TECHNIQUES FOR ESTIMATING THE MAGNITUDE AND FREQUENCY OF FLOODS IN MINNESOTA

By J. E. Jacques and D. L. Lorenz

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CONVERSION FACTORS AND ABBREVIATIONS

Readers who prefer to use metric (International System) units rather than inch-pound units can make conversions using the following factors:

Multiply Inch-Pound Unit	By	To obtain Metric Unit
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	.02832	cubic meter per second (m^3/s)
foot per mile (ft/mi)	.1894	meter per kilometer (m/km)

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ABSTRACT

Log-Pearson type III flood-frequency analyses were made of annual series peak-flow records from 246 gaging stations on unregulated streams in Minnesota having watersheds ranging in area from 0.08 to 2,520 square miles. These flood discharges were related to watershed and climatic characteristics by using multiple-regression techniques. On the basis of this preliminary regression analysis of the frequency-analysis results, the data from these stations were grouped into four hydrologically distinct regions for the State. Regression analyses were performed on data from each region relating the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence interval flood discharges to basin characteristics. The resulting regression equations, which may be used to estimate flood flows at ungaged sites, relate basin characteristics (contributing drainage area, main-channel slope, percent of basin covered by water, percent of basin covered by lakes, and mean annual runoff) to estimated flood flows. Different basin characteristics are significant for each of the four regions. Drainage area was found to be most significant and is included in all regional equations. Standard errors of estimate of the regression equations ranged from 33 to 60 percent.

INTRODUCTION

Background

Knowledge of the magnitude and frequency of floods is essential for regulation, planning, and design along Minnesota's rivers and streams. Ideally, discharge information necessary for such projects would be obtained by hydrologic analysis of nearby long-term flood records from gaging stations on the rivers and streams. Because such records are rarely available at all sites of interest, particularly in small basins, techniques are needed to estimate the magnitude and frequency of floods at ungaged sites.

This report is one of a series of reports prepared in cooperation with the Minnesota Department of Transportation that discuss flood-flow-frequency on small streams. The U.S. Water Resources Council (1981a) indicates that regression equations present a more accurate technique than other methods tested (for example the rational equation and rainfall-runoff models).

Annual maximum-discharge and basin-characteristic data used in this study are stored, maintained, and updated by the U.S. Geological Survey in the National Water Data Storage and Retrieval System (WATSTORE). In addition, these data are published by the U.S. Geological Survey as part of cooperative programs with various local, State, and Federal agencies. For this study, gaging stations with less than 10 years of record were not used because of the increased probability of time-sampling errors. Stations with more than 3,000 square miles of drainage area and stations influenced by natural and (or) manmade regulation also were excluded. Application of these criteria resulted in the selection of 246 gaging stations in Minnesota (57 continuous record, 140 crest stage, and 49 combination sites).

Purpose and Scope

The purposes of this report are to (1) describe the analytical techniques used for annual series flood-frequency computations, regionalization, and development of estimating equations for small watersheds, (2) present flood-frequency data at gaged sites, and (3) develop equations for estimating flood-flows and present examples of flood-flow estimations at gaged and ungaged sites on unregulated streams.

This report supersedes previous reports by Prior (1949), Prior and Hess (1961), Wiitala (1965), Patterson and Gamble (1968), and Guetzkow (1977); all of which dealt with techniques for estimating flood magnitudes in Minnesota.

ANALYTICAL TECHNIQUES

Flood-Frequency Analysis of Gaging Stations

An annual series peak-flood-frequency analysis at each gaging station was prepared according to the procedures outlined in Bulletin 17B [U.S. Water Resources Council, 1981b.] Federal agencies are requested to use these guidelines for all analysis of flood frequencies of unregulated streams. The equation for fitting the log-Pearson Type III frequency-distribution function to the T-year recurrence interval is defined below:

$$\text{Log } Q_T = M + KS$$

where:

Q_T is the peak discharge for T-year recurrence interval,

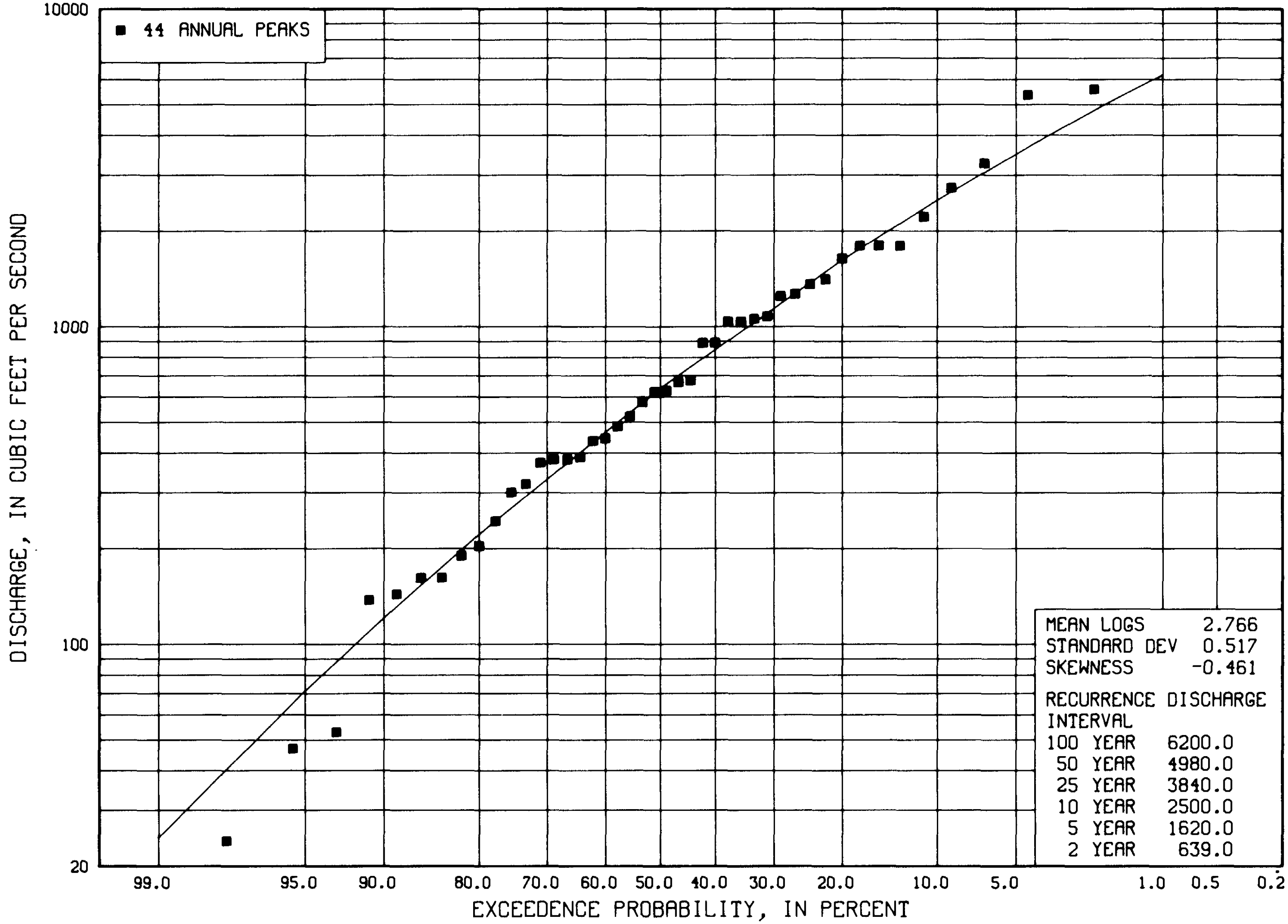
M is the mean of the logarithms of annual peaks,

K is a factor dependent on T and the coefficient of skewness available from Bulletin 17B, appendix 3, and

S is the standard deviation of the logarithms of annual peaks.

An example plot from the Log-Pearson analysis of the Redwood River near Marshall, Minnesota, (station number 05315000) is shown on figure 1.

Recorded flood peaks at some stations with less than 25 years of record exceed the high-outlier criterion defined in Bulletin 17B. Stations in an area in which a well-documented historic flood occurred were considered for adjustment in the peak-flow analysis. A regional analysis of the occurrence of the historic floods was used to evaluate whether a peak of record also should be included in the historic period. Criteria in Bulletin 17B for identifying low and high outliers were used in all cases.



Log-Pearson type III flood-frequency estimate for stream-gaging station

05315000 REDWOOD RIVER NEAR MARSHALL

Figure 1.--Example of flood-frequency plot.

Figure 2 shows the locations of the 246 gaging stations that were used in this analysis.

Multiple-Regression Analysis

Multiple-linear-regression techniques were used to define relations between flood flows and basin characteristics. Previous studies by Benson (1962) and Guetzkow (1977) have shown that the logarithmic transform of the data results in linear relations between flood flows and basin characteristics. This study used the logarithmic transformation that results in general linear-regression models described by the equations below.

For transformed variables:

$$\text{Log } Q_T = B_0 + B_1 \log X_1 + B_2 \log X_2 + \cdots + B_n \log X_n$$

or as untransformed variables:

$$Q_T = e^{B_0} (X_1)^{B_1} (X_2)^{B_2} \cdots (X_n)^{B_n}$$

where:

Q_T is the peak discharge for T-year recurrence interval,

B_i are regression coefficients,

X_i are independent variables (basin characteristics), and

e is the base of the natural logarithms.

The stepwise method of multiple-regression analysis used is described in Hocking (1976). Only those independent variables statistically significant at the 10-percent level of significance are included in the equations. The 10-percent criterion was used to standardize, on a regional basis, the basin characteristics used to define flood flows at the various recurrence intervals. The inclusion of the same variables in all equations for a region improves the continuity of the frequency curves constructed from the equations.

Bevington (1969, p. 100-102) and Draper and Smith (1981, p. 108) indicate that when the variance of the dependent variable is not constant for all observations, the equations resulting from the regression analysis may be a poor estimate of the "true" relation. Because it is well known that predicted flow magnitudes are more accurate from long-term gaging records than from short-term records (Linsley and others, 1982, p. 358), residuals were analyzed to determine any trend as a function of gaging-record length. A significant decrease in the variance of the residuals was observed as gaging record increased. Bobee (1973) defines an equation to estimate the variance of a calculated flood magnitude given the return period, standard deviation, coefficient of skewness, and the number of years of record. The variances of the flood estimates of different return periods were found to be proportional to the return period. Because of this relationship, only the calculated flood-magnitude variance for each station, for the 10-year return period, was

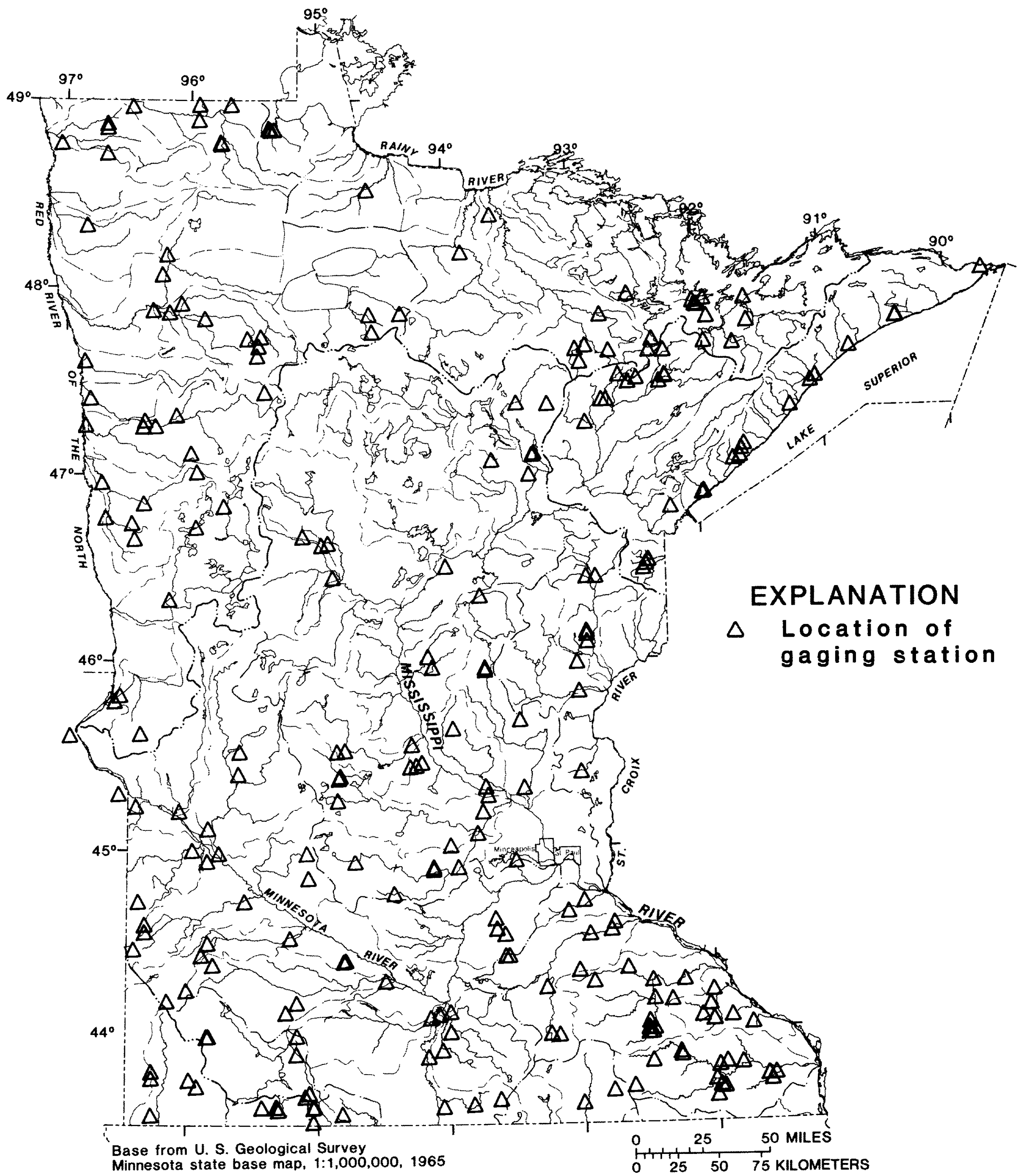


Figure 2.--Location of gaging stations used to define regression equations.

used to compute weights for the regression performed for this report. The resulting weighting factors for some stations deviate significantly from unity, apparently because of different basin characteristics and other unexplained factors that affect the standard deviation of the logarithms of the annual peaks. Thus, the reciprocal of the number of years of station record was normalized and averaged with the variance to define the final station weights;

$$S_i = (VAR(Q10_i) + a/N_i),$$

where $VAR(Q10_i)$ is the variance of the 10-year estimate, a is a normalizing factor, chosen to give equal weight to the variance and years of record, and N_i is the number of years of record for the station. The final station weight is the reciprocal of the sum of the variance and the reciprocal number of years of record;

$$W_i = b/S_i,$$

where W is the final station weight and b is chosen so that the sum of the weights equals the number of stations used in the regression analysis.

Regional Analysis

Hydrologic regions shown on figure 3 were defined by several techniques of regional analysis. Preliminary residual analysis indicated within the state five loosely defined regions. Subsequent analysis of residuals of equations obtained for each region indicated that only minor boundary adjustments were necessary to reduce regional bias that was not indicated by the analysis of clusters. The regression equations from two of the original regions were very similar and were joined into one group.

Intraregional comparisons of the regression equations shows differences which may help understand factors that affect flood magnitudes in each region. For example, the coefficients in the equations for region C are all similar except for slope. This implies that slope is the major determining factor, in region C, for the differences between streams for the various T-year flood magnitudes. Compare this to region A, where only the coefficient for area is roughly constant.

Equations derived by further subdivision of these regions did not vary significantly from those for the region as a whole. For example, region D was divided into 5 subregions and regression analysis performed on the data with different subregions deleted. The results from those regression analyses did not vary significantly from the regression on the whole dataset.

Regional boundaries outlined on figure 3 generally follow basin divides. The single exception is the boundary between regions B and C where the boundary crosses the watershed of the St. Louis River. Headwaters of the St. Louis River are in a flat region, but the tributaries to Lake Superior are very steep, similar to region C. Based on these topographic and geologic features, the boundary between regions B and C crosses the St. Louis River below Thompson Reservoir.

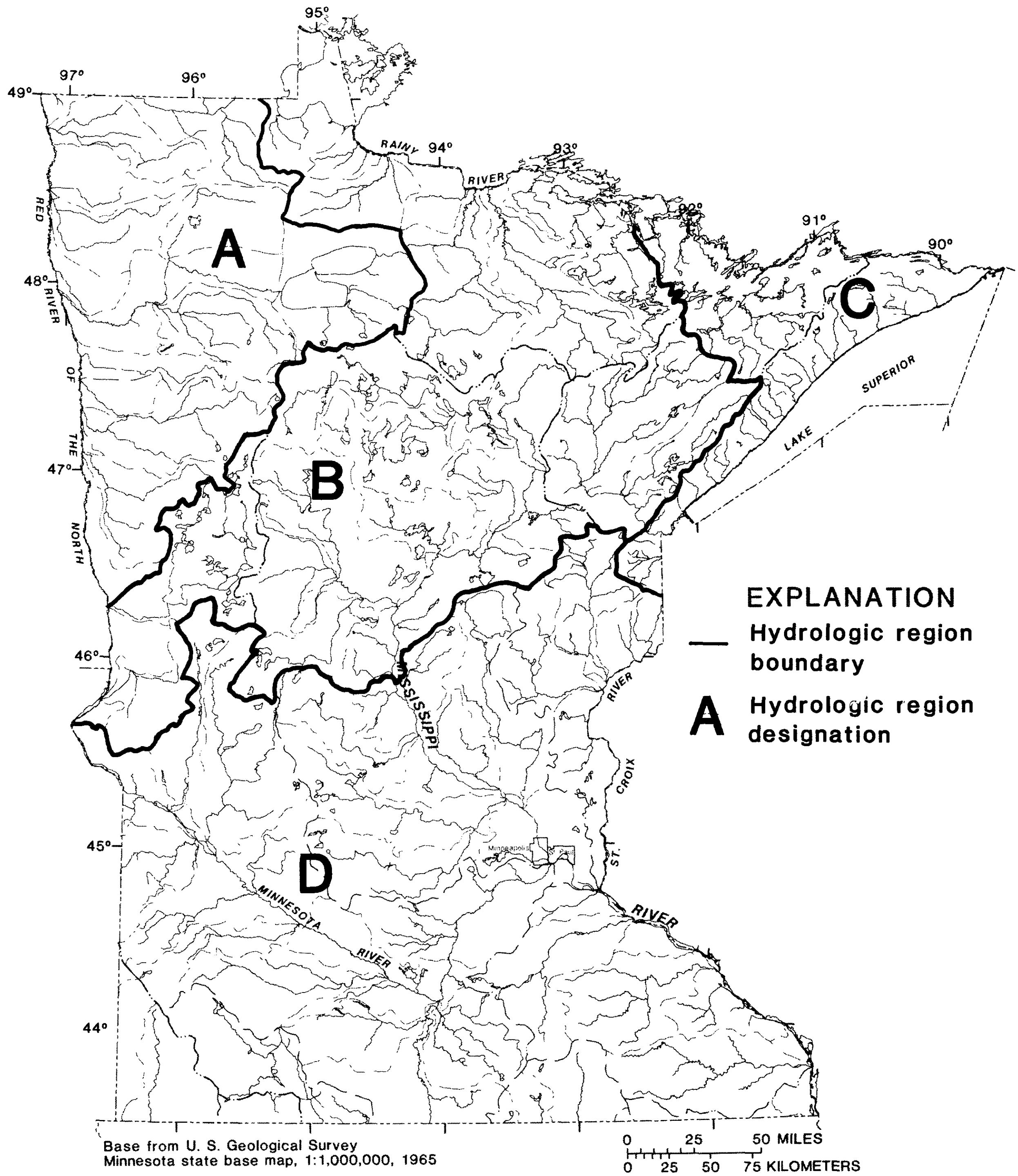


Figure 3.--Hydrologic regions in Minnesota.

Basin Characteristics Investigated

Necessary preconditions for development of useful transfer equations are that the basin characteristics used be limited in number and easily determined from maps. The basin characteristics (independent variables) investigated for this analysis were contributing drainage area, main channel slope, percent area of storage, percent area of lakes and of forest cover, basin shape, mean annual runoff, and 30-year-normal annual precipitation (Baker and Kuehnast, 1978). Regression analysis indicated that both runoff and precipitation were significant characteristics in some regions. However, runoff generally produced a more linear fit than did precipitation. For that reason, mean annual runoff was used rather than normal annual precipitation in the regression equations.

Definitions and procedures for calculating selected basin characteristics are given in the glossary. Figure 4 shows the mean annual runoff for the State of Minnesota.

ESTIMATING FLOOD FREQUENCY OF UNREGULATED STREAMS

The most reliable estimates of flood-flow magnitudes for specific recurrence intervals are based on an analysis of recorded floods at the site under consideration. Such records are not available at most places of interest, and estimates of floods must be obtained by transfer of information from gaged sites or by analysis of generalized flood-frequency relations. The following is a discussion of both techniques along with example computations.

Analyses of Ungaged Sites using Generalized Relationships

Equations, obtained from multiple-regression analyses of gaging-station data in each hydrologic region, can be used to obtain flood-frequency estimates for ungaged sites on unregulated streams. Peak discharges for selected recurrence intervals can be computed from the empirical equations that relate flood magnitude to basin characteristics. A set of equations to estimate flood peaks for 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals (identified as Q_2, Q_5, Q_{10}, etc.) are provided in table 1 for each of the four hydrologic regions in Minnesota. The four regions of the State are outlined on figure 3.

The regions represent areas in which each of the stations in the region exhibits an unbiased response to the equations for that region. However, regional boundaries cannot be precisely defined and particular care should be exercised when the site in question has basin characteristics that differ from the general characteristics of a region. The limiting basin characteristics for each region are discussed in the section on Accuracy and Limitations of Estimating Techniques. If an estimate is to be made downstream from a regional boundary that a stream crosses (the St. Louis River is the only such stream in the State), the discharge at the site should be determined by transfer from the gaged site.

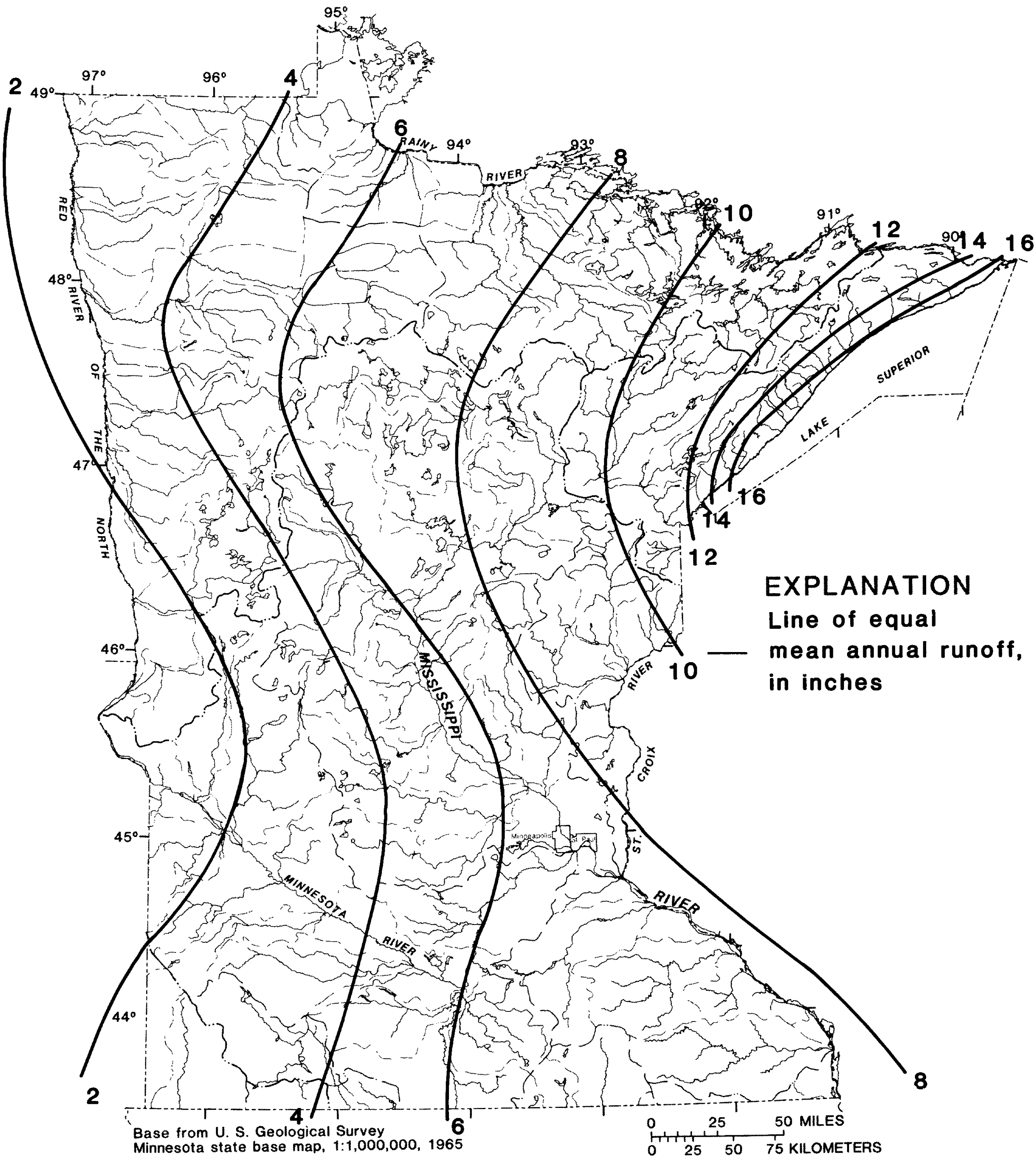


Figure 4.--Mean annual runoff in Minnesota.
(Modified from Baker, Nelson, and Kuenast, 1979, p. 6)

Table 1.--*Prediction equations, standard errors of the estimate (SEE), and equivalent years of record (EY) for all regions*

Prediction equations	SEE (percent)	EY
Region A (39 stations used)		
$Q2 = 28.2\ A^{0.616}\ (St+1)^{-0.108}$	36	5.5
$Q5 = 62.3\ A^{0.617}\ (St+1)^{-0.186}$	37	6.1
$Q10 = 92.5\ A^{0.615}\ (St+1)^{-0.227}$	40	6.7
$Q25 = 139.\ A^{0.613}\ (St+1)^{-0.270}$	45	7.5
$Q50 = 179.\ A^{0.610}\ (St+1)^{-0.298}$	49	7.5
$Q100 = 224.\ A^{0.608}\ (St+1)^{-0.323}$	53	7.5
Region B (41 stations used)		
$Q2 = 2.98\ A^{0.843}\ (Lk+1)^{-0.531}\ R^{0.902}$	33	3.8
$Q5 = 8.88\ A^{0.836}\ (Lk+1)^{-0.587}\ R^{0.654}$	39	3.4
$Q10 = 14.8\ A^{0.833}\ (Lk+1)^{-0.612}\ R^{0.544}$	43	3.6
$Q25 = 24.5\ A^{0.829}\ (Lk+1)^{-0.636}\ R^{0.444}$	48	4.2
$Q50 = 33.1\ A^{0.827}\ (Lk+1)^{-0.651}\ R^{0.387}$	51	4.3
$Q100 = 42.7\ A^{0.825}\ (Lk+1)^{-0.662}\ R^{0.342}$	54	4.5

Table 1.--*Prediction equations, standard errors of the estimate (SEE), and equivalent years of record (EY) for all regions*--continued

Prediction equation	SEE (percent)	EY
Region C (27 stations used)		
Q2 = 20.3 $A^{0.856}$ $(St+1)^{-0.327}$ $S^{0.288}$	49	1.4
Q5 = 24.1 $A^{0.851}$ $(St+1)^{-0.339}$ $S^{0.383}$	50	1.9
Q10 = 24.3 $A^{0.852}$ $(St+1)^{-0.338}$ $S^{0.451}$	50	2.5
Q25 = 23.0 $A^{0.855}$ $(St+1)^{-0.333}$ $S^{0.536}$	51	3.4
Q50 = 21.4 $A^{0.858}$ $(St+1)^{-0.326}$ $S^{0.599}$	51	4.1
Q100 = 19.7 $A^{0.862}$ $(St+1)^{-0.318}$ $S^{0.660}$	52	4.7
Region D (139 stations used)		
Q2 = 3.24 $A^{0.738}$ $(St+1)^{-0.377}$ $S^{0.302}$ $R^{1.08}$	43	4.5
Q5 = 7.92 $A^{0.732}$ $(St+1)^{-0.392}$ $S^{0.324}$ $R^{0.937}$	44	5.3
Q10 = 12.3 $A^{0.728}$ $(St+1)^{-0.401}$ $S^{0.335}$ $R^{0.869}$	47	6.1
Q25 = 19.5 $A^{0.723}$ $(St+1)^{-0.409}$ $S^{0.347}$ $R^{0.801}$	52	7.1
Q50 = 25.9 $A^{0.720}$ $(St+1)^{- .415}$ $S^{0.355}$ $R^{0.760}$	56	7.2
Q100 = 33.1 $A^{0.716}$ $(St+1)^{-0.419}$ $S^{0.362}$ $R^{0.724}$	60	7.3

The basin characteristics used in the estimating equations include drainage area (A), slope (S), percent storage (St), percent lakes (Lk), and mean annual runoff (R). Values for the basin characteristics should be determined by the methods described in the glossary.

Various combinations of basin characteristics define the significant independent variables in the equations for the regions (table 1). Years of record is used to determine a weighting factor for calculating peak discharges at sites on gaged streams. The standard error of the estimate and equivalent years of record are discussed in the section "Accuracy and Limitations of Estimating Techniques".

The use of regression equations to estimate flood discharges on ungaged streams is explained in the example below. The technique is similar for all regions and all recurrence intervals for which equations are provided. If an estimated discharge is required for a recurrence interval not defined by an equation, plots of frequency-curve values for the site can be obtained by solution of equations for all intervals. The desired discharge then may be estimated graphically.

Example 1

Estimate the 25-year peak discharge for an ungaged site on Spring Creek in Swift County, at the crossing of State Highway 9, 3 1/2 miles west of Sunburg.

1. Inspection of figure 3 shows that the site is located in Region D.

2. Inspection of table 5 indicates that no gaging-station data are available for this stream; therefore, flow-frequency estimates should be derived from regional equations. The appropriate equation for the 25-year flood is found in table 1.

3. Drainage area above the point of interest is outlined on the De Graff SE 7-1/2-minute topographic map. The drainage area (A) is planimetered as 1.28 mi^2.

4. Total lake, pond, and swamp area is determined from the map by the grid method described in the discussion on storage in the glossary. Fifteen of the small grid squares are counted as storage area; the area computation follows:

   $$15 \text{ squares} \times 0.00144 \text{ mi}^2 = 0.02 \text{ mi}^2$$

   Percent storage is computed by dividing the storage area by the drainage area and multiplying by 100:

   $$\text{Storage} = 0.02/1.28 \times 100 = 1.6 \text{ percent}$$

5. The mean annual runoff, estimated from figure 4 is 3.0 inches.

6. The main channel slope is computed as follows:

The length of the main channel is measured to be 1.49 miles to the end of the watershed divide.

Elevation at mile 0.15 (10% of channel length) is 1,212 ft

Elevation at mile 1.27 (85% of channel length) is 1,235 ft

Main channel slope is (1235-1212)/1.12 = 20.5 ft/mi.

7. Region D equation for 25-year flood (table 1):

$$Q_{25} = 19.5A^{0.723}(St+1)^{-0.409}S^{0.347}R^{0.801}$$

$$Q_{25} = 19.5(1.28)^{0.723}(2.6)^{-0.409}(20.5)^{0.347}(3.0)^{0.801}$$

$$Q_{25} = 19.5x1.195x.6765x2.852x2.411$$

$$Q_{25} = 108\ ft^3/s\ (3.06\ m^3/s)$$

Although the discharge is reported to three significant digits, the accuracy of the estimating technique does NOT warrant confidence to this degree of accuracy. The 95-percent confidence limits are 40 ft^3/s to 290 ft^3/s.

Transfer of Flood-Flow Information from a Gaged Site

The flood characteristics defined by frequency analyses of gaging-station records listed in tables 2 through 5 (tables 2 - 5 are at end of the report) provide estimates for ungaged locations near a station, particularly where long-term records are available. Transfer of defined flow-frequency information to upstream or downstream sites on the same stream should be accomplished by an adjustment factor that is a function of the basin characteristics showing significant intrabasin variation. The transfer equation may be a function of several characteristics; however, the equation always includes drainage area. Consequently, frequency data are transferred most often using the following equation:

$$Q_{T,u} = Q_{T,g}(A_u/A_g)^B$$

where:

$Q_{T,u}$ is the T-year flood-magnitude estimate for the ungaged site,

$Q_{T,g}$ is the computed T-year flood-frequency value for the gaged site (from tables 2 to 8),

A_u is the drainage area for the ungaged site,

A_g is the drainage area for the gaged site (from tables 2 to 8), and

B is the exponent for drainage area for the T-year flood obtained from the regression equation for the region in which the site is located.

Use of the transfer relation should be limited to sites that differ in area by no more than 50 percent from the area of the gaged site. If other characteristics of the ungaged site are significantly different from the gaged site, the T-year flood should be multiplied by the ratio of the basin characteristics of ungaged and gaged sites raised to the regional exponent of that characteristic for the T-year flood (see example 3). Where the period of record is shorter than 20 years, flood-frequency estimates should be based on transfer of information from gaged sites and results from the regional estimating equations.

Example 2

Estimate the 50-year flood on the Sauk River at Cold Spring, an ungaged site.

1. Inspection of figure 2 and table 5 indicate the availability of gaging-station data for the Sauk River in close proximity to Cold Spring. The station is identified as Sauk River near St. Cloud, (station no. 05270500). Because the gaged site has 55 years of record, a simple transfer of peak flow will provide an accurate estimate for the ungaged site.

2. A contributing drainage area of 832 mi^2 at Cold Spring is obtained by planimetering topographic maps.

3. The reduction in drainage area at Cold Spring is only 10 percent from the 925 mi^2 listed in table 5 for the St. Cloud gaging station. Therefore, a transfer of flood characteristics by drainage area ratio is appropriate. Visual inspection of the topographic maps indicates that the other significant basin characteristics are similar to the gaged site. Area only will be used to determine the 50-year-peak flood at Cold Spring.

4. Region B exponent for drainage area for the 50-year flood is 0.827.

5. From table 4, $Q_{50,g} = 6,300\ ft^3/s$.

6. By substitution into the transfer equation:

$$Q_{50,u} = Q_{50,g}(A_u/A_g)^{(0.827)}$$

$$Q_{50,u} = 6,300(832/925)^{0.827}$$

$$Q_{50,u} = 6,300x0.916$$

$$Q_{50,u} = 5,770\ ft^3/s\ (153\ m^3/s)$$

Example 3

Estimate the 10-year flood on Silver Creek at the crossing of County Highway 11 east of Rochester.

1. Inspection of figure 2 and table 5 reveals a gage on Silver Creek, station number 05372950, downstream from the selected site. Because the gaged site has only 15 years of record, a weighted estimate of the flood discharge should be made. The proper equation for this site, located in region D, is found in table 1.

2. The drainage area, outlined on the Chester, Minnesota, 7-1/2-minute topographic map, is planimetered and found to be 9.87 mi^2.

3. The main channel is extended to the drainage boundary and the length is measured at 6.28 mi. The 10- and 85-percent points are located on the map and the elevations interpolated. The difference in elevation is 1290-1150 = 140 ft and contributing main channel length is 0.75x6.28 = 4.71 mi, thus:

$$S = 140/4.71 = 29.7 \text{ ft/mi.}$$

4. Total storage is determined by counting the grid squares of pond area within the drainage boundary and multiplying by the area per square.

$$St = 2 \text{ squares} \times 0.00144 = 0.003 \text{ mi}^2$$

$$St = (0.003/9.87)\text{x}100 = 0.03 \text{ percent.}$$

5. Mean annual runoff is estimated to be 7.2 inches from figure 4.

6. The 10-year flood is estimated using the regression equations for Region D:

$$Q_{10} = 12.3A^{0.728}(St+1)^{-0.401}S^{0.335}R^{0.869}$$

$$Q_{10} = 12.3(9.87)^{0.728}(1.03)^{-0.401}(29.7)^{0.335}(7.2)^{0.869}$$

$$Q_{10} = 1{,}114 \text{ ft}^3/\text{s} \ (31.5 \text{ m}^3/\text{s})$$

7. The 10-year flood is estimated by transfer of data from the gaged site, using the basin characteristics of slope and drainage area, which change significantly between sites. Thus, the computed 10-year flood at the gaged site will be factored by the ratio of the areas raised to the 0.728 power times the ratio of slopes raised to the 0.335 power.

$$Q_{10,u} = Q_{10,g} \ (A_u/A_g)^{0.728} \ (S_u/S_g)^{0.335}$$

$$Q_{10,u} = 1{,}990 \ (9.87/17.3)^{.728} \ (29.7/32.3)^{.335}$$

$$Q_{10,u} = 1{,}285 \text{ ft}^3/\text{s} \ (36.4 \text{ m}^3/\text{s})$$

8. The discharges computed in steps 6 and 7 above are weighted and combined to yield an adjusted 10-year flood estimate. The weighting factors used are the equivalent years of record for the regression estimate (step 6) and the actual years of record for the estimate from the gaged site (step 7). The equivalent years of record for estimating a 10-year flood by regression equation in region D is 6.1 from table 1. The number of years of record at the gaged site is 15 from table 5.

$$Q_{10} = (6.1x1,114+15x1,285)/(6.1+15)$$

$$Q_{10} = 14500/21.1 = 1,240 \text{ ft}^3/\text{s} \ (35.1 \text{ m}^3/\text{s})$$

ACCURACY AND LIMITATIONS OF ESTIMATING TECHNIQUE

The accuracy of a statistically defined equation is measured by the closeness of the estimated value to the true value. The U.S. Water Resources Council (1981a, p. 48-49) describes two elements of accuracy, variance, and bias. Variance is a measure of the random variation about the mean of the estimate, and bias is the deviation of the mean of the estimate from the true value of the mean.

Random variation about the mean is caused by a combination of factors. Three of the most significant factors are discussed below. Errors in predicting flood-flow magnitudes result from short sampling records, which may not be a representative sample of the population of annual peaks, and from the assumptions made in procedures for defining the magnitude of flood flows. Errors also result from the inability to completely describe drainage-basin characteristics. No matter how complete the description of a drainage basin, differences exist that contribute, in varying degrees, to the runoff characteristics of a basin. As an example, morphologic features such as storage may be described as a statistic (percent storage), but the impact of each area of storage, its size or relative position in the drainage basin, cannot be accounted for completely. The third source of random error is a result of the empirical nature of the model. The assumptions of a linear-regression model may not be adequately met even though every effort is made to reduce departures from the assumptions.

Bias of an estimate may result from bias in the dependent variable or from an inadequate statistical model. Any bias in the dependent variable (the T-year flood discharge) is most likely the result of time-sampling error. Because most of the data used in this analysis are based on gages operated between 1958 and 1983, the derived flood statistics reflect that period of time and may or may not be a representative sample of the entire population. The statistical model also may be biased because the assumptions of linear regression are not adequately met or because of misspecification of the independent variables. The equations obtained by linear-regression techniques may contain extraneous independent variables or a significant variable may have been omitted.

The accuracy of an estimate made using a statistically derived equation is a function of the accuracy described above and also random variations produced by different users of that equation. Each user or planner will make certain decisions based on his or her best judgment about the actual outline of the drainage basin, what constitutes storage, tracing the path of the main channel, and interpolating values from contour lines. These decisions introduce additional random variations into the model that are not accounted for by the statistical techniques used. The variations introduced in this way differ from user to user and basin to basin. For example, the drainage-basin outline generally is much easier to define in hilly terrain than in flat terrain because the more closely spaced contours reduce ambiguity in the location of the basin divide. Therefore, the random errors introduced by the hydrologist generally will be smaller where the topography is hilly because the judgments regarding drawing of the drainage outline will be easier and will be more consistent between users than in areas of flat topography.

In general, estimates of the probability of future flood occurrences become more accurate with greater length of record (Hardison, 1969). The standard error of the estimate of a predicted flood magnitude for a given recurrence interval decreases approximately proportionally to the square root of the length of gaging station record. At or near gage sites, flood characteristics may be based on analysis of actual records collected at the gage (from tables 2 to 5) or may be computed from regional estimating relations. Weighted averages of flood estimates by regression equations and by transfer relations generally are used when the percent change in any basin characteristic exceeds 10 percent or when the period of gaging is less than 20 years.

The standard error of the estimate is a measure of the distribution of the observed data about the regression surface. The standard error, reported in percent of estimated flow, is the range of deviations from the regression surface to be expected approximately two-thirds of the time. Because the variables used in these analyses are expressed in logarithmic form, the percent standard errors are larger in the positive direction. The values of percent standard error reported in table 1 are the average values. The equivalent number of years of record is an estimate of the information obtained from the regression equation when applied to an ungaged site. In other words, an estimate of a flood based on a regression equation is approximately as good as that obtained from a gaged site operated for that period of time. Hardison (1971) presents an equation that defines the equivalent years of record represented by a regression equation. The equivalent number of years of record is computed from the ratio of the mean variance of the logs of the annual peaks to the mean square error of the regression, multiplied by a factor dependent on the return period and mean coefficient of skewness.

Flood-frequency relations expressed in this report may be used to estimate magnitude and frequency of floods on most Minnesota streams. The applicability and accuracy of these relationships depends on whether the basin characteristics above the site under consideration are within the range of characteristics used to define the frequency relations. The range in sampled basin characteristics is large enough to allow use of the frequency relations at most sites where streamflow is not significantly affected by regulation, diversion, or urbanization. The acceptable range for each of the physical characteristics to be considered is tabulated in table 6 (table 6 is at end of the report). Where runoff is included as an independent variable in an equation, the sampling is complete enough to ensure that the entire range of values may be used.

Corrections must be made at sites immediately below a lake or ponding area where the storage capacity is large in relation to total drainage area and could seriously alter flood characteristics. In such places, the frequency relations may be used as an aid in developing a hydrograph of inflow for use in routing flow through the storage area to the site.

SUMMARY AND CONCLUSIONS

This report contains an analysis of significant flood information for Minnesota streams, except for miscellaneous flood measurements, and very short or unpublished records (see tables 2 to 5). Flood-frequency analyses of the annual series peak data from 246 gaging stations were used to investigate regional relations. A regression analysis of the regionalized data relates peak flows to basin characteristics. The resulting regional equations can be used to estimate flood flows at ungaged, unregulated sites for 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals. Analyses of the standard errors of estimate, regression coefficients, and residuals show that these equations provide good estimates of selected frequency annual series peak flows subject to certain limitations.

The use of weighting factors for stations in the regression analysis provides an expedient technique for reduction of standard error. This technique increases the weight of data from longer-term stations and stations with more accurately defined flood characteristics so that shorter-term records may be incorporated into the analysis without adversely affecting the results.

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GLOSSARY

Basin shape (Sh) - Conceptually, the ratio between width and length of the basin, dimensionless. To compute the value for basin shape the area of basin is divided by the main channel length squared.

Drainage area (A) - The area contributing directly to runoff, in square miles. An outline of the drainage area should be drawn on topographic maps and the outline planimetered to determine the area. When available, 7 1/2-minute or 15-minute quadrangle maps should be used.

Forest cover (F) - Forest cover is defined on topographic maps, expressed as a percentage of the contributing drainage area. Forest cover can most easily be determined with a transparent grid. The grid is placed on the map and the number of squares covering forested areas are added together and multiplied by the area of each square, calculated at the scale of the map being used. (A transparent grid suitable to most map scales is enclosed in a packet at the back of this report.)

Lake storage (Lk) - Lake storage can be computed in a manner similar to that used to determine forest cover. Expressed as a percentage of the contributing drainage area.

Main channel slope (S) - Mean slope of the channel computed between points 10 and 85 percent of the main channel length upstream from the point of interest, in feet per mile. The main channel length is defined as the stream bed extending from the site to the basin divide. The 10- and 85-percent points are located on the map and the elevations of the points are interpolated from the topographic contours.

Mean annual runoff (R) - Average annual runoff during 1960-76, in inches. From Climate of Minnesota, Part XII-The Hydrologic Cycle and Soil Water, published by the Agricultural Experiment Station, University of Minnesota. The value for this basin characteristic is determined by locating the centroid of the basin on the map and interpolating between isolines. A copy of this map is found on figure 4.

Storage (St) - The storage area includes all lakes, ponds, and wetlands in the basin, expressed as a percentage of the contributing drainage area. The easiest technique to determine storage is by use of the grid method described above for forest cover.

TABLES 2, 3, 4, 5, AND 6

Table 2.--*Basin and flood-flow*

[mi², square mile; ft/mi, feet per mile; %, percent; in., inches; ft³/s, cubic feet per station; P, partial-record station]

Station number	Hydro-logic unit code	Station name	Basin characteristics: Area (mi²)	Slope (ft/mi)	Storage (%)	Annual runoff (in.)
05060800	09020106	Buffalo River near Callaway	94.5	6.03	27	4.3
05061000	09020106	Buffalo River near Hawley	322	8.10	5.2	3.9
05061200	09020106	Whisky Creek at Barnesville	25.3	18.6	9.0	2.5
05061400	09020106	Spring Creek above Downer	5.81	16.0	2.0	2.7
05061500	09020106	South Branch Buffalo River at Sabin	522	13.8	1.7	3.4
05062000	09020106	Buffalo River near Dilworth	1,040	9.70	2.5	2.9
05062280	09020108	Mosquito Creek near Bagley	3.98	11.4	3.0	6.2
05062470	09020108	Marsh Creek tributary near Mahnomen	11.90	4.01	5.0	4.4
05062500	09020108	Wild Rice River at Twin Valley	888	7.20	7.0	5.2
05062700	09020107	Wild Rice River tributary near Twin Valley	4.72	17.9	3	3.9
05062800	09020108	Coon Creek near Twin Valley	50.8	15.2	1.0	3.8
05063200	09020108	Spring Creek tributary near Ogema	4.99	20.2	21	4.3
05064000	09020108	Wild Rice River at Hendrum	1,600	7.50	1.0	4.5
05067500	09020107	Marsh River near Shelly	151	3.17	2.2	3.6
05069000	09020301	Sand Hill River at Climax	426	7.20	3.5	4.4
05073600	09020302	South Branch Battle River at Northome	2.80	9.72	14	7.2
05073750	09020302	Spring Creek near Blackduck	7.96	13.1	15	7.1
05073800	09020302	Perry Creek near Shooks	1.14	10.5	51	7.0
05076000	09020304	Thief River near Thief River Falls	959	1.00	31	4.6
05076600	09020303	Red Lake River tributary near Thief River Falls	2.33	5.71	.0	4.2
05077700	09020305	Ruffy Brook near Gonvick	45.2	13.0	24	6.0
05078000	09020305	Clearwater River at Plummer	512	4.40	12	6.0
05078100	09020305	Lost River at Gonvick	53.6	12.2	18	5.8
05078180	09020305	Silver Creek near Clearbrook	4.96	39.6	15	6.0
05078200	09020305	Silver Creek tributary at Clearbrook	6.02	36.4	9.0	6.0

characteristics for region A

second; B, both continuous and partial record; C, continuous record; D, discontinued

Peak-flow information									
Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)	Station weight	Years of record	Historic period	Type of station
206	393	519	670	773	868	0.8	23	23	P
665	1,260	1,690	2,250	2,680	3,100	1.2	39	63	C
142	268	368	512	631	757	.9	23	23	P
45.9	149	283	576	922	1,420	.5	23	23	P
1,180	2,690	4,080	6,280	8,230	10,500	.9	39	39	C
1,320	3,080	4,760	7,560	10,200	13,300	1.2	53	53	C
32.9	62.6	83.9	111	132	151	1.0	23	23	P
112	234	333	474	588	709	.8	23	23	P
1,250	2,580	3,670	5,230	6,500	7,850	1.6	62	75	C
87.1	171	234	319	384	450	.9	23	23	P
449	1,170	1,810	2,750	3,510	4,310	.4	22	22	P
52.8	79.1	95.1	113	126	137	1.2	21	75	P
1,920	3,030	3,740	4,590	5,180	5,740	.8	19	19	C
914	2,230	3,320	4,870	6,080	7,320	.8	40	40	C
1,030	2,150	3,070	4,410	5,510	6,680	1.1	41	41	C
50.5	77.4	96.0	120	139	157	1.4	25	25	P
81.5	176	269	429	585	779	.9	24	24	P
33.5	59.2	79.0	107	130	154	1.2	24	24	P
1,410	2,630	3,440	4,390	5,030	5,620	2.0	72	72	C
73.9	120	155	202	239	279	1.0	20	20	P,D
219	329	398	477	530	580	1.1	22	22	P,D
1,460	2,440	3,170	4,160	4,930	5,750	1.7	45	45	P
151	243	302	372	422	468	.6	13	13	P
50.0	81.8	103	131	151	170	1.0	20	20	P
54.1	93.5	122	160	189	218	1.1	22	22	P,D

Station number	Hydro-logic unit code	Station name	Basin characteristics			
			Area (mi^2)	Slope (ft/mi)	Storage (%)	Annual runoff (in.)
05078230	09020305	Lost River at Oklee	266	5.20	15	5.0
05078400	09020305	Clearwater River tributary near Plummer	6.51	8.31	2.0	4.5
05078500	09020305	Clearwater River at Red Lake Falls	1,370	4.60	7.3	5.4
05087500	09020309	Middle River at Argyle	265	7.50	7.5	3.7
05094000	09020312	South Branch Two Rivers at Lake Bronson	444	3.20	8.3	3.6
05095500	09020312	Two Rivers below Hallock	644	5.40	8.5	3.5
05096000	09020312	North Branch Two Rivers near Lancaster	32	4.80	10	3.1
05096500	09020312	State Ditch #85 near Lancaster	95	1.80	31	3.1
05104000	09020314	South Fork Roseau River near Malung	312	5.10	3.8	4.2
05104500	09020314	Roseau River below South Fork near Malung	573	5.30	6.5	4.7
05106000	09020314	Sprague Creek near Sprague, Manitoba	169	6.40	20	3.7
05107000	09020314	Pine Creek near Pine Creek	74.6	11.0	1.3	3.7
05107500	09020314	Roseau River at Ross	1,220	3.70	12.8	4.0
05112000	09020314	Roseau River below State Ditch 51 near Caribou	1,570	2.90	20	3.9

Peak-flow information									
Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)	Station weight	Years of record	Historic period	Type of station
1,220	2,060	2,620	3,320	3,830	4,320	0.8	23	87	C
45.5	97.7	136	183	216	248	.5	15	87	P
3,150	5,670	7,570	10,200	12,200	14,400	1.8	58	58	C
872	1,870	2,640	3,640	4,390	5,120	.8	35	35	C
1,220	2,270	3,090	4,230	5,140	6,090	1.4	46	46	B
932	1,840	2,550	3,540	4,310	5,110	.3	11	11	B,D
79.2	225	364	584	773	980	.5	24	60	B,D
129	237	321	439	535	637	1.0	24	60	B,D
447	996	1,440	2,040	2,520	3,000	.5	20	20	B,D
1,560	3,230	4,510	6,210	7,500	8,780	1.3	54	54	C
546	1,130	1,560	2,120	2,530	2,930	1.4	52	52	C,D
290	533	703	919	1,080	1,230	.9	25	25	B,D
1,670	2,870	3,750	4,930	5,850	6,790	2.0	57	88	C
1,600	2,300	2,710	3,170	3,480	3,770	3.1	65	65	C

Table 3.--*Basin and flood-flow*

[mi^2, square mile; ft/mi, feet per mile; %, percent; in., inches; ft^3/s, cubic feet per station; P, partial-record station]

Station number	Hydro-logic unit code	Station name	Basin characteristics: Area (mi^2)	Slope (ft/mi)	Lake (%)	Annual runoff (in.)
04015500	04010201	Second Creek near Aurora	22.4	20.8	1.1	11.1
04016000	04010201	Partridge River near Aurora	148	5.98	1.2	11.4
04016500	04010201	St. Louis River near Aurora	277	9.80	2.8	11.6
04017000	04010201	Embarrass River at Embarrass	93.8	4.90	3.5	10.8
04017700	04010201	McKinley Lake tributary at McKinley	.37	259	.0	10.7
04018800	04010201	East Two River tributary at Virginia	3.46	21.9	1.0	10.3
04018900	04010201	East Two River near Iron Junction	40.0	6.80	2.2	10.2
04019000	04010201	West Two River near Iron Junction	65.3	10.8	1.2	10.3
04019500	04010201	East Swan River near Toivola	112	11.2	.4	10.1
05030000	09020103	Otter Tail River near Detroit Lakes	270	3.40	21	5.4
05040000	09020103	Pelican River near Detroit Lakes	123	4.50	23	3.6
05040500	09020103	Pelican River near Fergus Falls	482	3.10	19	3.9
05047700	09020102	West Branch Mustinka River tributary near Graceville	3.37	13.3	.0	2.0
05049000	09020102	Mustinka River above Wheaton	834	.70	7.9	2.0
05049200	09020102	Eighteen Mile Creek near Wheaton	68.5	5.03	.0	2.0
05128300	09030002	Pike River near Gilbert	.73	114	.0	10.5
05128500	09030002	Pike River near Embarrass	115	12.1	1.4	10.6
05128700	09030002	Pike River tributary near Wahlsten	1.93	18.1	.3	10.5
05129000	09030002	Vermilion River below Vermilion Lake near Tower	483	2.80	14	10.2
05129650	09030005	Little Fork River at Cook	62.0	23.4	1.9	9.6

characteristics for region B

second; B, both continuous and partial record; C, continuous record; D, discontinued

Peak-flow information									
Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)	Station weight	Years of record	Historic period	Type of station
122	165	196	236	268	302	1.6	26	26	C,D
953	1,610	2,090	2,720	3,210	3,710	1.5	40	40	C,D
1,500	2,310	2,910	3,750	4,430	5,160	1.9	41	41	C
578	998	1,320	1,760	2,120	2,500	.9	22	22	B,D
12.8	24.5	33.4	45.4	54.7	64.2	1.1	22	22	P,D
54.2	73.2	85.3	100	111	122	.9	14	14	P,D
340	504	609	737	828	915	.7	13	13	B,D
551	800	954	1,130	1,260	1,370	1.2	23	23	B,D
1,190	1,530	1,740	1,990	2,160	2,320	1.0	16	16	B,D
171	255	306	363	401	436	1.8	35	35	C,D
140	186	213	246	269	291	.7	11	11	B,D
300	475	606	785	928	1,080	2.0	40	40	C,D
30.4	73.2	115	184	248	324	.7	20	20	P
760	1,960	3,050	4,660	6,010	7,440	.7	36	36	B,D
141	445	780	1,380	1,960	2,670	.4	19	19	P
22.8	38.1	50.4	68.4	83.6	101	.9	16	16	P,D
727	1,180	1,530	2,050	2,490	2,980	.6	14	30	B,D
47.8	72.6	89.9	112	130	147	1.2	21	21	P,D
1,090	1,540	1,840	2,210	2,470	2,740	3.1	59	59	C,D
537	884	1,170	1,590	1,950	2,360	.7	16	16	P

Table 3.--*Basin and flood-flow*

Station number	Hydro-logic unit code	Station name	Basin characteristics Area (mi^2)	Slope (ft/mi)	Lake (%)	Annual runoff (in.)
05129710	09030005	Johnson Creek near Britt	6.92	4.42	17	10.0
05130300	09030005	Boriin Creek near Chisholm	13.7	13.8	.3	9.7
05130500	09030005	Sturgeon River near Chisholm	187	9.60	2.9	9.5
05131000	09030005	Dark River near Chisholm	50.6	16.2	3.9	9.6
05131500	09030005	Little Fork River at Littlefork	1,730	2.20	1.2	8.9
05132000	09030006	Big Fork River at Big Falls	1,460	1.90	4.1	7.9
05134200	09030007	Rapid River near Baudette	543	2.70	.1	6.0
05139500	09030009	Warroad River near Warroad	110	6.30	.0	5.1
05140000	09030009	Bulldog Run near Warroad	14.2	8.00	.0	4.5
05140500	09030009	East Branch Warroad River near Warroad	102	6.20	.1	5.1
05210200	07010101	Smith Creek near Hill City	8.00	41.9	1.3	8.9
05212700	07010103	Prairie River near Taconite	360	2.47	23	8.3
05216700	07010103	O'Brien Creek near Nashwauk	8.26	42.4	.1	9.4
05216980	07010103	Swan River tributary at Warba	3.95	15.9	2.1	9.4
05217000	07010103	Swan River near Warba	254	5.10	11	9.3
05217700	07010103	Bluff Creek near Jacobson	1.50	12.7	.0	9.2
05241500	07010104	Rabbit River near Crosby	8.38	8.00	17	7.9
05244000	07010106	Crow Wing River at Nimrod	1,010	3.80	8.3	6.2
05244100	07010106	Kitten Creek near Sebeka	14.7	15.4	.4	5.5
05244200	07010106	Cat River near Nimrod	49.2	6.90	.2	5.8
05244440	07010106	Leaf River near Aldrich	860	1.46	14	4.8

Peak-flow information									
Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)	Station weight	Years of record	Historic period	Type of station
26.0	31.6	34.8	38.4	40.9	43.1	1.0	14	14	P,D
204	342	446	588	702	821	1.2	25	25	P
1,040	1600	2020	2590	3050	3540	1.9	41	41	C
307	504	660	888	1,080	1,300	1.6	33	33	B,D
9,360	14,200	17,500	21,800	25,100	28,400	2.5	63	63	C
5,470	8,910	11,300	14,400	16,800	19,100	2.0	58	58	B
2,890	4,700	5,900	7,370	8,430	9,450	1.0	27	34	C
593	1,180	1,640	2,280	2,780	3,290	1.0	35	35	B,D
140	338	498	717	884	1,050	.6	23	23	B
331	662	920	1,280	1,560	1,850	.8	26	26	B
105	234	342	498	626	760	.7	23	23	P
1,330	2,230	2,910	3,850	4,600	5,400	.6	16	16	C
77.3	97.0	108	121	130	138	.9	14	14	P,D
37.4	56.4	68.7	83.6	94.2	104	1.3	23	23	P
745	1,130	1,430	1,870	2,230	2,630	.8	16	20	B,D
34.3	63.9	87.5	122	150	180	1.0	21	21	P,D
22.2	39.5	52.9	71.7	86.8	103	.9	18	18	B,D
1,290	1,980	2,460	3,090	3,560	4,040	2.6	58	58	C
106	204	282	390	477	569	.7	18	18	P
216	370	477	615	717	817	1.0	23	23	P
2,010	3,940	5,390	7,330	8,800	10,300	.3	12	12	P

Table 4.--*Basin and flood-flow*

[mi^2, square mile; ft/mi, feet per mile; %, percent; in., inches; ft^3/s, cubic feet per station; P, partial-record station]

			Basin characteristics			
Station number	Hydro-logic unit code	Station name	Area (mi^2)	Slope (ft/mi)	Storage (%)	Annual runoff (in.)
04010500	04010101	Pigeon River at Middle Falls near Grand Portage	600	13.0	14	14.4
04011370	04010101	Little Devil Track River near Grand Marais	7.49	51.4	10	14.9
04011390	04010101	Little Devil Track River tributary near Grand Marais	.47	192	.0	15.1
04012500	04010101	Poplar River at Lutsen	112	25.0	7.9	14.4
04013100	04010101	Lake Superior tributary near Taconite Harbor	1.56	226	8.0	16.0
04013200	04010101	Caribou River near Little Marais	22.7	52.6	7.0	15.9
04014500	04010101	Baptism River near Beaver Bay	140	57.6	4.4	14.9
04015150	04010102	Crow Creek near Silver Creek	1.07	108	19	14.9
04015200	04010102	Encampment River tributary at Silver Creek	.96	183	.0	15.2
04015250	04010102	Silver Creek Tributary near Two Harbors	3.72	110	.0	15.3
04015300	04010102	Little Stewart River near Two Harbors	5.54	53.8	3.0	15.2
04015360	04010102	Lake Superior tributary #2 at French River	1.41	144	.0	14.6
04015370	04010102	Talmadge River at Duluth	5.79	92.7	3.0	14.6
04015400	04010201	Miller Creek at Duluth	4.92	28.0	8.0	13.0
04024095	04010301	Nemadji River near Holyoke	118	13.9	16	10.8
04024100	04010301	Rock Creek near Blackhoof	4.94	41.7	.0	11.6
04024110	04010301	Rock Creek tributary near Blackhoof	.20	90.9	.0	11.6
04024200	04010301	South Fork Nemadji River near Holyoke	19.4	36.8	8.0	10.8
05124480	09030001	Kawishiwi River near Ely	253	7.20	30	11.6
05124500	09030001	Isabella River near Isabella	341	7.60	27	13.5

characteristics for region C

second; B, both continuous and partial record; C, continuous record; D, discontinued

Peak-flow information									
Q2 (ft³/s)	Q5 (ft³/s)	Q10 (ft³/s)	Q25 (ft³/s)	Q50 (ft³/s)	Q100 (ft³/s)	Station weight	Years of record	Historic period	Type of station
4,670	6,480	7,700	9,270	10,500	11,700	3.0	59	59	C
151	247	316	410	484	560	1.1	22	22	P
13.4	27.3	40.1	61.1	80.6	104	.8	16	16	P,D
885	1,370	1,740	2,260	2,690	3,160	1.9	39	39	B
78.0	170	263	428	594	803	.7	18	18	P,D
584	1,060	1,490	2,190	2,840	3,620	.9	23	23	P
2,490	4,070	5,350	7,250	8,880	10,700	2.1	53	53	C
41.5	76.4	108	158	206	262	.8	16	16	P
53.1	95.5	132	190	242	302	1.2	24	24	P
334	651	936	1,390	1,810	2,300	.7	20	20	P
187	299	381	492	581	675	1.2	23	23	P
150	322	485	759	1,020	1,330	.6	18	18	P,D
315	543	729	1,010	1,240	1,510	.9	20	20	P
235	353	434	538	617	696	1.2	24	24	P
1,810	2,390	2,750	3,160	3,460	3,740	.7	12	12	P
431	742	969	1,270	1,510	1,750	.9	22	22	P
17.1	30.3	40.2	53.7	64.3	75.3	1.2	23	23	P
770	1,310	1,710	2,250	2,660	3,080	.9	23	23	P
1,090	1,360	1,520	1,690	1,800	1,910	1.1	17	88	C
1,920	3,000	3,770	4,770	5,540	6,320	.5	11	11	B,D

Table 4.--*Basin and flood-flow*

Station number	Hydro-logic unit code	Station name	Basin characteristics Area (mi^2)	Slope (ft/mi)	Storage (%)	Annual runoff (in.)
05125500	09030001	Stony River near Isabella	180	12.6	19	13.0
05126000	09030001	Dunka River near Babbitt	49.4	18.8	32	11.6
05126500	09030001	Bear Island River near Ely	68.5	2.6	26	11.5
05127205	09030001	Burntside River near Ely	68.9	9.00	31	10.7
05127210	09030001	Armstrong Creek near Ely	5.29	31.4	32	10.8
05127215	09030001	Longstorff Creek near Ely	8.84	30.2	32	10.9
05127220	09030001	Burgo Creek near Ely	3.04	51.3	14	10.9

Peak-flow information									
Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)	Station weight	Years of record	Historic period	Type of station
821	1,320	1,690	2,210	2,620	3,050	.5	12	12	B,D
329	512	646	829	976	1,130	.8	16	16	B,D
240	332	388	453	498	541	.7	13	13	B,D
246	323	371	432	475	518	.7	11	11	B,D
54.0	78.6	96.8	122	143	164	.7	11	11	B,D
98.8	141	171	213	246	281	.7	11	11	B,D
68.9	118	161	229	291	365	.5	11	83	B,D

Table 5.--*Basin and flood-flow*

[mi^2, square mile; ft/mi, feet per mile; %, percent; in., inches; ft^3/s, cubic feet per station; P, partial-record station]

Station number	Hydro-logic unit code	Station name	Basin characteristics Area (mi^2)	Slope (ft/mi)	Storage (%)	Annual runoff (in.)
05267800	07010201	Big Mink Creek tributary near Lastrup	1.53	24.9	10	6.5
05267900	07010201	Hillman Creek near Pierz	46.7	9.53	20	6.5
05270300	07010202	Sauk River tributary at Spring Hill	7.06	16.8	2.0	4.0
05270310	07010202	Sauk River tributary #2 near St. Martin	.24	78.4	2.0	4.2
05270500	07010202	Sauk River near St. Cloud	925	2.30	4.3	4.2
05271800	07010203	Johnson Creek tributary at Luxemburg	3.82	7.38	14	5.1
05272000	07010203	Johnson Creek tributary #2 near St. Augusta	13.4	16.6	4.0	5.2
05272300	07010203	Johnson Creek near St. Augusta	46.7	15.4	2.0	5.3
05273700	07010203	Otsego Creek near Otsego	3.11	24.1	2.0	6.4
05274200	07010203	Stony Brook tributary near Foley	2.26	10.7	9.0	6.2
05275000	07010203	Elk River near Big Lake	615	4.70	1.3	6.0
05276000	07010204	North Fork Crow River near Regal	215	5.10	7.9	4.4
05276100	07010204	North Fork Crow River tributary near Paynesville	.55	48.1	2.0	4.0
05278000	07010204	Middle Fork Crow River near Spicer	179	2.60	9.7	3.6
05278350	07010204	Fountain Creek near Montrose	6.73	3.49	12	5.6
05278500	07010205	South Fork Crow River at Cosmos	221	1.10	8.6	3.7
05278700	07010205	Otter Creek near Lester Prairie	30.2	3.27	4.0	5.4
05278750	07010205	Otter Creek tributary near Lester Prairie	1.54	14.5	3.0	5.4
05278850	07010205	Buffalo Creek tributary near Brownton	9.45	2.90	14	4.8
05279000	07010205	South Fork Crow River near Mayer	1,170	3.10	3.9	3.5

characteristics for region D

second; B, both continuous and partial record; C, continuous record; D, discontinued

Peak-flow information									
Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)	Station weight	Years of record	Historic period	Type of station
12.0	27.6	41.8	64.0	83.6	106	0.7	17	17	P
538	1,240	1,830	2,700	3,420	4,190	.5	20	20	P
154	254	338	467	581	712	1.2	24	65	P
20.4	45.0	70.8	119	169	236	1	23	65	P,D
1,480	2,700	3,690	5,110	6,300	7,600	1.8	55	55	C,D
33.6	54.3	69.1	88.6	104	119	1.1	20	65	P
84.9	144	187	245	290	336	1.0	20	20	P
312	534	691	893	1,040	1,190	.8	20	20	P
94.4	176	238	323	389	456	.8	20	20	P
43.3	87.2	124	178	224	273	1.0	24	24	P
1,610	3,080	4,140	5,510	6,510	7,480	1.6	60	60	C
826	1,260	1,550	1,920	2,200	2,480	.5	11	11	B,D
19.9	36.8	49.9	68.4	83.4	99.2	1.2	24	24	P
189	312	389	480	542	599	1.5	35	35	C
49.9	74.1	91.3	114	132	151	1.3	22	22	P
343	679	969	1,420	1,810	2,260	.7	20	20	B,D
119	232	326	464	582	710	.9	23	23	P
30.5	45.5	56.4	71.4	83.2	95.8	1.3	22	22	P
33.8	59.8	78.6	103	122	141	1.1	23	23	P
2,230	4,560	6,540	9,490	12,000	14,800	1.3	50	50	B

Station number	Hydro-logic unit code	Station name	Basin characteristics Area (mi²)	Slope (ft/mi)	Storage (%)	Annual runoff (in.)
05280000	07010204	Crow River at Rockford	2,520	3.30	4.6	4.6
05280300	07010204	School Lake Creek tributary near St. Michael	2.04	10.6	6.0	6.2
05284100	07010207	Mille Lacs Lake tributary near Wealthwood	.58	33.9	7.0	8.1
05284600	07010207	Robinson Brook near Onamia	4.79	9.48	24	7.7
05284620	07010207	Rum River tributary near Onamia	2.37	13.1	20	7.6
05284920	07010207	Stanchfield Creek tributary near Day	1.26	34.9	9.0	9.0
05286000	07010207	Rum River near St. Francis	1,360	3.70	37	7.5
05289500	07010206	Minnehaha Creek at Minnetonka Mills	130	.14	30	6.7
05290000	07020001	Little Minnesota River near Peever, SD	447	3.20	1.1	2.0
05291000	07020001	Whetstone River near Big Stone City, SD	389	10.9	1.5	2.0
05293000	07020001	Yellow Bank River near Odessa	398	17.7	1.3	2.0
05294000	07020002	Pomme De Terre River at Appleton	905	2.50	5.4	2.1
05299100	07020003	Lazarus Creek tributary near Canby	2.97	67.9	2.0	2.1
05300000	07020003	Lac Qui Parle River near Lac Qui Parle	983	12.7	.9	2.0
05301200	07020004	Minnesota River tributary near Montevideo	.40	10.3	5.0	2.3
05302970	07020005	Outlet Creek tributary near Starbuck	.47	51.2	.0	2.5
05303450	07020005	Hassel Creek near Clontarf	7.53	40.4	2.0	2.5
05304500	07020005	Chippewa River near Milan	1,870	4.10	5.2	2.5
05305200	07020005	Spring Creek near Montevideo	16.0	5.68	1.0	2.3
05311200	07020004	North Branch Yellow Medicine River near Ivanhoe	14.8	11.8	3.0	2.1

characteristics for region D--Continued

Peak-flow information									
Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)	Station weight	Years of record	Historic period	Type of station
3,400	6,700	9,300	12,900	15,800	18,800	1.5	62	62	C
29.2	62.6	95.9	154	212	285	.8	20	65	P
13.9	29.4	42.7	62.6	79.6	98.3	.5	12	12	P
83.5	156	205	264	304	341	.9	24	65	P
53.5	109	160	245	325	421	1.0	24	24	P
35.3	66.1	89.7	122	148	175	1.1	23	23	P
3,880	6,450	8,120	10,100	11,500	12,800	1.8	54	54	C
68.2	175	270	413	532	660	.3	12	12	B,D
795	1,900	2,940	4,590	6,070	7,750	.9	42	42	C,D
1,150	3,110	4,990	7,980	10,600	13,500	.9	56	74	C
1,190	2,750	4,070	5,960	7,480	9,070	.9	44	44	C
704	1,470	2,130	3,140	4,010	4,980	1.5	53	53	C
125	303	453	666	834	1,010	.6	24	24	P
1,460	3,490	5,490	8,870	12,100	15,900	1.2	57	57	C
7.1	25.4	48	92.1	138	197	.4	16	16	P
9.9	20.7	29.6	42.3	52.7	63.6	1.0	22	22	P
48.9	79.6	105	145	181	223	1.1	19	62	P,D
1,680	3,410	4,890	7,120	9,040	11,200	1.2	47	65	C
96.1	234	359	551	718	902	.7	25	25	P
78.5	230	389	659	912	1,210	.5	24	24	P

Station number	Hydro-logic unit code	Station name	Basin characteristics			
			Area (mi^2)	Slope (ft/mi)	Storage (%)	Annual runoff (in.)
05311250	07020004	North Branch Yellow Medicine River tributary near Wilno	0.33	87.7	0.0	2.2
05311300	07020004	North Branch Yellow Medicine River tributary #2 near Porter	3.70	30.9	1.0	2.1
05313500	07020004	Yellow Medicine River near Granite Falls	653	12.4	.5	2.3
05313800	07020004	Kandiyohi County Ditch #16 near Blomkest	.83	7.75	.0	3.3
05314900	07020006	Redwood River at Ruthton	6.18	42.4	.0	2.6
05315000	07020006	Redwood River near Marshall	307	17.0	1.7	2.5
05315200	07020006	Prairie Ravine near Marshall	5.63	11.4	.0	2.2
05316500	07020006	Redwood River near Redwood Falls	697	11.0	.4	2.8
05316550	07020004	West Fork Beaver Creek near Olivia	12.2	4.57	4.0	3.5
05316690	07020007	Spring Creek tributary near Sleepy Eye	3.69	6.33	6.0	4.3
05316700	07020007	Spring Creek near Sleepy Eye	31.3	2.88	4.0	4.3
05316800	07020008	Cottonwood River tributary near Balatan	.91	42.8	.0	2.7
05316850	07020008	Meadow Creek tributary near Marshall	.54	57.0	.0	2.8
05316900	07020008	Dry Creek near Jeffers	3.13	61.4	.0	3.7
05316920	07020008	Cottonwood River tributary near Sanborn	.42	46.6	.0	3.8
05317000	07020007	Cottonwood River near New Ulm	1,280	6.00	.7	3.5
05317850	07020009	Foster Creek near Alden	2.26	20.1	.0	6.4
05318000	07020009	East Branch Blue Earth River near Bricelyn	132	3.20	5.3	6.3
05318100	07020009	East Branch Blue Earth River tributary near Blue Earth	9.20	10.5	.0	6.1
05318300	07010010	Watonwan River near Delft	13.0	15.7	2.0	3.9

Peak-flow information									
Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)	Station weight	Years of record	Historic period	Type of station
16.9	33.6	46.1	63.0	75.8	88.7	1.1	24	24	P
92.5	136	168	211	245	281	.9	16	16	P
1,230	3,360	5,390	8,570	11,300	14,400	.8	52	103	C
31.8	56.5	72.5	91.2	104	115	.6	14	92	P
120	277	408	591	737	887	.6	23	23	P,D
639	1,620	2,500	3,840	4,980	6,200	.9	44	44	C,D
38.1	76.8	108	152	187	224	1.0	25	25	B
995	2,940	5,000	8,570	12,000	16,000	.9	58	58	C
75.0	149	208	291	358	429	.9	23	23	P,D
41.8	80.4	110	151	182	215	.8	18	18	P
185	365	515	740	930	1,140	.9	25	25	P
32.9	102	175	302	421	562	.6	25	25	P
17.7	54.4	92.9	158	219	290	.3	12	12	P
127	280	416	623	802	1,000	.7	23	23	P
24.4	54.6	80.3	118	149	183	.7	18	18	P
3,050	6,550	9,820	15,100	20,000	25,800	1.3	57	57	C
87.1	165	218	283	328	369	1.0	25	25	P
369	771	1,090	1,530	1,880	2,230	.9	31	31	B
157	289	391	533	645	764	1.0	24	24	P
101	317	574	1,080	1,620	2,330	.5	24	24	P

Table 5.--*Basin and flood-flow*

Station number	Hydro-logic unit code	Station name	Basin characteristics Area (mi^2)	Slope (ft/mi)	Storage (%)	Annual runoff (in.)
05320000	07020009	Blue Earth River near Rapidan	2,430	2.70	0.8	5.5
05320200	07020011	Le Sueur River tributary near Mankato	.07	158	.0	6.1
05320300	07020011	Cobb River tributary near Mapleton	7.25	4.02	4.0	6.1
05320400	07020011	Maple River tributary near Mapleton	6.22	9.30	.0	6.1
05320440	07020011	Judicial Ditch #49 near Amboy	18.0	8.82	1.0	5.9
05320500	07020011	Le Sueur River near Rapidan	1,100	8.10	2.7	6.2
05330150	07020012	Sand Creek tributary near Montogomery	.36	68.7	6.0	6.4
05330200	07020012	Rice Lake tributary near Montgomery	3.16	10.0	12	6.4
05330300	07020012	Sand Creek near New Prague	62.4	5.97	11	6.4
05330550	07020012	Raven Stream tributary near New Prague	22.1	10.0	10	6.3
05330600	07020012	Sand Creek tributary #2 near Jordan	2.62	30.9	6.0	6.3
05336200	07030003	Glaisby Brook near Kettle River	24.2	11.5	17	9.9
05336300	07030003	Moose River tributary at Moose Lake	1.23	30.4	3.0	10.1
05336550	07030003	Wolf Creek tributary near Sandstone	5.46	12.4	58	9.4
05336600	07030003	Kettle River tributary at Sandstone	.65	32.4	28	9.4
05336700	07030003	Kettle River below Sandstone	863	6.38	10	9.9
05338200	07030004	Mission Creek near Hinckley	3.84	12.7	20	9.1
05338500	07030004	Snake River near Pine City	958	5.30	43	8.6
05340000	07030005	Sunrise River near Stacy	167	1.90	47	8.2
05345000	07040001	Vermillion River near Empire	110	17	5.6	6.8

Peak-flow information									
Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)	Station weight	Years of record	Historic period	Type of station
6,420	12,000	16,500	22,800	27,900	33,400	1.4	53	76	C
21.4	51.0	82.7	141	203	282	1.0	25	25	P
136	229	301	401	483	571	1.2	25	25	P
122	270	413	652	880	1,150	.8	25	76	P
184	320	428	583	713	855	.6	14	65	P
3,870	7,540	10,600	15,300	19,400	23,900	1.1	41	65	C
20.6	32.2	40.9	53.0	62.8	73.3	1.2	21	21	P,D
47.9	83.0	108	141	166	192	1.2	24	65	P
240	469	662	952	1,200	1,480	.9	24	24	P
160	262	344	465	569	684	1.2	24	65	P
45.5	92.1	135	205	270	348	1.0	24	65	P
434	740	971	1,290	1,550	1,820	1.0	24	24	B
72.2	146	211	313	404	508	.9	22	22	P,D
57.8	128	185	267	333	402	.8	24	24	P
16.6	34.4	48.9	69.3	85.7	103	1.0	22	22	P,D
6,130	9,920	12,800	16,900	20,300	23,900	.8	22	22	C
75.3	126	162	208	244	280	1.2	24	24	P
5,010	8,140	10,300	13,000	14,900	16,900	1.3	38	38	B
308	465	571	707	809	911	.9	17	17	B,D
778	1,750	2,620	3,990	5,190	6,560	.4	15	15	C

Station number	Hydro-logic unit code	Station name	Basin characteristics Area (mi^2)	Slope (ft/mi)	Storage (%)	Annual runoff (in.)
05345900	07040001	Vermillion River tributary near Hastings	14.3	5.53	16	7.2
05352700	07040002	Turtle Creek tributary #2 near Pratt	1.26	36.2	1.0	6.7
05352800	07040001	Turtle Creek tributary near Steele Center	5.01	16.4	1.0	6.7
05353800	07040002	Straight River near Faribault	442	3.57	3.8	6.6
05355100	07040002	Little Cannon River tributary near Kenyon	2.20	53.4	.0	6.9
05355150	07040002	Pine Creek near Cannon Falls	20.2	12.8	1.0	7.1
05355200	07040002	Cannon River at Welch	1,320	4.20	2.4	6.7
05355230	07040002	Cannon River tributary near Welch	.05	158	.0	7.4
05372800	07040004	South Fork Zumbro River on Belt Line at Rochester	155	12.9	.0	7.0
05372930	07040004	Bear Creek at Rochester	80.0	19.0	.1	7.1
05372950	07040004	Silver Creek at Rochester	17.3	32.3	.7	7.2
05372990	07040004	Cascade Creek at Rochester	37.0	15.4	.2	7.1
05373000	07040004	South Fork Zumbro River near Rochester	304	9.30	.2	7.1
05373350	07040004	Zumbro River Tributary near South Troy	.16	156	.0	7.3
05373700	07040004	Spring Creek near Wanamingo	9.93	20.7	.0	7.0
05373900	07040004	Trout Brook tributary near Goodhue	.40	88.9	.0	7.3
05374000	07040004	Zumbro River at Zumbro Falls	1,130	7.70	.1	7.1
05374400	07040004	Long Creek near Potsdam	4.46	41.3	.0	7.4
05374500	07040004	Zumbro River at Theilman	1,320	6.40	.1	7.1
05375800	07040003	East Indian Creek tributary near Weaver	.22	604	9.0	7.5

characteristics for region D--Continued

Peak-flow information									
Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)	Station weight	Years of record	Historic period	Type of station
26.2	113	237	513	838	1,300	.3	14	14	P
52.1	120	177	260	326	396	.7	22	22	P
100	193	265	365	445	528	.9	24	24	P
2,840	4,350	5,260	6,310	7,010	7,650	.7	18	18	C
178	368	521	737	909	1,090	.8	24	24	P
158	346	501	723	901	1,090	.6	21	21	P,D
6,050	10,600	14,100	19,200	23,500	28,000	1.8	57	96	B
20.7	43.3	61.3	86.3	106	126	.9	22	22	P,D
2,100	3,810	5,200	7,250	8,990	10,900	.5	15	96	P
1,040	2,110	3,210	5,210	7,290	10,000	.5	15	96	P
507	1,200	1,990	3,600	5,410	7,950	.4	15	96	P
580	1,060	1,430	1,960	2,400	2,860	.5	14	14	P
4,410	8,890	12,800	18,900	24,200	30,300	.8	31	74	C,D
30.9	67.6	99.9	149	192	240	.9	22	22	P
424	917	1,340	1,970	2,490	3,070	.7	24	24	P
78.5	147	213	324	433	568	1.1	24	96	P
10,900	17,100	21,200	26,300	29,900	33,300	2.1	59	122	B,D
186	342	480	701	903	1,140	.8	18	125	P
12,200	18,000	21,800	26,400	29,600	32,800	.8	19	69	B,D
11.9	25.4	37.1	54.7	69.9	86.6	.6	14	14	P

Station number	Hydro- logic unit code	Station name	Basin characteristics Area (mi^2)	Slope (ft/mi)	Storage (%)	Annual runoff (in.)
05376000	07040003	North Fork Whitewater River near Elba	101	10.1	9.0	7.5
05376500	07040003	South Fork Whitewater River near Altura	76.8	22.3	.0	7.4
05376800	07040003	Whitewater River near Beaver	271	15.5	.0	7.4
05378300	07040003	Straight Valley Creek near Rollingstone	5.16	113	.0	7.2
05379000	07040003	Gilmore Creek at Winona	8.95	109	.0	7.2
05383600	07040008	North Branch Root River tributary near Stewartville	.73	47.3	.0	7.1
05383700	07040008	Mill Creek tributary near Chatfield	2.36	80.8	.0	7.3
05383720	07040008	Mill Creek near Chatfield	22.4	50.4	.0	7.3
05383850	07040008	South Fork Bear Creek near Grand Meadow	14.0	14.5	.0	7.1
05384000	07040008	Root River near Lanesboro	615	7.50	.0	7.2
05384100	07040008	Duschee Creek near Lanesboro	3.85	70.8	.0	7.3
05384150	07040008	Root River tributary near Whalan	.08	243	.0	7.4
05384200	07040008	Gribben Creek near Whalen	7.80	101	.0	7.4
05384300	07040008	Big Springs Creek near Arendahl	.14	100	.0	7.4
05384400	07040008	Pine Creek near Arendahl	28.1	18.3	.0	7.4
05384500	07040008	Rush Creek near Rushford	129	28.0	.0	7.5
05385000	07040008	Root River near Houston	1,270	6.50	.0	7.3
05385500	07040008	South Fork Root River near Houston	275	7.60	.0	7.5
05386000	07040008	Root River below South Fork near Houston	1,560	6.40	.0	7.3
05457000	07080201	Cedar River near Austin	425	4.00	.7	6.8

Peak-flow information									
Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)	Station weight	Years of record	Historic period	Type of station
2,050	5,090	8,190	13,600	18,900	25,500	0.4	19	19	C
1,660	3,150	4,270	5,790	6,980	8,190	1.3	44	96	B
4,110	7,700	10,500	14,400	17,600	21,000	.8	28	46	C
300	712	1,060	1,560	1,970	2,390	.6	25	25	B
365	1,040	1,770	3,070	4,370	5,960	.5	25	25	B,D
68.5	151	225	344	451	573	.9	26	26	B,D
407	596	721	878	993	1,110	.9	17	17	P
1,570	3,480	5,170	7,730	9,940	12,400	.5	22	22	P
748	1,670	2,540	3,970	5,300	6,870	.6	22	22	P
8,680	14,100	17,500	21,700	24,600	27,400	1.7	51	51	C
220	589	952	1,550	2,090	2,720	.5	25	25	P
27.7	67.5	106	171	232	304	.8	23	23	P,D
651	1,750	2,900	4,950	6,960	9,440	.5	25	25	P
17.9	45.9	74.0	122	168	223	.8	23	23	P
810	1,870	2,730	3,910	4,830	5,760	.5	25	25	P,D
2,470	5,100	7,280	10,500	13,100	15,900	1.0	42	42	B
10,700	17,900	22,900	29,200	33,800	38,300	1.9	62	62	C
2,790	5,850	8,510	12,600	16,100	20,100	.8	32	32	C
13,500	22,300	28,600	37,100	43,800	50,600	.8	24	24	B,D
4,240	7,270	9,170	11,300	12,800	14,000	1.3	44	44	C

Station number	Hydro-logic unit code	Station name	Basin characteristics Area (mi²)	Slope (ft/mi)	Storage (%)	Annual runoff (in.)
05457080	07080201	Rose Creek tributary near Dexter	1.17	37.9	.0	7.0
05474750	07100001	Beaver Creek tributary #2 near Slayton	3.53	43.7	.0	3.1
05474760	07100001	Beaver Creek tributary above Slayton	2.20	38.8	.0	3.1
05475400	07100001	Warren Lake tributary near Windom	1.39	17.4	.0	3.9
05475800	07100001	Des Moines River tributary near Jackson	1.52	20.6	1.0	4.2
05475900	07100001	Des Moines River tributary #2 near Lakefield	5.18	12.1	.0	4.2
05476000	07100001	Des Moines River at Jackson	1,220	2.60	4.5	3.4
05476010	07100002	Nelson Creek at Jackson	6.19	46.3	.0	4.3
05476100	07100002	Story Brook near Petersburg	25.8	23.2	.0	4.3
05476900	07100003	Fourmile Creek near Dunnell	14.0	17.2	.0	4.8
06482950	10170203	Mound Creek near Hardwick	2.47	25.3	.0	2.8
06482960	10170204	Mound Creek tributary at Hardwick	.19	112	.0	2.8
06483050	10170204	Rock River tributary near Luverne	.21	100	.0	2.9
06483200	10170204	Kanaranzi Creek tributary near Lismore	.14	66.0	.0	3.1
06483210	10170204	Kanaranzi Creek tributary #2 near Wilmont	2.14	37.4	.0	3.2
06603000	10230003	Little Sioux River near Lakefield	17.1	4.80	2.9	3.3
06603500	10230003	Jackson County Ditch #11 near Lakefield	7.69	1.80	3.0	3.9
06603520	10230003	Judicial Ditch #28 tributary near Spafford	2.66	14.5	.0	3.8
06603530	10230003	Little Sioux River near Spafford	41.1	6.39	.3	3.9

Peak-flow information									
Q2 (ft^3/s)	Q5 (ft^3/s)	Q10 (ft^3/s)	Q25 (ft^3/s)	Q50 (ft^3/s)	Q100 (ft^3/s)	Station weight	Years of record	Historic period	Type of station
102	204	294	436	563	709	.9	22	22	P
73.8	124	164	220	267	319	1.2	23	23	P
52.6	94.3	124	164	194	224	1.1	23	23	P
48.6	114	183	308	436	599	.9	24	24	P
25.2	51.8	72.7	101	124	146	1.0	24	24	P
74.1	122	154	196	226	255	1.2	24	24	P
1,560	3,330	4,900	7,360	9,550	12,000	1.4	58	58	C
363	809	1,230	1,930	2,570	3,330	.4	12	17	P
666	1,380	1,960	2,780	3,450	4,140	.4	13	13	P
257	613	948	1,490	1,990	2,560	.6	24	24	P
37.7	104	174	301	427	582	.7	25	25	P
38.2	115	190	306	405	512	.6	25	25	P
35.1	104	176	299	416	552	.4	14	14	P
93.9	166	221	297	358	421	1.0	23	23	P,D
140	311	467	714	935	1,190	.6	18	18	P
74.7	277	545	1,120	1,770	2,670	.3	15	15	B,D
45.1	204	433	943	1,540	2,360	.2	12	12	B,D
46.5	110	173	279	381	502	.5	14	14	P
214	651	1,190	2,320	3,590	5,370	.4	19	19	P

Table 6.--*Ranges of basin characteristics for each of the regions used in the regression analysis*

	Area (square mile)	Slope (feet per mile)	Storage[1] (percent)	Lakes[2] (percent)
		REGION A		
Upper limit	1,600	40	51	--
Lower limit	1.1	1	0	--
		REGION B		
Upper limit	1,730	259	--	23
Lower limit	.4	1	--	0
		REGION C		
Upper limit	600	226	32	--
Lower limit	.2	3	0	--
		REGION D		
Upper limit	2,520	604	58	--
Lower limit	.1	1	0	--

[1] Percentage of basin area covered by lakes, ponds, and wetlands.

[2] Percentage of basin area covered by lakes and ponds.