gaged Sites

Streamflow information from gaging stations on natural-flow streams that was used in the regression analysis is listed in table 6. Listed in the first line for each gaging station are the average discharge and annual maximum 1-, 7-, and 15-day mean discharges for recurrence intervals of 10, 50, and 100 years. These values are based on the indicated period of observed record. Gaging-station locations and numbers are shown on plate 1. The station-numbering system is the standard system used in reports of the U.S. Geological Survey (1982, p. 24).

Streamflow characteristics for gaging stations in Utah that were not used in the regression analysis are available in the data report by Christensen and others (1986). These stations are on streams or reaches of streams that are materially affected by diversions, regulation, or lack hydrologic homogeneity with tributary streams due to the large size of their drainage basins. The streamflow characteristics presented by Christensen and others (1986) apply to the streams for the conditions (such as volume of diversions and reservoir releases) that were present during the period of record used to define those characteristics. If there are major changes in the regime of the streams, then the streamflow characteristics given by Christensen and others (1986) may not be representative of future streamflows.

If a gaging-station record covers only a wet or dry climatic cycle, the data may not represent the best base for future estimates. This time-sampling error usually is small for long periods of record, but it may be extremely large for short periods. A procedure described by Sauer (1974, p. 23-25) reduces such time-sampling errors by providing a weighted average of discharge from the station value and the regression value. The weighted average is computed from the equation

$$Q_W = \frac{(Q_S)(N)+(Q_R)(M)}{N + M} \quad (1)$$

where

Q_W = weighted discharge in cubic feet per second, for the streamflow characteristic;

Q_S = gaging-station value of the streamflow characteristic, in cubic feet per second;

Q_R = regression-equation estimate of the streamflow characteristic, in cubic feet per second;

N = the number of years of gaging-station data used to compute Q_S; and

M = the equivalent years of record for Q_R.

Equivalent years of record represents an estimate of the number of years of actual streamflow record required at a site to achieve an accuracy equivalent to the estimate of a streamflow characteristic from a regional regression equation. The equivalent-years weighting factors for the regression-equation estimates were computed by the following equations developed by Hardison (1971, p. C231):

for average discharge

$$N_U = \left(\frac{100\,\overline{C_V}}{SE_p}\right)^2 \quad (2)$$

for annual maximum n-day mean discharge

$$N_U = R^2\left(\frac{\overline{I_V}}{SE_p}\right)^2 \quad (3)$$

where

N_U = the equivalent years of record (M) for the regression-equation estimate (Q_R) in equation (1);

$\overline{C}_V$ = the average coefficient of variation of the logarithms of the annual average discharges for all stations in the region;

SE_p = the standard error of prediction for the regression equation, in percent for average discharge and in log units for annual maximum n-day mean discharge;

$\overline{I}_V$ = the average standard deviation of the logarithms of the annual maximum n-day mean discharges for all stations in the region; and

R = a factor which is a function of recurrence interval and average logarithmic skewness of the annual maximum n-day mean discharges for all stations in the region.

The computation of equivalent years of record require an estimate of the standard error of prediction (SE_p) which includes estimates of both the space-sampling error (error in the underlying relation between a streamflow characteristic and a set of basin characteristics) and time-sampling error (error in the streamflow characteristics at the gaging station used in the regression analysis). The interaction of these errors sometimes results in equivalent years of record which seem unreasonable. For average discharge, regression-equation estimates have an indicated accuracy equivalent to not more than 2 years. It is reasonable to believe that the regression-equation estimates are more accurate than can be provided by 2 years of observed record. For annual maximum n-day mean discharge, the equivalent years of record shown in tables 1-4 that is less than 10 years seems unreasonably low for the accuracy of estimates made from the regression equations.

A weighted discharge was computed for each streamflow characteristic at most gaged sites, and it is listed below the station value in table 6. For average discharge, the weighted value was not computed when the equivalent years of record was less than 1. The weighted discharge, where provided, should be a better indicator of the true value because the regression estimate is an average of the streamflow records of many gaging stations over a long period of time.

Streamflow Information near Gaged Sites on the Same Stream

Streamflow information at sites near gaging stations on the same stream can be computed by the following equation:

$$Q_U = \left(\frac{A_U}{A_G}\right)^x Q_W \qquad (4)$$

where

Q_U = discharge, in cubic feet per second, at ungaged site for streamflow characteristic;

A_U = drainage area, in square miles, at ungaged site;

A_G = drainage area, in square miles, at gaged site;

Q_W = weighted discharge, in cubic feet per second, at gaged site for streamflow characteristic; and

x = exponent for each streamflow characteristic and region as follows:

Streamflow characteristic	Region (See plate 1)			
	Mountains	Northern Plateaus	Central Plateaus	Southwestern Plateaus
Average discharge	1.0	0.6	0.2	0.8
Annual maximum 1-day mean discharge	.9	.4	.5	.3
Annual maximum 7-day mean discharge	.9	.3	.3	.5
Annual maximum 15-day mean discharge	.9	.3	.2	.7

The exponent (x) was determined by regressing the logarithm of the streamflow characteristic (Q_S) against the logarithm of the drainage area (A_G) using the relation $Q_S = (a)\ (A_G)^x$ for each region, where "a" is the regression constant. For the 10-, 50-, and 100-year annual maximum 1-, 7-, and 15-day mean discharges, the average of the exponents for the three equations for each consecutive-day period was taken for each region. Equation (4) is applicable to ungaged sites where the ratio of the drainage areas is between 0.75 and 1.5. In addition to the ratio method for sites near gaged sites, if a site is between two gages, the streamflow characteristic may be estimated by interpolation between values for the two gages, with allowance for major tributaries.

Equation (4) should not be used for computing average discharge on a stream where discharge decreases with increasing contributing drainage area. According to available records, this streamflow condition exists on Dry Fork and Rock Creek in the Mountains Region and Hill and Bitter Creeks in the Northern Plateaus Region (table 6).

Streamflow Information at Ungaged Sites

Streamflow information at ungaged sites is obtained using a series of regression equations (tables 1-4) which relate streamflow characteristics to basin and climatic characteristics. A discussion of the multiple-regression analysis that defined the regression equations is given in the section "Analytical Development of Regression Equations." The equations are of the linear form,

$$Y = a+b_1X_1+b_2X_2+\ldots b_nX_n$$

or logarithmic form,

$$Y = a\ (X_1)^{b_1}\ (X_2)^{b_2}\ \ldots\ (X_n)^{b_n}$$

where

Y = a streamflow characteristic,

X_1 to X_n = basin and climatic characteristics,

a = regression constant, and

b_1 to b_n = regression coefficients.

Each basin or climatic characteristic that appears in the regression equations is defined below with a brief explanation of the computation procedure.

Contributing drainage area, A, in square miles, is the total area of a basin contributing to discharge at a stream site. It is measured from U.S. Geological Survey topographic maps, usually by planimetering. Simpler but less reliable indexes of drainage-area size might be obtained by overlaying a grid of known square areas on the outlined basin and counting the number of squares.

Mean basin elevation, E, in thousands of feet, is obtained from topographic maps by placing a transparent grid over the drainage basin, determining the elevation at each grid intersection, averaging the elevations, and dividing by 1,000. The grid size is chosen so that at least 20 elevation points are sampled in the basin.

Mean annual precipitation, P, in inches, is determined from the map "Normal Annual Precipitation (1931-60) for the State of Utah" (U.S. Weather Bureau, 1963). The mean annual precipitation is obtained by outlining the drainage basin on the map, placing a transparent grid over the basin, determining the precipitation at each grid intersection, and averaging the values. The grid size is chosen so that at least 20 points are sampled in the basin.

Main-channel slope, S, in feet per mile, is the slope between two points at 10 and 85 percent of the distance from the stream site to the basin divide. It is computed by dividing the difference in elevation, in feet, by the distance, in miles, between the two points (Benson, 1964, p. D22-D23).

Forested area, F, in percent, is the percentage of the contributing drainage area shown as forested on the topographic map. The forested area is obtained by outlining the drainage basin on the map, placing a transparent grid over the basin, and determining the percentage of the grid intersections within the basin that are on the forested area. The grid size is chosen so that at least 20 grid intersections are within the basin.

Regional equations were developed for average discharge and the 10-, 50-, and 100-year annual maximum 1-, 7-, and 15-day mean discharges for four regions (pl. 1). The selection and description of the four regions are explained in the section "Analytical Development of Regression Equations," and the equations for each are listed in tables 1-4.

Limitations of Methods

The following limitations apply to use of the methods presented in this manual.

1. The three methods may not apply to urban areas unless the effects of urbanization on streamflow are insignificant. An example of this condition would be a large stream flowing through an urban area.

2. The three methods may not apply to streams where manmade works, such as flood-detention structures, storage reservoirs, and major diversions have a significant effect on streamflow. For these conditions, streamflow routing or stream-system studies will be required to evaluate streamflow characteristics.

3. The regression equations for computing streamflow characteristics at ungaged sites may not apply when the basin and climatic characteristics are outside the range of those used to develop the equations (table 5).

APPLICATION OF METHODS

Estimates of streamflow characteristics are determined for sites on natural-flow streams in the Colorado River Basin in Utah by the following steps:

1. From plate 1 and the description of regional boundaries in sections "Mountains Region", "Northern Plateaus Region", "Central Plateaus Region", and "Southwestern Plateaus Region", determine the region in which the site lies.

2. From plate 1 and table 6, determine if the site is at a gaged site or near a gaged site on the same stream. For more specific information regarding gaging-station locations, see Christensen and others (1986).

3. If the site is at a gaged site listed in table 6, use the method described under "Gaged Sites".

4. If the site is near a gaged site on the same stream, use the method described under "Sites near Gaged Sites on the Same Stream".

5. If the site is not at or near a gaged site, then use the method described under "Ungaged Sites".

Table 1.--Regression equations for average discharge and annual maximum 1-, 7-, and 15-day mean discharges for the Mountains Region

Equation: Q, discharge, in cubic feet per second; A, contributing drainage area, in square miles; and E, mean basin elevation, in thousands of feet.

Recurrence interval, in years	Equation	Number of stations used in regression analysis	Standard error of estimate, in percent	Equivalent years of record
		Average discharge		
--	$Q = 1.39 \times 10^{-5} A^{1.06} E^{4.67}$	65	42	(1)
		Annual maximum 1-day mean discharge		
10	$Q = 0.00102 A^{0.914} E^{4.21}$	58	42	2
50	$Q = 0.00598 A^{0.864} E^{3.66}$	58	45	4
100	$Q = 0.0103 A^{0.846} E^{3.50}$	58	49	4
		Annual maximum 7-day mean discharge		
10	$Q = 0.00133 A^{0.930} E^{3.98}$	58	41	2
50	$Q = 0.0109 A^{0.892} E^{3.24}$	58	40	6
100	$Q = 0.0219 A^{0.878} E^{3.00}$	58	42	6
		Annual maximum 15-day mean discharge		
10	$Q = 0.00205 A^{0.937} E^{3.70}$	58	40	2
50	$Q = 0.0231 A^{0.900} E^{2.82}$	58	38	5
100	$Q = 0.0510 A^{0.886} E^{2.53}$	58	40	6

(1) Computed equivalent years of record was less than 1 when rounded to nearest whole number.

Table 2.--Regression equations for average discharge and annual maximum 1-, 7-, and 15-day mean discharges for the Northern Plateaus Region

Equation: Q, discharge, in cubic feet per second; A, contributing drainage area, in square miles; E, mean basin elevation, in thousands of feet; F, forested area, in percent; and S, main-channel slope, in feet per mile.

Recurrence interval, in years	Equation	Number of stations used in regression analysis	Standard error of estimate, in percent	Equivalent years of record
	Average discharge			
--	$Q = 8.76 \times 10^{-15} A^{1.93} E^{15.0} F^{-3.61} S^{2.23}$	22	87	1
	Annual maximum 1-day mean discharge			
10	$Q = 95.0 + 0.310A$	9	33	8
50	$Q = 157 + 0.702A$	9	45	10
100	$Q = 187 + 0.950A$	9	52	11
	Annual maximum 7-day mean discharge			
10	$Q = 89.6 + 0.176A$	9	30	10
50	$Q = 160 + 0.388A$	9	39	14
100	$Q = 198 + 0.515A$	9	45	15
	Annual maximum 15-day discharge			
10	$Q = 78.3 + 0.144A$	9	28	11
50	$Q = 141 + 0.324A$	9	33	16
100	$Q = 174 + 0.433A$	9	39	17

Table 3.--Regression equations for average discharge and annual maximum 1-, 7-, and 15-day mean discharges for the Central Plateaus Region

Equation: Q, discharge, in cubic feet per second; A, contributing drainage area, in square miles; E, mean basin elevation, in thousands of feet; P, mean annual precipitation, in inches; and S, main-channel slope, in feet per mile.

Recurrence interval, in years	Equation	Number of stations used in regression analysis	Standard error of estimate, in percent	Equivalent years of record
	Average discharge			
--	$Q = 2.08 \times 10^{-4} A^{0.709} P^{1.46} S^{0.554}$	33	59	2
	Annual maximum 1-day mean discharge			
10	$Q = 1.08 \times 10^{3} A^{0.355} E^{-1.39}$	23	58	5
50	$Q = 63.0 A^{0.534}$	23	74	7
100	$Q = 80.1 A^{0.538}$	23	84	9
	Annual maximum 7-day mean discharge			
10	$Q = 1.79 A^{0.439} P^{0.832}$	23	54	5
50	$Q = 3.02 A^{0.478} P^{0.824}$	23	53	11
100	$Q = 3.49 A^{0.496} P^{0.829}$	23	59	13
	Annual maximum 15-day mean discharge			
10	$Q = 0.432 A^{0.435} P^{1.21}$	23	53	5
50	$Q = 0.716 A^{0.476} P^{1.20}$	23	46	22
100	$Q = 0.809 A^{0.493} P^{1.22}$	23	50	32

Table 4.--Regression equations for average discharge and annual maximum 1-, 7-, and 15-day mean discharges for the Southwestern Plateaus Region

Equation: Q, discharge, in cubic feet per second; A, contributing drainage area, in square miles; and E, mean basin elevation, in thousands of feet.

Recurrence interval, in years	Equation	Number of stations used in regression analysis	Standard error of estimate, in percent	Equivalent years of record
		Average discharge		
--	$Q = 3.54 + 0.294A$	13	30	1
		Annual maximum 1-day mean discharge		
10	$Q = 2.25 \times 10^3 A^{0.567} E^{-1.91}$	10	39	7
50	$Q = 7.24 \times 10^5 A^{0.361} E^{-3.91}$	10	31	14
100	$Q = 5.76 \times 10^6 A^{0.283} E^{-4.62}$	10	32	18
		Annual maximum 7-day mean discharge		
10	$Q = 70.9 + 3.05A$	10	28	16
50	$Q = 234 + 5.14A$	10	16	34
100	$Q = 385 + 5.97A$	10	26	28
		Annual maximum 15-day mean discharge		
10	$Q = 56.8 + 2.62A$	10	36	10
50	$Q = 144 + 4.51A$	10	13	35
100	$Q = 212 + 5.42A$	10	14	35

Table 5.--Range of basin and climatic characteristics used in regression equations

[Dash (-) indicates characteristic is not used in the regional regression equations.]

Region	Contributing drainage area (square miles)	Mean basin elevation (feet)	Mean annual precipitation (inches)	Main-channel slope (feet per mile)	Forested area (percent)
Average discharge equations					
Mountains	2.89-660	7,560-10,960	-	-	-
Northern Plateaus	24.5-897	5,490-8,750	-	32.8-312	17-94
Central Plateaus	1.9-1,410	-	7.5-34.5	17.9-672	-
Southwestern Plateaus	5.65-344	-	-	-	-
Annual maximum 1-, 7-, and 15-day mean discharge equations					
Mountains	2.89-660	8,120-10,960	-	-	-
Northern Plateaus	25.1-897	-	-	-	-
Central Plateaus	7.98-1,410	4,810-9,700	7.5-34.5	-	-
Southwestern Plateaus	9.85-344	6,070-9,000	-	-	-

Gaged Sites

Streamflow characteristics at gaged sites can be obtained from table 6, and the recommended values for each gaging station are the weighted discharges on the second line. If no weighted value is listed, use the unweighted-station value on the first line. The procedure for computing weighted discharges was described in the section "Streamflow Information at Gaged Sites", and is illustrated in Example 1.

Example 1.--Average Discharge at a Gaged Site

Determine the best estimate of average discharge for gaging station 09406700, South Ash Creek below Mill Creek, near Pintura (lat 37°21'50", long 113°20'01", in SW1/4SW1/4SE1/4 sec. 29, T.39S., R.13W.).

Map coverage: New Harmony quadrangle, scale, 1:62,500.

Determine the regression estimate of average discharge (Q_R) at the station using the regression equation for the Southwestern Plateaus Region (table 4). Basin characteristic required is the drainage area (A).

A = 11.0 square miles, from table 6

Compute average discharge (Q_R) using regression equation:

$$Q_R = 3.54 + 0.294A = 3.54 + 0.294\ (11.0) = 6.8 \text{ cubic feet per second}$$

Obtain average discharge for the gaging station (Q_S) from table 6:

$$Q_S = 7.11 \text{ cubic feet per second}$$

Compute weighted discharge (Q_W) to be used at the gaging station with equation (1):

$$Q_W = \frac{(Q_S)(N)+(Q_R)(M)}{N + M}$$

where

N = 15 years (length of station record), from table 6, and

M = 1 year (equivalent years of record for average discharge), from table 4.

$$Q_W = [(7.11)(15)+(6.8)(1)]/[15+1] = 7.1 \text{ cubic feet per second.}$$

Sites near Gaged Sites on the Same Stream

Streamflow characteristics at sites near gaged sites on the same stream can be computed using the method described in the section "Streamflow Information near Gaged Sites on the Same Stream". First, determine the ratio of the drainage area at the ungaged site to that at the gaged site. If this ratio is between 0.75 and 1.5, use equation (4) as illustrated below in

Example 2. If the ratio lies outside the above range, use the method described in the section "Streamflow Information at Ungaged Sites".

Example 2.--Annual Maximum 1-Day Mean Discharges near a Gaged Site

Determine the 10-, 50-, and 100-year annual maximum 1-day mean discharges, indicated as $Q_{1,10}$, $Q_{1,50}$, and $Q_{1,100}$, for South Ash Creek, 0.9 mile south of Pintura (lat 37°21', long 113°17', in NE1/4 sec. 11, T.40S., R.13W.).

Map coverage: New Harmony quadrangle, scale, 1:62,500

From the New Harmony quadrangle, plate 1, and table 6, it is noted that gaging station 09406700, South Ash Creek below Mill Creek, near Pintura, is upstream from the ungaged site and has a drainage area (A_G) of 11.0 square miles.

Determine the drainage area at the ungaged site (A_U = 14.0 square miles). Determine the drainage-area ratio of ungaged site (A_U) to gaged site (A_G).

$$A_U / A_G = 14.0 / 11.0 = 1.27.$$

The ratio of 1.27 meets the drainage-area requirement for this method, therefore, equation (4) is used as follows:

$$Q_{U(T)} = \left(\frac{A_U}{A_G}\right)^x Q_{W(T)}$$

where

$Q_{U(T)}$ is the annual maximum 1-day mean discharge at the ungaged site for the recurrence interval T; x = 0.3 from the table on page 5, for the Southwestern Plateaus Region; and $Q_{W(T)}$ is the weighted discharge at the gaged site for the recurrence interval T from table 6.

Weighted discharges ($Q_{1,10}$, $Q_{1,50}$, and $Q_{1,100}$) at the gaged site are:

$Q_{1,10}$ = 296 cubic feet per second

$Q_{1,50}$ = 1,030 cubic feet per second

$Q_{1,100}$ = 1,600 cubic feet per second

Compute discharges ($Q_{1,10}$, $Q_{1,50}$, and $Q_{1,100}$) at ungaged site:

$Q_{1,10} = (14.0/11.0)^{0.3}(296)=(1.27)^{0.3}(296)=(1.07)(296) =$

317 cubic feet per second

$Q_{1,50} = (14.0/11.0)^{0.3}(1,030)=(1.27)^{0.3}(1,030)=(1.07)(1,030) =$

1,100 cubic feet per second

$$Q_{1,100} = (14.0/11.0)^{0.3}(1,600) = (1.27)^{0.3}(1,600) = (1.07)(1,600) =$$

1,710 cubic feet per second.

Ungaged Sites

Streamflow characteristics at ungaged sites on natural-flow streams in the Colorado River Basin in Utah can be computed by one of the following procedures, depending on the location of the basin. If the basin lies entirely in a single region, Procedure 1 is used. If the basin lies partly in the Mountains Region and partly in the Northern Plateaus or the Central Plateaus Region, Procedure 2 is used.

Procedure 1.--Computation of Streamflow Characteristics for Sites Where Regression Equations for One Region Are Used

1. From plate 1 identify the region in which the basin is located, and from tables 1-4 select the appropriate equations for the streamflow characteristics.

2. Compute the required basin and climatic characteristics using the definitions and instructions given in the section "Streamflow Information at Ungaged Sites".

3. Solve the equations for the desired streamflow characteristics.

Example 3.--Annual maximum 7-day mean discharges at site where basin lies within one region

Discharges for the 10-, 50-, and 100-year annual maximum 7-day mean discharges, indicated as $Q_{7,10}$, $Q_{7,50}$, and $Q_{7,100}$, are required at the State Highway 24 crossing of Temple Wash, 22 miles north of Hanksville (lat 38°39'09", long 110°33'10", in SE1/4NE1/4 sec.11, T.25S., R.12E.).

The basin covers parts of two U.S. Geological Survey 15-minute topographic maps, Temple Mtn. and The Wickiup, scale, 1:62,500.

From plate 1 and the topographic maps, Temple Wash lies in the Central Plateaus Region.

The equations for the annual maximum 7-day mean discharges for the Central Plateaus Region are listed in table 3. The equations require that the following basin and climatic characteristics be known:

A, drainage area, in square miles, and
P, mean annual precipitation, in inches.

Using the procedures described in the section "Streamflow Information at Ungaged Sites", the following values for the required characteristics were obtained:

A = 38.2 square miles and

P = 8.6 inches.

The characteristics are inserted in the appropriate equations in table 3, which are computed as follows:

$$Q_{7,10}=1.79A^{0.439}P^{0.832}=1.79(38.2)^{0.439}(8.6)^{0.832}=1.79(4.95)(6.0)=$$

53 cubic feet per second

$$Q_{7,50}=3.02A^{0.478}P^{0.824}=3.02(38.2)^{0.478}(8.6)^{0.824}=3.02(5.70)(5.9)=$$

100 cubic feet per second

$$Q_{7,100}=3.49A^{0.496}P^{0.829}=3.49(38.2)^{0.496}(8.6)^{0.829}=3.49(6.09)(6.0)=$$

130 cubic feet per second

Procedure 2.--Weighting Procedure for Sites Where Regression Equations for Two Regions Are Used

Determine the streamflow characteristics at a stream site when the basin is in the Mountains Region and the Northern Plateaus or the Central Plateaus Region.

1. Compute basin and climatic characteristics for the entire basin and the portion of the basin in each region.

2. Compute streamflow characteristics using the regression equations for the Mountains Region in table 1. In the special case where the site is in the transition zone described in the section "Northern Plateaus Region", and it is on a stream originating above the elevation of 9,000 feet, then the streamflow characteristics are computed using only the regression equations for the Mountains Region.

3. For sites on other streams, compute streamflow characteristics using the regression equations for the appropriate plateaus region in tables 2 or 3.

4. From steps 1 through 3, weight the streamflow-characteristic discharges based on the corresponding drainage area in each region using the following equation:

$$Q_{Weighted} = Q_{Mountains}\left(\frac{A_{Mountains}}{A_{Total}}\right) + Q_{Plateaus}\left(\frac{A_{Plateaus}}{A_{Total}}\right) \qquad (5)$$

Application of this procedure is illustrated in Example 4:

Example 4.--Annual maximum 15-day mean discharges at site where basin is in two regions

Discharges for the 10-, 50-, and 100-year annual maximum 15-day mean discharges, indicated as $Q_{15,10}$, $Q_{15,50}$, and $Q_{15,100}$, are required at a site on Deer Creek, 3.5 miles above mouth and 6.4 miles southeast of Boulder (lat 37°51', long 111°21', in NE1/4 sec. 16, T.34S., R.5E.).

Map coverage: Boulder Town, King Bench, and Steep Creek Bench quadrangles, scale, 1:24,000; and Grover quadrangle, scale, 1:62,500.

Using plate 1, the description of the regional boundary in the vicinity of the basin in the section "Mountains Region", and the topographic maps, the Deer Creek basin is found to lie in the Mountains and Central Plateaus Regions. Procedure 2 should be used to compute the streamflow characteristics for this site.

The streamflow-characteristic equations for the Mountains and Central Plateaus Regions are obtained from tables 1 and 3. The equations require that the following basin and climatic characteristics be computed for the entire basin:

A, drainage area, in square miles,
E, mean basin elevation, in thousands of feet, and
P, mean annual precipitation, in inches.

Using the procedures outlined in the section "Streamflow Information at Ungaged Sites", the following values for the required characteristics were obtained:

A = 63 square miles,
E = 7,680/1,000 = 7.68 thousands of feet,
P = 15.4 inches,
Area of basin in Mountains Region = 4 square miles, and
Area of basin in Central Plateaus Region = 59 square miles.

Compute $Q_{15,10}$, $Q_{15,50}$, and $Q_{15,100}$ using the Mountains Region equations.

$$Q_{15,10} = 0.00205A^{0.937}E^{3.70} = 0.00205(63)^{0.937}(7.68)^{3.70} = 0.00205(49)(1,890) =$$

190 cubic feet per second

$$Q_{15,50} = 0.0231A^{0.900}E^{2.82} = 0.0231(63)^{0.900}(7.68)^{2.82} = 0.0231(42)(314) =$$

300 cubic feet per second

$$Q_{15,100} = 0.0510A^{0.886}E^{2.53} = 0.0510(63)^{0.886}(7.68)^{2.53} = 0.0510(39)(174) =$$

350 cubic feet per second.

Compute $Q_{15,10}$, $Q_{15,50}$, and $Q_{15,100}$ using the Central Plateaus Region equations.

$$Q_{15,10} = 0.432A^{0.435}P^{1.21} = 0.432(63)^{0.435}(15.4)^{1.21} = 0.432(6.1)(27.3) =$$

72 cubic feet per second

$$Q_{15,50} = 0.716A^{0.476}P^{1.20} = 0.716(63)^{0.476}(15.4)^{1.20} = 0.716(7.2)(26.6) =$$

140 cubic feet per second

$$Q_{15,100} = 0.809A^{0.493}P^{1.22} = 0.809(63)^{0.493}(15.4)^{1.22} = 0.809(7.7)(28.1) =$$

180 cubic feet per second.

Compute the values of weighted streamflow-characteristics based on the ratio of the basin area in each region to the total basin area.

$$Q_{15,10} = 190(4/63)+72(59/63) = 190(0.06)+72(0.94) = 79 \text{ cubic feet per second}$$

$$Q_{15,50} = 300(4/63)+140(59/63) = 300(0.06)+140(0.94) =$$

150 cubic feet per second

$$Q_{15,100} = 350(4/63)+180(59/63) = 350(0.06)+180(0.94) =$$

190 cubic feet per second.

ANALYTICAL DEVELOPMENT OF REGRESSION EQUATIONS

Regression equations for estimating streamflow characteristics were developed from multiple-regression analysis of streamflow characteristics and basin and climatic characteristics using the linear and logarithmic equations described in the section "Streamflow Information at Ungaged Sites". The characteristics, available as of September 30, 1981, are based on 135 gaged basins in Utah, Arizona, Colorado, and Wyoming (pl. 1), and the stations and characteristics are listed in table 6. The stations used in Arizona and Wyoming have parts of their drainage basins in Utah. The stations in Colorado are in the western Colorado plateau areas similar to plateau areas of eastern Utah. Three stations in the Great Basin in southwestern Utah near the Great Basin-Colorado River Basin drainage divide were used to provide a larger data base for the region in that area. The length of record of all stations used was at least 5 years for average discharge and at least 10 years for annual 1-, 7-, and 15-day mean discharges. Of the 135 gaging stations, 34 stations have 5 to 9 years of record and 101 stations have records equal to or greater than 10 years.

Station records were screened to omit those records affected more than 10 percent by diversions, regulation, or urbanization. Several of the stations that are now regulated have natural streamflow for parts of the records. The records of unregulated flows were used to determine the natural-streamflow characteristics for these streams. This information, although useful for defining regional streamflow characteristics, is not applicable to these gaged sites under present-day conditions. A footnote in table 6 identifies each gaging station in this category.

Average Discharge

The average discharge for the station record was obtained from a publication by the U.S. Geological Survey (1982) or a prior publication when the station was discontinued before 1981. The average discharge for each gaging station used in this analysis is listed in table 6.

Annual Maximum Mean Discharge-Frequency Relations

Annual maximum 1-, 7-, and 15-day mean discharges for recurrence intervals of 10, 50, and 100 years were determined for each gaging-station record with 10 or more years as of September 30, 1981. The annual maximum mean discharges of the selected recurrence intervals were determined by fitting a Pearson Type III frequency distribution (Meeks, 1977, p. G20-G27) to logarithms of observed discharges. A subjective appraisal of high and low outliers was made based on the reasonableness of the computed discharge-frequency curves. High outliers cause frequency curves to indicate extremely large discharges, especially for large recurrence intervals, through an increased standard deviation and large positive skewness. Low outliers cause large negative skewness, but they increase the standard deviation of the frequency distribution. To some degree, these characteristics are compensating, but extreme negative skewness can produce mean discharge-frequency relations which estimate little or no increase in discharge with increases in recurrence interval. High outliers were not deleted, but the discharge-frequency curves were reconstructed manually to more reasonable frequency curves based on frequency curves of nearby stations that were not affected by high outliers. Low outliers were deleted, where warranted, and the discharge-frequency curves were recomputed based on the remaining discharges.

The computed 10-, 50-, and 100-year annual maximum 1-, 7-, and 15-day mean discharges for each gaging station used in this analysis are listed in table 6.

Regression Analysis

Multiple-regression techniques were used to develop relations between streamflow characteristics (dependent variables) and basin and climatic characteristics (independent variables). Multiple regression provides a mathematical equation of the relation between a single dependent variable and one or more independent variables. It also provides a measure of the accuracy of the defined relation, the standard error of estimate, and measures of the usefulness of each independent variable for estimating the flow characteristics in the relation.

The standard error of estimate is a measure of how well the observed data agree with estimates from the regression equation. The usefulness of each independent variable to any relation is judged both on its statistical significance and on the reduction in the standard error of estimate that is brought about by including the variable. Those independent variables that were significant at the 5 percent level were considered important to the equation.

The following independent variables (basin and climatic characteristics) were included in the multiple-regression analysis prior to selecting the best regression equations for estimating the dependent variables (streamflow characteristics):

1. Contributing drainage area, in square miles;

2. Mean basin elevation, in thousands of feet;

3. Mean annual precipitation, in inches;

4. Main-channel slope, in feet per mile;

5. Forested area, in percent;

6. Azimuth of main channel (a ranked variable numbered from one to eight corresponding to the eight points of the compass; S = 1, SW = 2, SE = 3, W = 4, E = 5, NW = 6, NE = 7, N = 8).

7. Basin area above elevation of 6,000 feet, in percent;

8. Area of lakes and ponds, in percent;

9. Length of main channel, in miles;

10. 2-year, 24-hour rainfall, in inches (Miller and others, 1973);

11. 100-year, 24-hour rainfall, in inches (Miller and others, 1973);

12. Geology factor (based on relative infiltration rates assigned to surface geologic formations outlined on a geologic map of Utah) (Hintze, 1980).

The independent variables 1 through 5 appear in the final regression equations (tables 1-4). Except for main-channel azimuth and main-channel length, the statistical significance of the independent variables 6 through 12 were not fully tested to explain the variations in the dependent variables because the values for those variables were not defined for several stations.

Selection of independent variables was made using the "stepwise" procedure with the maximum R-square improvement option and the "general linear model" (GLM) procedure in the Statistical Analysis System (SAS Institute Inc., 1982, p. 101-110, 139-199). The "stepwise" procedure is a statistical technique which finds the one-variable equation producing the highest R-square. Then another variable, the one that yields the greatest increase in R-square, is added. Once the two-variable equation is obtained, each of the variables in the equation is compared to each variable not in the equation. After comparing all the alternative two-variable models, the model is selected that results in the greatest R-square. The process continues to find the best three-variable equation, and so forth; until only those that are significant at the 5-percent level remain in the equation. The GLM procedure provided graphical plots of dependent variables versus independent variables, residuals versus independent variables and predicted values, and map plots of residuals for evaluation of the equations.

Final selection of independent variables for the equations (tables 1-4) was made using the following guidelines:

1. Independent variables were selected that explained the largest practical percent variation of the dependent variable (R-square) and the smallest standard error of estimate compared to other combinations of independent variables.

2. No equation contained two or more variables that were highly correlated.

3. The regression coefficients were significant at the 5-percent level, however, for a few equations with no other choice, coefficients were accepted at the 8-percent level.

The first regional regression trials for the 10 streamflow characteristics were made using all gaging-station records in the data set for natural-flow streams in the Colorado River Basin in Utah and Wyoming (pl. 1 and table 6). The adequacy of these first regression equations were generally fair to poor; however, regional deviations could be identified from geographic plots of the residuals. The fair-to-poor equations and the residual trends were attributed mainly to the extremely varied topography of the Colorado River Basin and the several sources and forms of precipitation that produce the streamflow characteristics. In general, gaging stations on streams originating in mountain areas above 9,000 feet and with mean basin elevations greater than 7,500 feet have similar hydrologic characteristics. Runoff is mainly from snowmelt. These stations are hydrologically different from other gaging stations in the Colorado River Basin which are on streams originating below 9,000 feet. Runoff results from combinations of snowmelt and rainfall.

Regional regression analysis continued with the data set being divided into two parts, the mountain stations and the plateau stations. The mountain stations included those having mean basin elevations greater than 7,500 feet and located in Utah and Wyoming. The plateau stations included the remaining stations in Utah and including those in the Great Basin in southwestern Utah (pl. 1), and stations in western Colorado and in northern Arizona. Regression analysis of the mountain stations required only small adjustments in the data set. The addition of nearby Great Basin stations in central and northern Utah made no significant change in the R-square and standard error of estimate in the regression equation. Therefore, those Great Basin stations were not included in the data set. For the plateau stations, several different regional configurations were tested using geographic plots of residuals and knowledge of topographic and meterologic conditions.

The final results of the regression analyses indicate that the streamflow characteristics of natural-flow streams in the Colorado River Basin in Utah can best be defined at this time (1985) by dividing the basin into four regions. The regions, as outlined on plate 1 and described in the following sections, are the Mountains, Northern Plateaus, Central Plateaus, and the Southwestern Plateaus Regions. For the streamflow characteristic average discharge, the Northern Plateaus Region includes the small cross-hatched area on plate 1. The streamflow-characteristic equations are listed by region in tables 1-4.

Mountains Region

The Mountains Region (pl. 1) comprises all areas in the Colorado River Basin in Utah in which streamflow is predominantly from snowmelt. The northern part of the region consists mostly of the Wasatch Plateau-Uinta Mountains area, which is bounded on the west by the Great Basin-Colorado River Basin drainage divide and on the east by a boundary that generally corresponds to an elevation of 7,500 feet. The east boundary departs from 7,500 feet at the Strawberry-Price Rivers drainage divide southwest of Duchesne and at the south end of this northern area near Emery. From the Strawberry River basin to the Price River basin, the boundary crosses the Strawberry River just upstream of Current Creek and runs southeast along the 7,500-foot contour to the drainage divide between the Right and Left Forks of Indian Canyon, where it follows that divide to the Strawberry-Price Rivers divide. Then the boundary runs southeast along the Price River divide to the head of Coal Creek, where it turns to a southwesterly direction and follows a drainage divide to the Price River just downstream of Castle Gate. The boundary crosses the river and continues in a southwesterly direction along the 7,500-foot contour. Northwest of Emery, the boundary follows the Ferron-Muddy Creeks drainage divide from an elevation of 7,500 feet to 10,000 feet, then it turns southwest across the Muddy Creek basin to the Great Basin-Colorado River Basin drainage divide at 10,000 feet. In the southern part of the basin, the region includes the areas above 10,000 feet in the mountains in the Fish Lake area, the Henry Mountains south of Hanksville, the Boulder and Escalante Mountains north and west of Escalante, and above 9,000 feet in the LaSal Mountains southeast of Moab and the Abajo Mountains west of Monticello.

The Mountains Region is slightly different than that described above for the streamflow characteristic average discharge. The small cross-hatched area shown on plate 1 is in the Mountains Region for streamflow characteristics of annual maximum 1-, 7-, and 15-day mean discharges and in the Northern Plateaus Region for the streamflow characteristic average discharge. For average discharge, the common boundary for the Mountains and Northern Plateaus Regions runs west along the Avintaquin Creek south drainage divide from the main regional boundary (pl. 1) to the Utah-Wasatch County line north of Colton, then the boundary runs south across the Price River just southeast of Colton. From the Price River crossing, the boundary continues in a southwesterly direction along a drainage divide to the Manti-LaSal National Forest Boundary just south of the town of Clear Creek, then it turns east to the main regional boundary at an elevation of 7,500 feet.

The principal form of precipitation during the winter is snow derived from moisture moving eastward from the Pacific Ocean. Infrequently, high streamflows are caused by rainfall on snow or a thick snowpack that melts rapidly because of a rapid rise in temperature. During the summer, rainfall falls throughout the region, but because of the high elevation, intense thunderstorms rarely occur over areas large enough to cause significant streamflow. The streamflow-characteristic equations apply to all unregulated streams in this region except the upper part of Castle Creek, which is on the north side of the LaSal Mountains. The records from station 09182000, Castle Creek above diversions, near Moab (not shown on pl. 1), indicate that the surface runoff from the basin is significantly less than runoff from similar gaged basins in the area. George A. Birdwell (oral commun., U.S. Geological Survey, 1984) stated that several springs discharge downstream from the gaging station.

The regression equations relating streamflow characteristics to basin and climatic characteristics for the Mountains Region are listed in table 1, with the corresponding number of stations used in the regression analysis, the standard error of estimate, and equivalent years of record.

Northern Plateaus Region

The Northern Plateaus Region includes the northern areas of the Colorado River Basin in Utah east and south of the Mountains Region and north of the Roan Cliffs (pl. 1). The south boundary follows the drainage divide along the Roan Cliffs from the Colorado State line to a point northeast of Helper where it meets with the east boundary of the Mountains Region. The location of the common boundary with the Mountains Region is described in the section "Mountains Region".

The Northern Plateaus Region is slightly enlarged from that described above for the streamflow characteristic average discharge. The small cross-hatched area shown on plate 1 is in the Northern Plateaus Region for the streamflow characteristic average discharge and in the Mountains Region for streamflow characteristics of annual maximum 1-, 7-, and 15-day mean discharges. The detailed description of the boundary for this special condition is given in the section "Mountains Region".

The sources of streamflow in this region are snowmelt and thunderstorms. Snowmelt in late winter and early spring generally results in greater continuous volumes of streamflow than does the thunderstorms, but thunderstorms generally cause the maximum instantaneous peaks for the period of station record. On rare occasions, rain on snow causes high peak discharges.

For streams originating in the Mountains Region, the area north of the Strawberry and Duchesne Rivers and northwest of the Green River is a transition zone between the Mountains Region and the Northern Plateaus Region. Streamflow characteristics at sites on unregulated streams originating from mountain areas above 9,000 feet should be computed using the Mountains Region regression equations. At sites on other streams originating in the Mountains Region, streamflow characteristics should be computed using a procedure that accounts for the percentage of drainage area in each region (See section "Procedure 2.--Weighting procedure for sites where regression equations for two regions are used").

The equations (table 2) for the Northern Plateaus Region should be used with discretion. The average discharge has a large exponent for elevation, primarily because the average discharge varys greatly among the drainage basins due to the extremely variable hydrologic conditions in the region. To account for the variability in the basin hydrology, contributing drainage area (A), mean basin elevation (E), forested area (F), and main-channel slope (S) are included in the equation to estimate average discharge. The equations for estimating annual maximum 1-, 7-, and 15-day mean discharges may not always provide estimated discharges at ungaged sites within the standard error of estimates given in table 2, due to the availability of only nine stations for the regional regression analysis.

The equations for the Northern Plateaus Region should be used with caution for sites north of the Green River and east of Manila in the extreme northeast corner of the region. The 5-year record at station 09234700, Red Creek near Dutch John (not shown on pl. 1), contains the only data available for the area. The lack of additional station records for this area prevented verification of the regression relations between the streamflow characteristics and the basin and climatic characteristics. The regional-correlation plot of residuals versus average discharge indicated a poor fit with other regional data; therefore, the station was excluded from this analysis.

The station 09306800, Bitter Creek near Bonanza, was included in the regional regression analysis for average discharge but not for annual maximum 1-, 7-, and 15-day mean discharges. The regional-correlation plots of annual maximum-mean discharges versus contributing drainage area indicated that the high runoff from Bitter Creek basin is much less than that from other basins in the region. The streamflow characteristics based on the station record are listed in table 6. In table 2, the regression equation for average discharge is the only equation applicable to the Bitter Creek basin.

The regression equations relating streamflow characteristics to basin and climatic characteristics for the Northern Plateaus Region are listed in table 2, with the corresponding number of stations used in the regression analysis, the standard error of estimate, and equivalent years of record.

Central Plateaus Region

The Central Plateaus Region comprises the central area of the Colorado River Basin in Utah, which consists of the plateau area from the southern boundary of the Northern Plateaus Region (Roan Cliffs), south to the Arizona State line, and southwest to and including Kanab Creek (pl. 1). The west boundary follows the Kanab Creek west drainage divide from the Arizona State line to the Great Basin-Colorado River Basin drainage divide, then northeasterly along an intermittent boundary with the Great Basin-Colorado River Basin drainage divide and the Mountains Region. The north boundary is described in detail in the section "Northern Plateaus Region". This region is the largest of the four regions and includes more than one-half of the Colorado River Basin area in Utah. Within this region the high-mountain areas are designated as part of the Mountains Region and are described in that section. For those streams originating in the Mountains Region, the streamflow characteristics at a site in the Central Plateaus Region should be computed using the method described in section "Procedure 2.--Weighting procedure for sites where regression equations for two regions are used".

Snowmelt in late winter and in the spring, high-intensity rainfall in the summer, and infrequent rainstorms in the fall are the sources of streamflow. The streamflow volume is generally greatest from snowmelt. Mean daily discharge from melting snow in the spring generally is exceeded by streamflow from rainfall. In the summer and fall, many days of no streamflow occur between storms at many of the stations.

The station 09372000, McElmo Creek near Colorado-Utah State line, was included in the regional regression analysis for annual maximum 1-, 7-, and 15-day mean discharges but not for average discharge. The average discharge is significantly affected by return water that is imported from the Dolores River basin and spread on irrigated lands in the Montezuma Irrigation District. The regression equation for average discharge in table 3 is not applicable to McElmo Creek, however, the equation may be used to estimate average discharge for natural flow tributaries to McElmo Creek.

The regression equations relating streamflow characteristics to basin and climatic characteristics for the Central Plateaus Region are listed in table 3 with the corresponding number of stations used in the regression analysis, the standard error of estimate, and equivalent years of record.

Southwestern Plateaus Region

The Southwestern Plateaus Region is the southwestern area of the Colorado River Basin in Utah, and it is west of the Central Plateaus Region (pl. 1). The area is bounded by the Arizona and Nevada State lines on the south and west, by the Great Basin-Colorado River Basin drainage divide on the north, and the west boundary of the Central Plateaus Region on the east which is described in detail in the section "Central Plateaus Region".

Streamflow in the Southwestern Plateaus Region is from rainfall and snowmelt. The volume of streamflow generally is greatest in late winter and early spring due to snowmelt or rain on snow. During the period of a station record, the annual peak discharges can occur in any month of the year. The annual maximum peak discharges generally result from summer thunderstorms.

The regression equations relating streamflow characteristics to basin and climatic characteristics for the Southwestern Plateaus Region are listed in table 4 with the corresponding number of stations used in the regression analysis, the standard error of estimate, and equivalent years of record. The equations in table 4 may not always provide estimates of discharge at ungaged sites within the standard error of estimates given in table 4, due to the small number of stations (13 for average discharge and 10 for annual maximum 1-, 7-, and 15-day mean discharges) available for the regional regression analysis.

FUTURE STUDY OF LOW-FLOW CHARACTERISTICS

Low-flow characteristics commonly are used to determine the adequacy of streamflow for municipal or industrial supplies, irrigation, disposal of mine liquid wastes, and maintenance of suitable streamflow conditions for fish. Certain low-flow characteristics also are useful as indicators of the quantity of ground-water discharge to the stream and legal indexes for stream pollution control.

In the Colorado River Basin in Utah, selected low-flow characteristics are available for most continuous-record gaging stations with 10 or more years of record as of September 1981 (Christensen and others, 1986). However, procedures are needed to transfer low-flow characteristics from gaged to ungaged sites. To provide such transfer capability, additional low-flow data from an expanded partial-record station network are needed. Significant streamflow gains or losses need to be determined through seepage run investigations and non-perennial streams identified. (For a detailed explanation of the methods used to define low-flow characteristics of streams, see Riggs, 1972.)

SUMMARY

Methods are presented for estimating average discharge and annual maximum 1-, 7-, and 15-day mean discharges for recurrence intervals of 10, 50, and 100 years at three types of sites on natural-flow streams in the Colorado River Basin in Utah. At or near gaged sites, two methods depend on the availability of daily-discharge records. At the gaged site, the weighted-average method is used to weight the station value and a regression-equation value. At a site near a gaged site on the same stream, the drainage-area-ratio method is used to transfer the weighted-average value from the gaged site to the nearby ungaged site. At sites on ungaged streams, a method uses regression equations to relate streamflow characteristics to basin and climatic characteristics. Examples are given on how to use the three methods.

Regression equations relating average discharge and 10-, 50-, and 100-year annual maximum 1-, 7-, and 15-day mean discharges to basin and climatic characteristics were developed for four regions in the Colorado River Basin in Utah. The equations relate the 10 streamflow characteristics to the following basin and climate characteristics: contributing drainage area, mean basin elevation, mean annual precipitation, main-channel slope, and forested area. The standard error of estimate for the 10 streamflow characteristics ranges from 13 to 87 percent.

Basin, climatic, and streamflow characteristics for 135 gaging stations on unregulated streams are tabulated. In addition, weighted estimates of streamflow characteristics based on station data and the regression-equation estimates are provided for most of the gaged sites. The use of weighted values at the gaged sites should provide more reliable streamflow estimates than the use of station data only.

A low-flow study is suggested to collect needed low-flow data and to develop methods for estimating low-flow characteristics at ungaged sites. Selected low-flow characteristics are available at most gaging stations with 10 or more years of record as of September 1981. However, procedures are needed to transfer low-flow characteristics from gaged to ungaged sites.

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Streamflow characteristics: (first line) values used in multiple-regression analysis; (second line) weighted averages of values from 1-4 was less than 1.
Dash (-) indicates no value was determined or no data were available.

Station number	Station name (in Utah except as indicated)	Period of record used (water years)	Basin and climatic characteristics: Contributing drainage area (square miles)	Mean basin elevation (feet)	Mean annual precipitation (inches)	Main-channel slope (feet per mile)	Forested area (percent)
			Mountains Region				
09169000	Twomile Creek near LaSal	1945-51	13.9	8,340	-	332	87
09177500	Taylor Creek near Gateway, CO	1945-67	12	9,000	17.0	180	50
09186000	Indian Creek near Monticello	1950-57	4.7	9,620	-	474	64
09217900	Blacks Fork near Robertson, WY	1938 1967-81	130	10,640	20.0	71.2	55
09218500	Blacks Fork near Millburne, WY	1940-70 (1)	152	10,270	19.0	76.0	61
09220000	East Fork of Smiths Fork near Robertson, WY	1940-71	53.0	10,250	20.0	109	70
09220500	West Fork of Smiths Fork near Robertson, WY	1940-71	37.2	9,790	20.0	156	89
09226000	Henrys Fork near Lonetree, WY	1943-71 (2)	56	10,270	23.0	160	61
09226500	Middle Fork Beaver Creek near Lonetree, WY	1949-70	28	10,480	30.5	224	68
09227000	East Fork Beaver Creek near Lonetree, WY	1949-62	8.2	10,680	22.2	241	-
09227500	West Fork Beaver Creek near Lonetree, WY	1949-62	23	10,490	32.0	239	29
09228500	Burnt Fork near Burntfork, WY	1944-71 (3)	52.8	10,300	29.3	209	69
09233000	Carter Creek near Manila	1949-54	11.3	10,280	-	341	71
09234000	Carter Creek at mouth, near Manila	1947-55	110	9,010	-	111	85
09235600	Pot Creek above diversions, near Vernal	1958-81	24.6	8,170	19.6	53.9	56
09260500	Jones Hole Creek near Jensen	1951-56 1961	120	7,560	-	83.6	15
09264000	Ashley Creek below Trout Creek, near Vernal	1944-54	27	9,930	28.0	156	85
09264500	South Fork Ashley Creek near Vernal	1944-55	20	10,480	30.3	164	60
09265300	Ashley Creek above Red Pine Creek, near Vernal	1965-75	55.8	9,810	28.6	163	76
09266500	Ashley Creek near Vernal	1914-81 (4)	101	9,440	23.0	208	83
09268000	Dry Fork above Sinks, near Dry Fork	1940-75	44.4	10,240	29.7	85.4	64
09268500	North Fork of Dry Fork, near Dry Fork	1947-81	8.62	10,120	29.6	503	80
09268900	Brownie Canyon above Sinks, near Dry Fork	1961-81	8.24	10,110	28.0	320	91
09269000	East Fork of Dry Fork, near Dry Fork	1947-63	12	9,360	28.6	348	90
09270000	Dry Fork below springs, near Dry Fork	1941-45 (5) 1954-69	97.4	9,360	27.5	180	78
09270500	Dry Fork at mouth, near Dry Fork	1955-81	115	9,190	23.0	173	73
09271000	Ashley Creek at sign of the Maine, near Vernal	1901-04 (6) 1940-65	241	9,100	23.0	190	75
09273000	Duchesne River at Provo River Trail, near Hanna	1930-33 (7) 1936-43 1945-53	39	9,730	35.9	360	79

gaging stations used in regression analysis

station records and regional-regression equations. Weighted values were not computed when the determined equivalent years of record listed in tables

Streamflow characteristics									
Average discharge (cubic feet per second)	Discharge, in cubic feet per second, for indicated consecutive-day period and recurrence interval								
	1-day 10-year	1-day 50-year	1-day 100-year	7-day 10-year	7-day 50-year	7-day 100-year	15-day 10-year	15-day 50-year	15-day 100-year
Mountains Region									
2.22	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
3.17	156	345	450	110	255	335	84	190	225
-	152	317	410	107	228	295	83	175	227
2.88	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
155	1,860	2,080	2,150	1,620	1,890	1,980	1,430	1,680	1,760
-	1,860	2,120	2,260	1,610	1,860	1,960	1,410	1,620	1,690
158	1,770	2,260	2,480	1,490	1,860	2,010	1,290	1,580	1,700
-	1,770	2,260	2,480	1,490	1,850	2,000	1,290	1,570	1,680
47.1	707	1,090	1,280	566	816	933	455	610	677
-	706	1,070	1,250	566	799	907	456	606	668
21.5	583	1,080	1,380	404	589	677	315	444	502
-	573	1,020	1,300	400	566	648	313	434	486
40.8	831	1,440	1,780	566	858	1,000	434	607	684
-	824	1,380	1,690	568	838	965	438	608	679
23.0	423	628	723	324	455	511	247	333	369
-	423	620	711	325	451	505	250	336	370
7.19	61	91	107	50	67	75	42	55	62
-	72	118	137	58	93	103	49	73	83
16.2	242	368	431	188	258	287	148	189	204
-	256	395	457	200	290	320	158	216	237
31.1	519	1,150	1,580	346	627	795	273	415	484
-	532	1,120	1,510	362	644	792	287	443	511
9.32	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
60.0	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
3.46	125	207	246	91	158	192	72	134	168
-	126	207	246	93	161	194	74	138	170
36.3	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
24.1	434	509	531	351	411	429	304	352	366
-	417	495	528	338	389	415	291	333	348
19.9	315	354	364	263	299	308	219	243	249
-	315	374	394	261	306	322	217	247	258
67.1	1,720	2,980	3,600	1,110	1,600	1,840	778	971	1,050
-	1,550	2,400	2,880	1,020	1,260	1,440	722	836	884
98.5	1,310	1,740	1,910	1,070	1,360	1,460	902	1,150	1,250
-	1,300	1,710	1,880	1,060	1,330	1,430	894	1,130	1,220
36.0	672	909	1,010	517	669	729	425	544	588
-	667	897	997	515	660	719	423	538	580
6.57	104	140	155	86	110	118	74	90	95
-	105	145	161	87	114	123	74	92	99
12.7	194	260	289	153	191	206	131	164	177
-	187	247	275	148	177	192	126	153	163
7.97	157	196	210	128	152	160	104	126	134
-	153	194	210	125	149	160	102	124	133
31.8	808	1,010	1,070	700	902	969	614	816	887
-	809	1,030	1,100	699	903	976	612	809	878
25.1	764	1,020	1,120	635	842	916	526	696	756
-	772	1,040	1,150	643	869	949	534	722	788
124	1,910	2,580	2,850	1,590	2,130	2,340	1,310	1,760	1,930
-	1,890	2,530	2,790	1,580	2,080	2,280	1,300	1,740	1,900
57.1	781	887	921	698	766	785	600	661	677
-	752	842	882	670	702	727	575	611	623

Station number	Station name (in Utah except as indicated)	Period of record used (water years)	Basin and climatic characteristics: Contributing drainage area (square miles)	Mean basin elevation (feet)	Mean annual precipitation (inches)	Main-channel slope (feet per mile)	Forested area (percent)
			Mountains Region--Continued				
09273500	Hades Creek near Hanna	1950-68	7.5	9,730	30.3	620	68
09274000	Duchesne River near Hanna	1922-23(8) 1947-53	78	9,810	32.5	218	74
09275000	West Fork Duchesne River below Dry Hollow, near Hanna	1950-68 1975-81	43.8	9,100	28.5	136	56
09275500	West Fork Duchesne River near Hanna	1923 1946-81	61.6	8,840	26.6	106	49
09276000	Wolf Creek above Rhoades Canyon, near Hanna	1946-81	10.6	9,040	26.6	274	80
09277500	Duchesne River near Tabiona	1919-53(8)	356	8,770	25.6	93.0	59
09277800	Rock Creek above South Fork, near Hanna	1966-81	98.9	10,360	35.5	192	66
09278000	South Fork Rock Creek near Hanna	1954-81	15.7	10,000	30.8	389	60
09278500	Rock Creek near Hanna	1950-69 1975-81	122	10,200	32.9	172	69
09279000	Rock Creek near Mountain Home	1938-81	147	10,000	31.6	137	64
09279100	Rock Creek near Talmage	1964-81	238	9,400	27.7	88.0	64
09279500	Duchesne River at Duchesne	1918-69	660	8,770	24.1	44.0	59
09280400	Hobble Creek at Daniels Summit, near Wallsburg	1964-81	2.89	9,060	29.3	446	88
09287000	Current Creek below Red Lodge Hollow, near Fruitland	1946-68 1975-81	50.1	8,880	27.8	219	72
09287500	Water Hollow near Fruitland	1947-71(9)	13.8	8,380	22.1	258	79
09288000	Currant Creek near Fruitland	1935-81(10)	140	8,360	24.6	82.0	65
09288150	West Fork Avintaquin Creek near Fruitland	1965-81	56.1	8,310	22.1	146	56
09289500	Lake Fork River above Moon Lake, near Mountain Home	1943-55 1964-81	77.9	10,800	35.4	224	51
09291500	Yellowstone Creek below Swift Creek, near Altonah	1950-55	99	10,810	-	198	43
09292500	Yellowstone River near Altonah	1945-81	132	10,440	32.6	170	60
09296000	Uinta River above Clover Creek, near Neola	1946-55	132	10,960	37.1	207	52
09296500	Clover Creek near Neola	1951-55	9.5	10,300	-	440	69
09297000	Uinta River near Neola	1926 1930-81	163	10,710	32.7	161	55
09298000	Farm Creek near Whiterocks	1950-81	14.9	9,180	23.1	406	85
09298500	Whiterocks River above Paradise Creek, near Whiterocks	1946-55	90	10,700	34.1	219	51
09299500	Whiterocks River near Whiterocks	1900-03(11) 1909-10 1914-81	113	10,370	32.1	185	80
09310500	Fish Creek above reservoir, near Scofield	1939-81	60.1	8,710	29.4	69.0	57

gaging stations used in regression analysis--Continued

Average discharge (cubic feet per second)	Streamflow characteristics: Discharge, in cubic feet per second, for indicated consecutive-day period and recurrence interval								
	1-day 10-year	1-day 50-year	1-day 100-year	7-day 10-year	7-day 50-year	7-day 100-year	15-day 10-year	15-day 50-year	15-day 100-year
				Mountains Region--Continued					
9.04	104	124	130	91	106	110	83	97	101
-	103	127	136	89	106	112	81	95	100
122	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
36.7	546	645	675	454	514	528	400	462	479
-	532	627	661	442	494	514	389	444	462
47.7	538	611	630	461	503	512	410	454	465
-	532	611	636	456	503	519	405	452	468
7.40	52	62	66	46	56	59	41	50	53
-	54	70	76	48	64	69	42	56	61
215	1,970	2,530	2,760	1,770	2,320	2,560	1,570	2,140	2,400
-	1,970	2,550	2,780	1,770	2,320	2,560	1,570	2,130	2,380
133	1,860	2,110	2,180	1,600	1,880	1,980	1,410	1,640	1,720
-	1,800	2,020	2,100	1,540	1,720	1,820	1,350	1,500	1,550
12.9	136	171	183	120	143	150	106	122	126
-	141	186	202	123	157	167	108	131	139
149	1,980	2,230	2,300	1,660	1,900	1,970	1,430	1,610	1,660
-	1,940	2,180	2,270	1,630	1,820	1,900	1,400	1,550	1,590
128	1,910	2,190	2,280	1,620	1,860	1,940	1,430	1,660	1,730
-	1,900	2,180	2,280	1,610	1,830	1,920	1,420	1,630	1,690
177	1,840	1,990	2,030	1,610	1,790	1,840	1,430	1,550	1,580
-	1,850	2,020	2,150	1,610	1,850	1,940	1,420	1,600	1,660
360	3,620	4,060	4,180	3,300	3,780	3,900	2,910	3,320	3,430
-	3,620	4,100	4,240	3,290	3,810	3,950	2,900	3,350	3,480
2.75	72	91	99	55	67	71	47	57	61
-	68	83	91	52	59	64	44	51	54
25.5	374	488	526	340	444	477	295	379	404
-	373	492	533	338	440	477	293	378	405
5.71	32	49	56	29	44	51	27	41	48
-	36	61	71	32	57	66	30	51	61
45.4	477	647	710	412	549	597	356	464	502
-	487	676	846	421	586	641	364	496	545
14.4	305	473	548	232	359	417	201	305	351
-	305	469	542	235	364	421	204	313	359
110	1,480	1,880	2,050	1,190	1,500	1,630	1,020	1,310	1,440
-	1,460	1,840	2,010	1,180	1,450	1,570	1,010	1,260	1,370
120	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
136	1,250	1,590	1,730	1,080	1,330	1,420	948	1,150	1,230
-	1,270	1,650	1,790	1,100	1,380	1,470	959	1,180	1,260
142	1,800	2,660	3,040	1,420	2,220	2,600	1,100	1,710	2,020
-	1,850	2,640	2,970	1,470	2,130	2,410	1,150	1,670	1,880
1.92	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
177	1,940	2,710	3,060	1,520	2,010	2,210	1,260	1,650	1,800
-	1,950	2,720	3,060	1,530	2,030	2,220	1,270	1,660	1,810
6.09	128	174	188	103	144	157	84	119	131
-	128	178	193	103	147	161	85	121	134
98.3	1,320	1,570	1,650	1,030	1,270	1,350	837	1,070	1,160
-	1,320	1,610	1,710	1,040	1,280	1,370	847	1,070	1,140
122	1,500	1,940	2,090	1,150	1,410	1,490	954	1,180	1,260
-	1,500	1,930	2,090	1,150	1,410	1,500	955	1,180	1,260
46.8	834	1,070	1,160	732	933	1,010	621	787	848
-	814	1,030	1,120	714	876	951	606	748	800

Station number	Station name (in Utah except as indicated)	Period of record used (water years)	Basin and climatic characteristics: Contributing drainage area (square miles)	Mean basin elevation (feet)	Mean annual precipitation (inches)	Main-channel slope (feet per mile)	Forested area (percent)
			Mountains Region--Continued				
09312000	North Fork White River near Soldier Summit	1943-47	23.3	8,000	-	138	69
09312500	White River near Soldier Summit	1940-67	53	8,360	26.3	94.4	53
09312600	White River below Tabbyune Creek, near Soldier Summit	1968-81	75.6	8,150	25.4	58.8	57
09312700	Beaver Creek near Soldier Summit	1961-81	26.1	8,750	21.0	114	61
09312800	Willow Creek near Castle Gate	1963-81	62.8	8,120	14.0	143	69
09318000	Huntington Creek near Huntington	1911-17 (13) 1922-29 1931-73 1978-79	190	9,000	22.7	84.0	56
09324500	Cottonwood Creek near Orangeville	1910-20 (14) 1922-27 1933-65	208	8,940	21.2	136	80
09326500	Ferron Creek (upper station) near Ferron	1912-23 1948-81	138	8,800	22.7	199	54
09329050	Seven Mile Creek near Fish Lake	1965-81	24.0	10,020	27.0	90.0	64
09330500	Muddy Creek near Emery	1911-13 1950-81	105	8,850	24.5	180	57
09338000	East Fork Boulder Creek near Boulder	1951-55 1958-72	21.4	10,500	28.8	252	50
09378630	Recapture Creek near Blanding	1966-81	3.77	8,880	22.9	573	91
			Northern Plateaus Region				
09091500	East Rifle Creek near Rifle, CO	1937-43 1957-64	34.3	8,500	25.3	285	90
09092000	Rifle Creek near Rifle, CO	1940-46 1953-64	137	8,200	22.4	243	-
09288900	Sowers Creek near Duchesne	1965-81	40.6	8,120	17.4	104	65
09304300	Coal Creek near Meeker, CO	1958-68	25.1	7,960	25.4	312	76
09306200	Piceance Creek below Ryan Gulch, near Rio Blanco, CO	1965-81	506	7,420	18.1	58.0	80
09306222	Piceance Creek at White River, CO	1965-66 1971-81	652	7,270	15.2	42.0	80
09306405	Hells Hole Canyon Creek at mouth, near Watson	1975 1977-81	24.5	6,610	12.1	93.2	65
09306410	Evacuation Creek above Missouri Creek, near Dragon	1975-81	100	7,220	17.4	77.6	89
09306430	Evacuation Creek near Watson	1975-81	284	6,700	13.4	50.0	47
09306625	Asphalt Wash near mouth, near Watson	1975-81	97.5	6,100	11.9	70.4	68
09306800	Bitter Creek near Bonanza	1971-81	324	7,300	16.1	62.5	94
09306850	Bitter Creek at mouth, near Bonanza	1975-81	398	6,890	14.8	43.3	82
09306870	Sand Wash near Ouray	1975-81	59.7	5,980	10.8	66.8	50
09306885	Cottonwood Wash at mouth, near Ouray	1977-81	70.6	5,490	9.0	55.8	17

gaging stations used in regression analysis--Continued

Average discharge (cubic feet per second)	Streamflow characteristics: Discharge, in cubic feet per second, for indicated consecutive-day period and recurrence interval								
	1-day 10-year	1-day 50-year	1-day 100-year	7-day 10-year	7-day 50-year	7-day 100-year	15-day 10-year	15-day 50-year	15-day 100-year
Mountains Region--Continued									
6.27	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
19.4	397	756	966	359	660	829	300	543	681
-	390	716	908	352	608	756	295	510	626
27.3	441	521	542	400	469	486	351	415	432
-	431	526	559	389	467	500	342	416	445
(12)	84	145	173	74	133	160	67	116	137
(12)	93	167	197	81	154	182	73	132	156
(12)	215	478	640	170	425	600	162	422	580
(12)	223	474	619	179	416	562	168	407	537
96.3	943	1,280	1,420	841	1,140	1,260	756	1,040	1,150
-	958	1,320	1,460	852	1,180	1,300	765	1,060	1,180
99.4	1,430	2,010	2,260	1,210	1,640	1,820	1,070	1,470	1,630
-	1,430	2,000	2,240	1,210	1,630	1,810	1,070	1,460	1,610
66.0	868	1,150	1,260	738	986	1,090	671	901	995
-	868	1,150	1,270	738	989	1,090	670	901	994
14.1	151	176	184	135	161	169	116	137	143
-	167	224	241	147	204	219	119	167	181
37.3	366	554	638	287	395	435	262	352	384
-	384	597	684	303	456	503	269	397	443
23.7	230	306	337	180	252	284	136	190	214
-	239	332	367	188	273	305	143	207	233
1.33	51	146	215	37	96	135	32	85	120
-	49	128	185	36	81	112	31	73	99
Northern Plateaus Region									
38.4	146	212	243	131	187	211	114	156	173
37	132	200	233	117	180	214	101	154	182
24.8	210	390	500	175	340	430	140	260	320
-	188	343	433	154	286	359	125	226	279
3.80	45	96	127	33	70	91	30	65	85
3.8	65	129	166	57	118	151	51	108	138
5.23	88	142	165	70	110	132	62	100	113
5.5	94	158	188	81	144	178	72	129	157
20.1	157	288	350	133	235	290	116	215	270
20	187	371	475	150	290	369	130	259	332
25.0	260	460	560	193	325	390	167	305	370
24	274	527	673	198	371	467	169	331	419
.06	-	-	-	-	-	-	-	-	-
.06	-	-	-	-	-	-	-	-	-
1.34	-	-	-	-	-	-	-	-	-
1.3	-	-	-	-	-	-	-	-	-
1.55	-	-	-	-	-	-	-	-	-
2.2	-	-	-	-	-	-	-	-	-
.18	-	-	-	-	-	-	-	-	-
.17	-	-	-	-	-	-	-	-	-
1.57	47	139	209	17	30	36	13	24	29
1.7	-	-	-	-	-	-	-	-	-
1.08	-	-	-	-	-	-	-	-	-
1.2	-	-	-	-	-	-	-	-	-
.03	-	-	-	-	-	-	-	-	-
.04	-	-	-	-	-	-	-	-	-
1.39	-	-	-	-	-	-	-	-	-
1.3	-	-	-	-	-	-	-	-	-

Table 6.--Selected basin, climatic, and streamflow characteristics for

Station number	Station (in Utah except as indicated)	Period of record used (water years)	Basin and climatic characteristics: Contributing drainage area (square miles)	Mean basin elevation (feet)	Mean annual precipitation (inches)	Main-channel slope (feet per mile)	Forested area (percent)
			Northern Plateaus Region--Continued				
09307200	Pariette Draw near Ouray	1976-81	153	5,920	-	59.0	20
09307500	Willow Creek above diversions, near Ouray	1951-55 (10) 1958-70 1975-81	297	7,710	16.8	47.6	81
09307800	Hill Creek above Towave Reservoir, near Ouray	1975-81	89.7	7,570	-	80.0	65
09307900	Hill Creek near mouth, near Ouray	1975-81	288	6,780	-	56.4	49
09308000	Willow Creek near Ouray	1948-55 (10) 1975-81	897	7,140	13.7	32.8	55
09308500	Minnie Maud Creek near Myton	1951-55 (10) 1958-81	32.0	8,460	18.7	156	90
09309000	Minnie Maud Creek at Nutter Ranch, near Myton	1948-55 (10)	231	7,880	16.8	86.0	76
09312700	Beaver Creek near Soldier Summit	1961-81	26.1	8,750	21.0	114	61
09312800	Willow Creek near Castle Gate	1963-81	62.8	8,120	14.0	143	69
			Central Plateaus Region				
09146600	Pleasant Valley Creek near Noel, CO	1956-67	7.98	9,100	22.2	222	40
09168100	Disappointment Creek near Dove Creek, CO	1958-81	145	8,000	24.5	180	80
09175900	Dry Creek near Naturita, CO	1967-78	78.6	7,400	18.8	121	53
09181000	Onion Creek near Moab	1951-55	18.8	5,700	12.3	161	51
09182500	Castle Creek near Moab	1951-55 (16) 1958	53.1	6,380	17.8	309	47
09183000	Courthouse Wash near Moab	1950-55 1961-81	162	4,810	7.5	36.8	6
09183500	Mill Creek at Sheley Tunnel, near Moab	1955-59	27.4	8,700	24.2	481	84
09184000	Mill Creek near Moab	1950-71 (17) 1973-81	74.9	7,170	16.7	259	56
09184500	Pack Creek at M4 Ranch, near Moab	1955-59	15.8	9,200	25.7	672	81
09185000	Pack Creek near Moab	1955-59	57.4	6,340	18.8	310	55
09185500	Hatch Wash near LaSal	1951-71	378	6,550	13.1	36.2	38
09186500	Indian Creek above Cottonwood Creek, near Monticello	1950-71	31.2	8,590	21.2	261	89
09187000	Cottonwood Creek near Monticello	1950-57	115	7,210	26.4	17.9	93
09187500	Indian Creek above Harts Draw, near Monticello	1950-57	258	6,580	15.6	83.6	69
09315500	Saleratus Wash at Green River	1949-70	180	5,050	7.5	49.2	39
09316000	Browns Wash near Green River	1950-68 (10)	75	5,220	9.3	102	30
09329900	Pine Creek near Bicknell	1965-80	104	9,300	20.3	115	50
09331500	Ivie Creek above diversions, near Emery	1951-61	50	8,870	20.3	236	65

gaging stations used in regression analysis--Continued

Average discharge (cubic feet per second)	Streamflow characteristics: Discharge, in cubic feet per second, for indicated consecutive-day period and recurrence interval								
	1-day 10-year	1-day 50-year	1-day 100-year	7-day 10-year	7-day 50-year	7-day 100-year	15-day 10-year	15-day 50-year	15-day 100-year
Northern Plateaus Region--Continued									
24.9	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-
20.6	189	308	370	162	280	340	142	255	312
20	188	325	401	156	278	344	135	248	308
9.39	-	-	-	-	-	-	-	-	-
8.7	-	-	-	-	-	-	-	-	-
5.09	-	-	-	-	-	-	-	-	-
5.6	-	-	-	-	-	-	-	-	-
25.2	442	1,020	1,400	267	620	840	220	500	680
26	417	923	1,240	259	564	747	214	464	615
5.03	129	330	460	103	285	413	92	258	375
5.0	124	290	391	101	247	344	89	219	304
20.4	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-
3.88	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)
4.1	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)
8.15	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)
8.6	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)
Central Plateaus Region									
2.22	134	180	197	92	123	130	65	86	92
2.1	125	184	218	82	114	129	61	82	97
17.2	425	750	920	230	415	510	195	370	470
17	412	783	987	230	428	536	193	363	468
2.60	462	1,690	2,880	99	294	457	57	179	286
2.9	419	1,310	2,000	111	284	399	70	188	259
1.13	-	-	-	-	-	-	-	-	-
1.1	-	-	-	-	-	-	-	-	-
5.25	-	-	-	-	-	-	-	-	-
5.3	-	-	-	-	-	-	-	-	-
1.81	429	789	976	74	124	148	40	62	71
1.7	489	830	1,050	77	143	180	41	77	98
11.4	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-
14.3	279	565	735	91	122	133	76	105	116
14	285	577	753	96	153	184	77	130	164
2.54	-	-	-	-	-	-	-	-	-
3.6	-	-	-	-	-	-	-	-	-
4.02	-	-	-	-	-	-	-	-	-
4.7	-	-	-	-	-	-	-	-	-
1.60	413	740	889	143	319	418	75	156	198
1.8	459	930	1,210	155	357	472	85	212	289
4.40	99	189	237	63	113	139	56	105	133
4.4	115	239	316	70	140	177	60	125	163
3.10	-	-	-	-	-	-	-	-	-
3.2	-	-	-	-	-	-	-	-	-
5.99	-	-	-	-	-	-	-	-	-
6.2	-	-	-	-	-	-	-	-	-
2.99	670	990	1,070	125	185	215	72	113	130
2.9	679	994	1,140	119	187	226	67	104	125
0.95	508	1,170	1,530	101	282	402	50	147	220
1.0	507	1,020	1,290	96	232	313	48	111	145
3.98	152	800	1,500	76	348	635	51	189	312
4.2	176	785	1,310	98	341	540	68	220	313
3.91	77	200	288	48	132	195	38	110	166
4.4	118	320	454	71	183	249	55	151	205

Station number	Station name (in Utah except as indicated)	Period of record used (water years)	Basin and climatic characteristics: Contributing drainage area (square miles)	Mean basin elevation (feet)	Mean annual precipitation (inches)	Main-channel slope (feet per mile)	Forested area (percent)
			Central Plateaus Region--Continued				
09334000	North Wash near Hanksville	1951-70[18]	136	5,400	10.0	110	13
09334500	White Canyon near Hanksville	1951-70[19]	276	6,090	13.0	49.0	50
09335500	North Creek near Escalante	1951-55	90	8,240	19.7	232	93
09337000	Pine Creek near Escalante	1951-55 1958-81	68.1	8,890	22.7	216	78
09337500	Escalante River near Escalante	1910-12[20] 1943-55 1973-81	320	8,030	18.4	174	83
09338500	East Fork Deer Creek near Boulder	1951-55	1.9	9,290	20.7	533	50
09362000	Lightner Creek near Durango, CO	1928-49	66	8,400	29.0	264	90
09366000	Cherry Creek near Red Mesa, CO	1929-50	66	7,900	22.4	127	-
09369000	East Mancos River near Mancos, CO	1938-51[10]	11.9	9,700	34.5	449	79
09369500	Middle Mancos River near Mancos, CO	1938-51	12.1	9,300	29.4	565	90
09372000	McElmo Creek near Colorado-Utah State line	1952-81	346	6,300	14.6	52.8	61
09376900	Spring Creek above diversions, near Monticello	1966-72	4.95	9,100	24.3	374	63
09378700	Cottonwood Wash near Blanding	1965-81	205	6,820	16.4	78.5	77
09379000	Comb Wash near Bluff	1960-68[10]	280	6,060	11.5	44.9	72
09382000	Paria River at Lees Ferry, AZ	1924-81	1,410	6,150	12.0	43.0	73
09403780	Kanab Creek near Fredonia, AZ	1964-80	1,085	6,100	12.0	56.4	60
			Southwestern Plateaus Region				
09404450	East Fork Virgin River near Glendale	1967-81	69.2	7,300	18.9	112	74
09405300	Crystal Creek near Cedar City	1957-61	10.2	9,280	31.6	357	70
09405400	North Fork Virgin River near Glendale	1974-78	5.65	8,080	-	360	90
09405420	North Fork Virgin River below Bullock Canyon, near Glendale	1975-81	29.6	7,670	-	283	90
09405500	North Fork Virgin River near Springdale	1926-81[21]	344	7,350	25.2	181	85
09406300	Kanarra Creek at Kanarraville	1960-81[10]	9.85	7,950	25.0	553	91
09406700	South Ash Creek below Mill Creek, near Pintura	1967-81	11.0	7,210	22.7	515	96
09408000	Leeds Creek near Leeds	1965-81	15.5	6,360	18.8	424	88
09408400	Santa Clara River near Pine Valley	1960-81[10]	18.7	8,720	27.3	472	99
09409500	Moody Wash near Veyo	1956-68	33	6,070	13.7	142	79

gaging stations used in regression analysis--Continued

Streamflow characteristics

Average discharge (cubic feet per second)	Discharge, in cubic feet per second, for indicated consecutive-day period and recurrence interval								
	1-day 10-year	1-day 50-year	1-day 100-year	7-day 10-year	7-day 50-year	7-day 100-year	15-day 10-year	15-day 50-year	15-day 100-year
Central Plateaus Region--Continued									
1.20	445	1,250	1,810	79	203	285	44	110	150
1.3	476	1,150	1,590	84	206	278	47	114	151
5.10	1,120	2,440	3,220	270	590	775	142	320	422
5.0	1,020	2,110	2,700	250	505	649	135	268	341
7.64	-	-	-	-	-	-	-	-	-
7.7	-	-	-	-	-	-	-	-	-
4.43	131	215	252	95	175	214	70	119	140
4.6	146	290	376	104	209	264	77	165	220
15.0	326	551	653	145	228	276	117	215	264
15	350	742	971	164	324	423	128	289	393
1.36	-	-	-	-	-	-	-	-	-
1.2	-	-	-	-	-	-	-	-	-
22.6	492	818	968	365	650	780	315	580	730
22	447	763	908	332	553	659	286	440	527
9.50	233	407	495	188	331	397	165	285	337
9.2	240	451	573	181	317	386	156	252	305
10.7	167	264	314	129	183	207	111	155	174
10	151	254	310	121	183	216	106	160	197
7.52	233	500	640	165	275	330	137	235	280
7.3	202	413	509	145	225	266	121	175	204
-	800	1,480	1,770	370	650	810	255	385	450
-	781	1,470	1,790	348	596	742	239	344	414
1.02	-	-	-	-	-	-	-	-	-
1.2	-	-	-	-	-	-	-	-	-
8.64	990	4,010	6,840	250	781	1,200	157	470	712
8.4	878	3,160	4,960	236	626	895	151	351	468
2.78	-	-	-	-	-	-	-	-	-
2.9	-	-	-	-	-	-	-	-	-
30.0	3,140	7,900	10,100	795	1,690	2,210	425	885	1,160
29	2,980	7,380	9,280	759	1,540	1,990	408	764	961
6.78	679	1,130	1,310	244	369	414	166	280	327
7.2	762	1,570	2,050	258	484	615	170	344	457
Southwestern Plateaus Region									
20.9	325	955	1,420	220	662	990	177	485	700
21	399	1,170	1,720	252	612	865	201	465	621
7.23	-	-	-	-	-	-	-	-	-
7.1	-	-	-	-	-	-	-	-	-
4.39	-	-	-	-	-	-	-	-	-
4.5	-	-	-	-	-	-	-	-	-
18.6	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-
102	1,830	3,490	4,420	1,080	2,020	2,510	905	1,670	2,070
102	1,780	3,270	4,060	1,090	2,010	2,490	913	1,680	2,070
4.18	137	555	950	62	252	455	49	139	203
4.3	142	533	863	79	272	449	60	170	242
7.11	340	1,280	2,050	128	517	890	88	292	450
7.1	296	1,030	1,600	116	360	604	87	223	325
7.60	310	1,220	2,000	99	302	450	58	147	208
7.6	310	1,300	2,220	108	310	467	73	192	267
10.3	182	363	467	115	215	269	101	199	257
10	184	393	527	121	286	399	103	217	292
2.83	480	1,950	3,200	125	345	490	85	235	335
3.6	495	2,090	3,750	151	388	553	110	277	376

Table 6.--Selected basin, climatic, and streamflow characteristics for

Station number	Station name (in Utah except as indicated)	Period of record used (water years)	Basin and climatic characteristics: Contributing drainage area (square miles)	Mean basin elevation (feet)	Mean annual precipitation (inches)	Main-channel slope (feet per mile)	Forested area (percent)
			Southwestern Plateaus Region--Continued				
10173450	Mammoth Creek above West Hatch Ditch, near Hatch	1965-81	105	9,000	24.2	152	86
10183900	East Fork Sevier River near Rubys Inn	1962-81	71.6	8,640	21.7	31.3	83
10242000	Coal Creek near Cedar City	1917, 1919[23] 1936-37 1939-81	80.9	8,640	28.8	239	69

(1) Period of record prior to regulation by Meeks Cabin Reservoir.
(2) No 1943-45 record for 1-, 7-, and 15-day discharges.
(3) No 1944-45 record for 1-, 7-, and 15-day discharges.
(4) No 1914 and 1918 record for 1-, 7-, and 15-day discharges.
(5) No average discharge for first year of record.
(6) No 1901-04 record for 1-, 7-, and 15-day discharges.
(7) Period of record prior to diversion to Duchesne Tunnel. Period of record for 1-, 7-, and 15-day discharges is 1931-53.
(8) Period of record prior to diversion to Duchesne Tunnel.
(9) Period of record prior to diversion to Water Hollow Tunnel.
(10) No 1-, 7-, and 15-day discharges for first year of record.
(11) Period of record for 1-, 7-, and 15-day discharges is 1910, 1919-20, and 1930-81.
(12) Average discharge for station listed under Northern Plateaus Region.
(13) Period of record for 1-, 7-, and 15-day discharges is 1922-23, 1925, 1927-29, 1938, 1940-73, and 1978-79.
(14) Period of record prior to regulation by Joes Valley Reservoir. No 1910 record for 1-, 7-, and 15-day discharges.
(15) Discharge for station listed under Mountains Region.
(16) No 1954 record for 1-, 7-, and 15-day discharges.
(17) Period of record prior to diversion to Sheley Tunnel. No 1981 record for average discharge.
(18) No 1966 record for 1-, 7-, and 15-day discharges.
(19) No 1966-67 record for 1-, 7-, and 15-day discharges.
(20) No 1910-11 record for 1-, 7-, and 15-day discharges.
(21) No 1926-27 record for 1-, 7-, and 15-day discharges.
(22) Weighted discharge adjusted so 7-day discharge-frequency curve will not cross 1-day and 15-day discharge-frequency curves through range of weighted discharges for station.
(23) No 1917 and 1919 record for average discharge.

gaging stations used in regression analysis--Continued

Average discharge (cubic feet per second)	Streamflow characteristics: Discharge, in cubic feet per second, for indicated consecutive-day period and recurrence interval								
	1-day 10-year	1-day 50-year	1-day 100-year	7-day 10-year	7-day 50-year	7-day 100-year	15-day 10-year	15-day 50-year	15-day 100-year
Southwestern Plateaus Region--Continued									
48.5	575	750	820	560	720 (22)	775 (22)	535	680	735
48	546	737	830	478	685	800	460	638	766
16.8	260	630	870	207	550	800	185	445	610
17	299	674	888	243	584	807	205	459	604
32.2	579	805	887	431	657	753	374	576	664
32	561	797	902	402	654	796	356	547	658