ESTIMATES OF MEAN MONTHLY STREAMFLOW FOR SELECTED SITES IN THE MUSSELSHELL RIVER BASIN, MONTANA, BASE PERIOD WATER YEARS 1937-86

By Charles Parrett and Dave R. Johnson

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CONVERSION FACTORS

The following factors can be used to convert inch-pound units in this report to metric (International System) units.

Multiply inch-pound unit	By	To obtain metric unit
acre	0.4047	hectare
cubic foot per second	0.028317	cubic meter per second
foot	0.3048	meter
foot per mile	0.1894	meter per kilometer
inch	25.4	millimeter
mile	1.609	kilometer
square mile	2.59	square kilometer

Temperature can be converted from degrees Fahrenheit (°F) to degrees Celsius (°C) by the equation:

$$°C = 5/9\ (°F - 32)$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

Water year: The 12-month period from October 1 through September 30. A water year is identified by the calendar year in which it ends.

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ABSTRACT

Estimates of mean monthly and mean annual streamflow were made and are presented in tabular form for 56 selected sites in the Musselshell River basin and for 1 site, used for streamflow-correlation purposes, outside the basin. The study area was divided into a Mountain Region and a Plains Region and the methods of estimation used at ungaged sites were applied separately in the two regions. Of the 56 sites in the Musselshell River basin, 11 sites are in the Mountain Region and 45 are in the Plains Region. In the Mountain Region, the methods of estimation used were those previously developed for a similar study in the upper Missouri River basin.

Each method of estimation developed was based on a common base period of record (water years 1937-86). The common base period ensured that mean monthly streamflow estimates at ungaged sites would be unbiased and representative of a consistent hydrologic period. The base period was developed using a mixed-station monthly flow record-extension procedure. Most of the streamflow-gaging stations used in the previous study were used in this study as potential base stations for the record-extension procedure for the Plains Region.

Four methods were developed to estimate mean monthly streamflow at ungaged sites. The first method was based on the regression relation between mean monthly streamflow and various basin and climatic characteristics. The standard errors for this method ranged from 35 to 71 percent in the Mountain Region and from 98 to 157 percent in the Plains Region. The second method was similar to the first and was based on the regression relations between mean monthly streamflow and active-channel width. The standard errors for this method ranged from 38 to 81 percent in the Mountain Region and from 71 to 98 percent in the Plains Region. The third method required measurements of streamflow at the ungaged sites and was based on correlation of the measured streamflow with concurrent daily mean streamflow at nearby gaged sites. The standard errors for this method ranged from 36 to 66 percent in the Mountain Region and from 109 to 321 percent in the Plains Region. The fourth method was used to estimate mean monthly streamflow at ungaged sites where more than one of the first three methods were used. For this method, mean monthly streamflows were estimated by weighting estimates from the individual methods in accordance with their variance and degree of independence. The standard error for the weighted-average-estimate method when all three individual estimates

are weighted ranged from 25 to 55 percent in the Mountain Region and from 71 to 97 percent in the Plains Region. In the Mountain Region, the standard errors of the weighted-average-estimate method generally are smaller than the standard errors determined by the other three methods. In the Plains Region, the standard errors of the weighted-average-estimate method were generally comparable to those of the channel-width method.

The most reliable estimates of mean monthly streamflow were for the 17 gaged sites. For the ungaged sites, estimates of mean monthly streamflow using the weighted-average-estimate method were considered to be more reliable than those determined by the other three methods. In general, estimates made at ungaged sites in the Mountain Region were substantially more reliable than estimates made at ungaged sites in the Plains Region. The large difference in reliability is attributed to the larger natural variability of streamflow and greater effect of irrigation on streamflow in the Plains Region.

INTRODUCTION

The Musselshell River drains about 8,000 square miles of the sparsely populated (less than 10,000 inhabitants) central Montana mountains and plains. The river is an important source of water for irrigation of about 70,000 acres of cropland. Although the water supply is marginally adequate in most years, serious shortages of water for irrigation are common. Shortages occur despite the presence of several State-managed water-storage projects and are reflective of the large natural variability in streamflows.

To identify the locations and severity of the shortages and to formulate a management plan to equitably distribute available water, the Montana Department of Natural Resources and Conservation is attempting to develop a water-accounting model of the Musselshell River basin. The model will enable irrigation demands and streamflow availability to be calculated at several locations along the Musselshell River. Some important factors to be considered when calculating streamflow availability and irrigation demands are: irrigated acreage, municipal water demand, evapotranspiration, irrigation return flows, mainstem streamflow, and tributary inflow. Although streamflow records generally are available at or near sites of interest on the Musselshell River, the periods of record at some sites are not concurrent. In addition, most of the tributaries are ungaged. Accordingly, the Lower Musselshell Conservation District and the Montana Department of Natural Resources and Conservation entered into a cooperative program with the U.S. Geological Survey to develop estimates of long-term mean monthly and mean annual streamflow at selected sites in the Musselshell River basin.

Purpose and Scope

The objective of the study was to estimate long-term mean monthly streamflow for each month at each identified site. This report presents those estimates for the selected sites, describes the methods used to make the estimates, and discusses the reliability of the estimates. Estimates were made for 56 sites in the Musselshell River basin, including 16 gaged sites. Mean monthly streamflow estimates also are presented for one gaged site (site 50) outside the Musselshell River basin that was used for streamflow correlation.

To ensure that all estimates were representative of the same hydrologic conditions, a common base period of record--water years 1937-86--was used to determine mean monthly streamflow at all gaged sites used in the analysis. A streamflow record-extension procedure was used to extend the period of record at short-record gaged sites.

Four methods were developed to estimate mean monthly streamflow at the 40 selected ungaged sites. The first method, used to estimate mean monthly streamflow at 30 ungaged sites, was based on the regression relation between mean monthly streamflow and various basin and climatic characteristics. The second method was similar to the first and was based on the regression relation between mean monthly streamflow and channel width. This method was used to estimate mean monthly streamflow at 26 ungaged sites. The third method required 12 measurements of streamflow at the ungaged sites and was based on the correlation of measured streamflow with concurrent daily mean streamflow at nearby gaged sites. This method was used to estimate mean monthly streamflow at all 40 ungaged sites. The fourth method was used to estimate mean monthly streamflow at 30 ungaged sites where more than one of the first three methods were used. For this method, mean monthly streamflow was estimated by weighting estimates from the individual methods in accordance with the variance and degree of independence of the individual methods.

Because estimates of mean annual streamflow are useful for many water management purposes, estimates of mean annual streamflow also were developed for this report by multiplying each mean monthly streamflow estimate by the number of days in the month, summing, and dividing by 365. Because the estimates of mean annual streamflow are derived from estimates of mean monthly streamflow, the reliability of only mean monthly streamflow is discussed. The 56 estimation sites in the Musselshell River basin and the 1 estimation site (site 50) outside the basin and the methods used to estimate mean monthly streamflow are identified in table 1. The estimates of mean monthly and mean annual streamflow for all selected sites are presented in table 2.

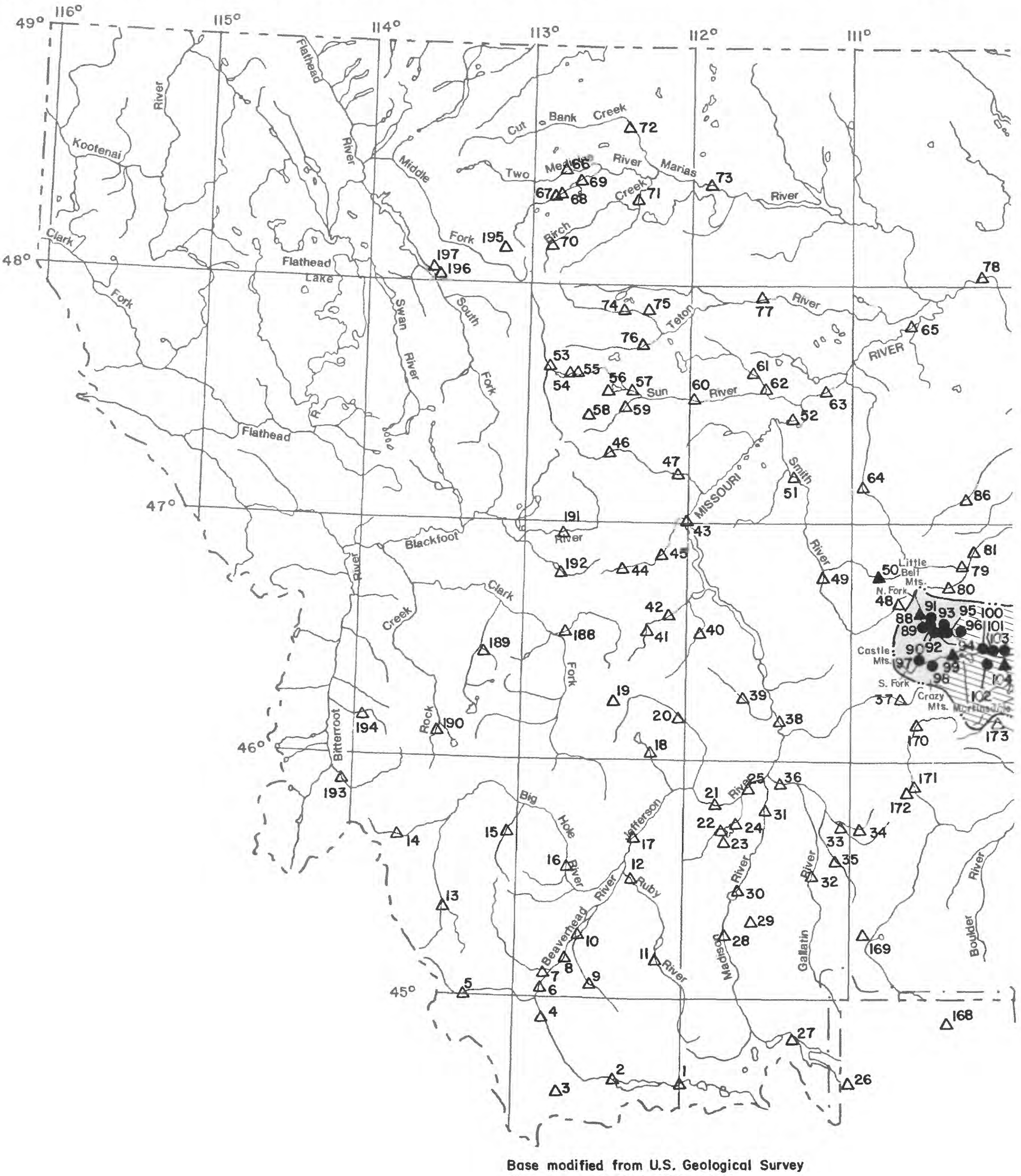
Description of Study Area

The Musselshell River is formed by the junction of the North and South Forks near Martinsdale. The headwaters of the North Fork Musselshell River are in the Little Belt Mountains. The headwaters of the South Fork Musselshell River are in the Castle and Crazy Mountains. The mountains are high and rugged, and receive as much as 30 inches of precipitation annually (U.S. Soil Conservation Service, 1981), mostly in the form of snow. Streams draining the mountains generally are perennial and have substantial baseflow, although irrigation withdrawals may decrease flows to near zero before the streams enter the North or South Fork.

Downstream from Martinsdale, the Musselshell River traverses a broad, flat plains area where annual precipitation is about 13 inches (U.S. Soil Conservation Service, 1981). Tributary streams draining the plains are mostly intermittent and subject to large variations in streamflow as a result of sporadic, but intense, rainstorms and substantial irrigation withdrawals and return flows.

Because the streams draining the mountains have substantially different streamflow characteristics from the streams draining the plains, the Musselshell River basin was divided into the Mountain Region and the Plains Region, and the estimation methods described in this report were applied separately to the two regions. The estimation methods for the Mountain Region were previously developed in a similar study done for mountain streams in the upper Missouri River basin (Parrett and others, 1989).

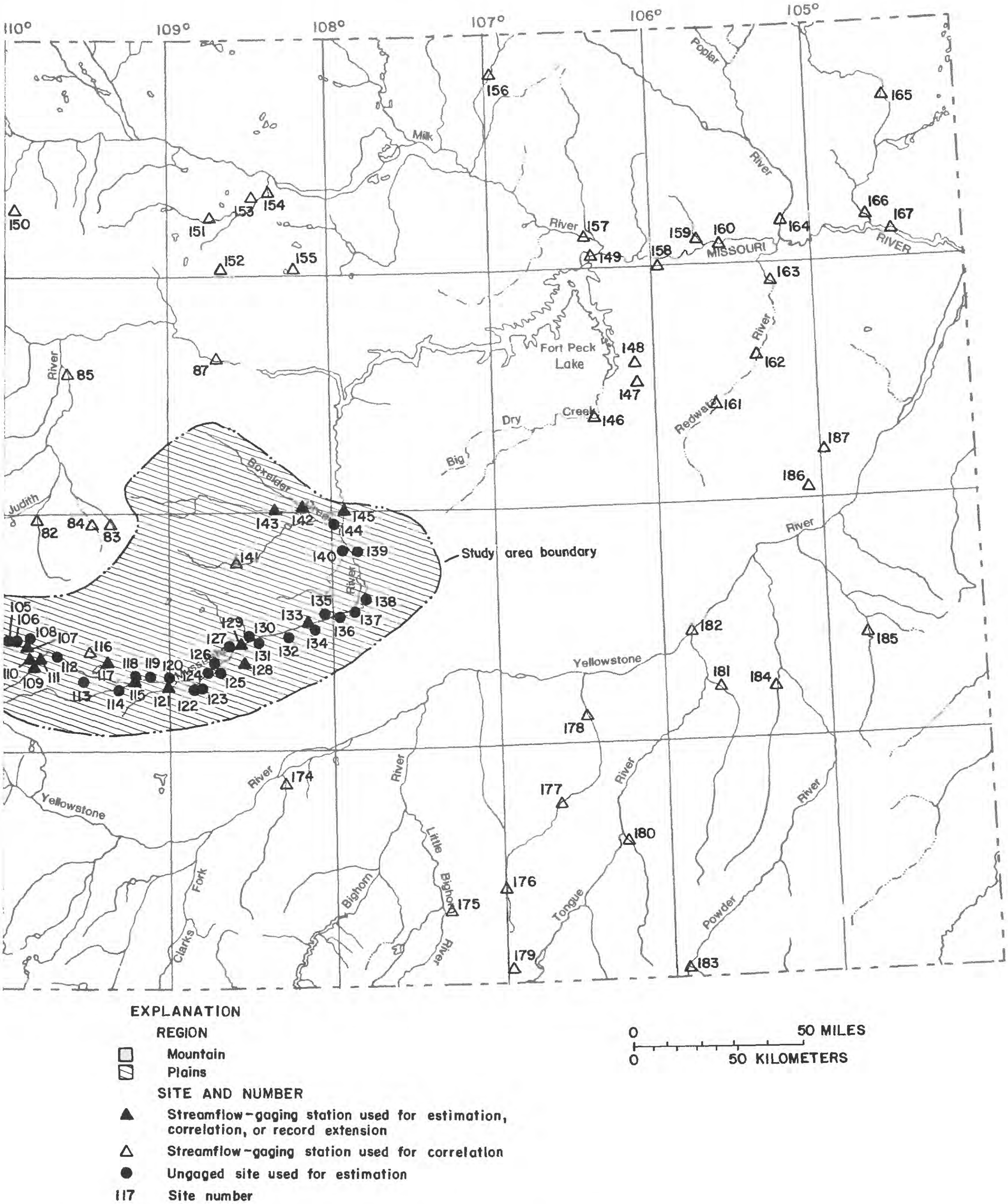
Estimation methods developed for the Plains Region are based on data from 18 gaging stations in the study area and 139 gaging stations outside the study area.



Base modified from U.S. Geological Survey
State base, 1:1,000,000, 1965

Figure 1.--Location of ungaged sites and streamflow-gaging stations

Although many of the stations are well beyond the study-area boundaries, they were considered to be potentially useful for correlation purposes with ungaged estimation sites within the Musselshell River basin and thus were included in the analysis. Location of the streamflow-estimation sites, regional boundaries, and location of all gages used for this study are shown in figure 1.



used for estimation, correlation, or record extension.

COMMON BASE PERIOD DEVELOPMENT

Each streamflow estimation method described in this report utilizes streamflow information from selected gaging stations within and outside the study area. To ensure that streamflow estimates would be unbiased and representative of a consistent hydrologic period, a monthly flow record-extension procedure was used to extend all short-term records to a common base period (water years 1937-86). This mixed-station procedure, described by Alley and Burns (1983, p. 1272-1274), selects the best base station from among all available base stations to fill in each month of missing data at a short-record gage site. Thus, several different base stations may be used to fill in different months of missing data. The criterion for selection is to use the base station that results in the smallest standard error of prediction for that month. Only stations with streamflow record for a particular month and year were used to estimate missing flows at other sites for that month and year; previously estimated flows are not used to estimate any missing flows.

The record-extension procedure differed between the Mountain and Plains Regions. For the Mountain Region, the record-extension procedure was the same used in the upper Missouri River basin study (Parrett and others, 1989). A total 154 gaging stations were used as potential base stations.

For the Plains Region, the record-extension procedure included most of the same gaging stations as in the Mountain Region. Several additions to the data base resulted in 157 potential base stations (table 3). To permit inclusion of data from stations discontinued before 1937, the procedure was used to estimate all missing monthly streamflow data for water years 1906-86. After the records were extended, all data prior to 1937 were excluded from the data base.

In addition to the capability of using more than one base station to extend a short-term record, the monthly record-extension procedure also has the option of using a cyclic or noncyclic equation to fill in missing record. If the cyclic option is selected, an extension equation is computed for each month using only concurrent streamflows for the month. If the noncyclic option is selected, a single extension equation is computed using all concurrent streamflows. For two stations with 5 years of concurrent monthly streamflows, for example, the cyclic correlations would be developed separately for each month and would be based on five concurrent flows for each month. The noncyclic correlation would be based on 60 concurrent monthly flows, but the same correlation would be used for all months. The smallest standard error criterion is also used to select the cyclic or noncyclic option each time a missing monthly streamflow is estimated. No base station was used to fill in missing record at another station unless the two stations had at least five concurrent monthly streamflows. The base stations with less than 5 years of record thus could be used only with the noncyclic option.

Most streamflow record-extension procedures use ordinary least-squares regression equations to estimate individual missing values at short-term stations. Unfortunately, ordinary least-squares regression commonly results in extended records with smaller variances than the unextended records. Techniques other than ordinary least-squares regression which can be used to estimate missing values and which tend to preserve the variance of the unextended records include regression plus noise (Matalas and Jacobs, 1964; U.S. Army Corps of Engineers, 1971) and two alternatives to regression described by Hirsch (1982), which he refers to as MOVE.1 and MOVE.2 (Maintenance of Variance Extension, Types 1 and 2). The streamflow-record extension procedure described by Alley and Burns (1983) has the capability of using any of these extension techniques, including ordinary least-squares regression.

For this study, the MOVE.1 curve-fitting technique was used to estimate missing values, because it is the simplest of the techniques that preserve variance of the unextended records. The MOVE.1 technique is analogous to ordinary least-squares regression, except that ordinary regression minimizes the squared vertical deviations of the response variable from the regression line, whereas the MOVE.1 technique minimizes the areas of the right triangles formed by the horizontal and vertical deviations from the regression line (Hirsch and Gilroy, 1984, p. 707).

Because the record-extension procedure results in estimated flows that are perfectly correlated with concurrent flows at the base station(s) used to make the estimates, extended flow records might have substantially larger inter-station correlations than the actual flow records. Parrett and others (1989) tested whether the average inter-station correlations increased for 47 of the 154 gaged sites used for record extension in the upper Missouri River basin study and concluded that they did not. The same conclusion is believed to apply to the Plains Region in this study because the data base of 157 stations is almost identical to the 154 stations used for the Mountain Region and the upper Missouri River basin study.

METHODS OF ESTIMATION

Basin-Characteristics Method

The first method used for estimating mean monthly streamflow at the ungaged estimation sites is based on a linear multiple-regression analysis that related mean monthly streamflow at selected gaged sites to various basin and climatic variables. This basin-characteristics method previously has been used in Montana to estimate monthly streamflow characteristics (Boner and Buswell, 1970; Parrett and Cartier, 1989; Parrett and others, 1989).

For both the Mountain and Plains Regions, the following basin and climatic characteristics were available for each of the gaged sites and were used as potential explanatory variables in the regressions:

A	drainage area, in square miles;
P	mean annual precipitation on the basin, in inches;
E	mean basin elevation, in thousands of feet above sea level;
E6	percentage of basin above 6,000 feet elevation, plus 1;
F	percentage of drainage area covered by forest, plus 1;
L	main-channel length, in miles;
S	main-channel slope, in feet per mile;
I24	precipitation intensity for a storm of 24 hours duration having a 2-year recurrence interval, in inches; and
TI	mean basin minimum January temperature, in degrees Fahrenheit, plus 10.

One or 10 was added to some basin and climatic characteristics to ensure that values of the characteristics were always greater than zero.

For the Mountain Region, equations previously developed for the upper Missouri River basin (Parrett and others, 1989) were considered to be applicable. Those equations were based on data from 47 gaged sites, including 3 in the study area, that were considered to be most representative of streams draining the mountains. Basin and climatic characteristics that were used as explanatory variables were drainage area and mean annual precipitation. Regression equations for the Mountain Region, coefficients of determination, and standard errors are given in table 4. The coefficients of determination ranged from 0.70 to 0.89, and the standard errors, in log units, ranged from 0.15 (35 percent) to 0.28 (71 percent). In general, the larger the coefficient of determination and the smaller the standard error of estimate, the more reliable the estimating equation. The regression equations in table 4 were used to estimate mean monthly streamflow at seven ungaged sites. The regression equations were not used to estimate mean monthly streamflow for two ungaged sites--Trail Creek at mouth, near Checkerboard (site 91) and Spring Creek at mouth, near Checkerboard (site 93), because streamflow at those sites is substantially affected by upstream diversions and regulations.

For the Plains Region, data from 31 gaged sites considered to be most representative of streams draining the plains were used in the basin-characteristics regression analysis. Because many streams draining the plains have some mean monthly streamflows close to or equal to zero, 1 cubic foot per second was added to all mean monthly streamflows prior to the regression analysis. All streamflow and basin and climatic characteristics data were then converted to logarithms, and regression equations of the following form were derived:

$$\log (Q+1) = \log a + b1 \log B + b2 \log C + \ldots bn \log N, \qquad (1)$$

where

$(Q+1)$ (response variable) is mean monthly streamflow, plus 1, in cubic feet per second;

a is the multiple-regression constant;

$b1$, $b2$, ... bn are the regression coefficients; and

B, C, ... N are values of the significant basin or climatic characteristics (explanatory variables).

The following nonlinear form of the regression equation results when antilogarithms of the terms are taken:

$$(Q+1) = aB^{b1}\, C^{b2} \ldots N^{bn}. \qquad (2)$$

A step-wise procedure (Minitab, Inc., 1986, p. 103-111) that added basin and climatic variables to the equation one at a time until all significant explanatory variables were included was used in this study. A variable was considered significant if the partial-F test statistic was equal to or greater than 5.0. A value of 5.0 for the partial-F test statistic corresponds to a significance level of about 97 percent for a regression analysis with 47 gaged sites (Mountain Region) and about 96 percent for a regression analysis with 31 gaged sites (Plains Region). The step-wise procedure also provided coefficients of determination and standard errors of estimate as measures of the regression reliability.

Meaningful regression equations could be developed only for February through July. For October through January, August, and September, no equations were statistically significant. For months wherein regression equations were meaningful, drainage area was the most significant explanatory variable. For some months, precipitation and slope were statistically significant variables, but their exclusion from the regressions did not result in any substantial decrease in regression reliability. Therefore, drainage area was the only explanatory variable used to estimate mean monthly streamflow from February through July. Regression equations based on basin and climatic characteristics for the Plains Region, and their coefficients of determination and standard errors, are given in table 5. The coefficients of determination ranged from 0.33 to 0.50 and the standard errors, in log units, ranged from 0.36 (98 percent) to 0.48 (157 percent).

For the Plains Region, the regression equations in table 5 were used to estimate mean monthly streamflow at 23 ungaged sites. Because the derived equations estimated $(Q+1)$ rather than Q, 1 cubic foot per second had to be subtracted from each estimate. Where the subtraction resulted in an estimate of zero or less, zero was used as the final estimate. The method was not used at ungaged sites where the streamflow is affected by significant irrigation withdrawals or returns and those where streamflow is ephemeral. At ungaged sites where the method was used, drainage area was planimetered on U.S. Geological Survey topographic maps at a scale of 1:250,000.

Channel-Width Method

The second method used to estimate mean monthly streamflow at the ungaged sites was also based on a regression analysis. In this method, the regression equations used active-channel width (W_{AC}) as the only explanatory variable. This channel-width method was previously used to estimate monthly streamflow characteristics in western Montana (Parrett and Cartier, 1989) and in the upper Missouri River basin (Parrett and others, 1989).

The active channel has been described by Osterkamp and Hedman (1977, p. 256) as "...a short-term geomorphic feature subject to change by prevailing discharges. The upper limit is defined by a break in the relatively steep bank slope of the active channel to a more gently sloping surface beyond the channel edge. The break in slope normally coincides with the lower limit of permanent vegetation...."

For the Mountain Region, equations previously developed for the upper Missouri River basin were considered to be applicable (Parrett and others, 1989). These equations were developed using the same 47 gaged sites in the mountains that were used for the basin-characteristics method. The equations for the Mountain Region, coefficients of determination, and standard errors are given in table 6. The coefficients of determination ranged from 0.64 to 0.87 and the standard errors, in log units, ranged from 0.16 (38 percent) to 0.31 (81 percent). The equations in table 6 were used to estimate mean monthly streamflow at seven ungaged sites. The equations were not used for the two ungaged sites (sites 91 and 93) that were most substantially affected by upstream diversion and regulation.

For the Plains Region, mean monthly streamflow and measured active-channel width at the 31 gaged sites used in the basin-characteristics method were used for the channel-width analysis. As with the basin-characteristics method, 1 cubic foot per second was added to all mean monthly streamflows prior to the regression analysis. All streamflow and basin-characteristics data were then converted to logarithms, and regression equations of the following form were derived:

$$\log (Q+1) = \log a + b \log W_{AC}, \quad (3)$$

where

$(Q+1)$ is mean monthly streamflow, plus 1, as previously defined;

a is the regression constant;

b is the regression coefficient; and

W_{AC} is active-channel width, in feet.

As before, the nonlinear form of equation 3 can be determined by taking antilogarithms as:

$$(Q+1) = a\, W_{AC}^{\;b}. \tag{4}$$

The channel-width regression equations for the Plains Region, coefficients of determination, and standard errors are given in table 7. The coefficients of determination ranged from 0.17 to 0.73 and the standard errors, in log units, ranged from 0.28 (71 percent) to 0.36 (98 percent).

The equations in table 7 were used to estimate mean monthly streamflow at 19 ungaged sites in the Plains Region. Because the derived equations estimated $(Q+1)$ rather than Q, 1 cubic foot per second had to be subtracted from each estimate. Where the subtraction resulted in a mean monthly streamflow estimate of zero or less, zero was used as the final estimate. The channel-width method was not used to estimate mean monthly streamflow at 12 ungaged estimation sites where the active-channel width could not be identified.

Concurrent-Measurement Method

The third method used to estimate mean monthly streamflow at ungaged sites was based on periodic measurements of streamflow at each ungaged site. The measured streamflows at each ungaged site were correlated with concurrent streamflows at a selected similar gaged site, and the relation between the streamflows at the two sites was used to transfer the long-term mean monthly streamflow at the gaged site to the ungaged site. This concurrent-measurement method was previously used to estimate monthly streamflow characteristics in western Montana (Parrett and Cartier, 1989) and in the upper Missouri River basin (Parrett and others, 1989).

For this study, the concurrent-measurement method was based on 12 streamflow measurements at 39 ungaged sites and on 7 streamflow measurements at 1 ungaged site (site 97). Streamflow at site 97 was measured from April through September 1988 and the results were used for estimation; this site also was an estimation site in the upper Missouri River basin study (Parrett and others, 1989). At the other ungaged sites, streamflow was measured during October 1987 and March through September 1988 to provide a range from near-base streamflow to near-peak streamflow. For both the Mountain and the Plains Regions, the logarithms of the measured streamflows at each ungaged site were paired with logarithms of the concurrent streamflows at a selected gaged site, and the equation of the best-fit line through the data pairs was determined from the MOVE.1 curve-fitting technique. Because zero flows are common in the Plains Region, 1 cubic foot per second was added to all streamflows before the data were converted to logarithms. Two examples of typical MOVE.1 and ordinary least-squares regression-line fits to measurement data at sites in the study area are shown in figure 2. The equations of the MOVE.1 lines were used to estimate long-term mean monthly streamflows at the ungaged sites from the long-term mean monthly streamflows at the gaged sites. The use of an equation to calculate mean monthly streamflow is equivalent to entering the mean monthly streamflow at the gaged line (x-axis) on the MOVE.1 line and reading the estimated mean monthly streamflow at the ungaged site off the y-axis as shown in figure 2. In the Plains Region, the long-term mean monthly streamflow at the gaged site plus 1 is entered on the MOVE.1 line, and 1 must be subtracted from the value read from the y-axis.

In the Mountain Region, the estimated reliability of the concurrent-measurement method was considered to be the same as previously determined in the upper Missouri River basin study (Parrett and others, 1989). To estimate the reliability of the concurrent-measurement method in the Plains Region, 20 of the gaged sites used in the basin-characteristics and channel-width regression analyses were considered to be ungaged sites for which the concurrrent-measurement method was used to estimate mean monthly streamflow. No more than 20 gaged sites could be used because of the lack of suitable gaged sites with concurrent record that could be used for comparison. Thus, a suitable gaged site was selected for comparison with each of the 20 gaged sites (herein called pseudo-ungaged sites). Twelve concurrent daily mean streamflows, occurring in October and March through September during a randomly selected water year of concurrent record, were correlated using the MOVE.1 curve-fitting technique. The pseudo-ungaged sites, their respective correlating gaged sites, and the year of record selected for the test are identified in table 8. The estimated mean monthly streamflows at each pseudo-ungaged site were then subtracted from the actual mean monthly streamflows determined from the extended streamflow record, and the standard deviations of the differences were calculated. The calculated standard deviations are equivalent to the standard errors of estimate determined by regression and thus are considered to be a comparable measure of reliability for the concurrent-measurement method.

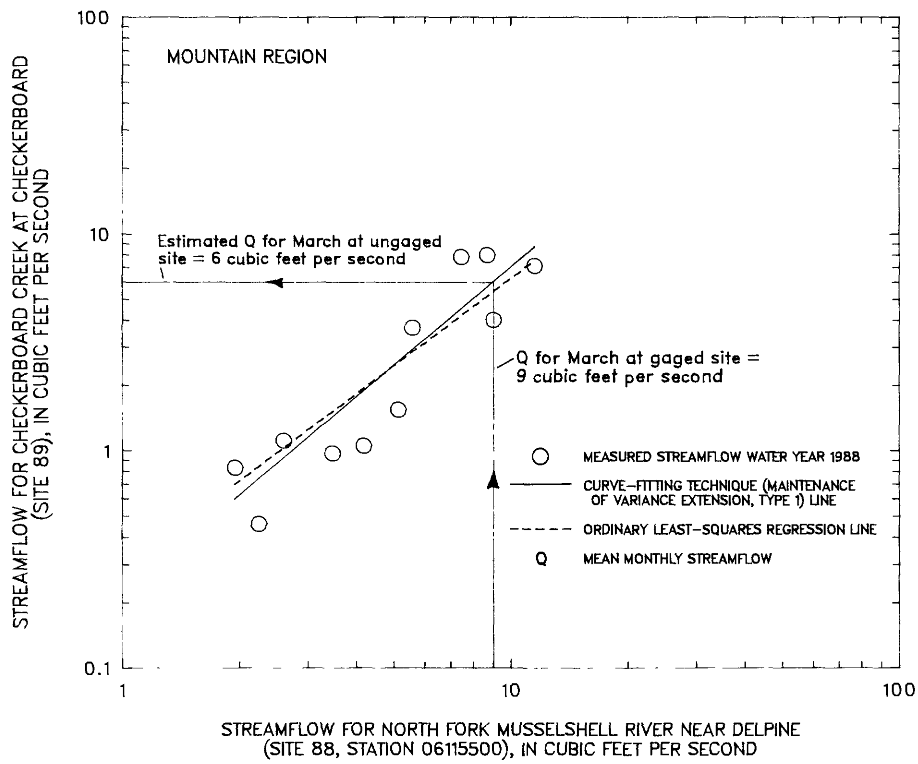
Standard errors for the concurrent-measurement method for the Mountain and Plains Regions are given in tables 9 and 10, respectively. Also shown for comparison are the standard errors for the basin-characteristics and channel-width estimation methods. For the concurrent-measurement method, standard errors, in log units, ranged from 0.15 (36 percent) to 0.26 (66 percent) in the Mountain Region and 0.39 (109 percent) to 0.68 (321 percent) in the Plains Region.

The concurrent-measurement method was used to estimate mean monthly streamflow at 9 ungaged sites in the Mountain Region and at 31 ungaged sites in the Plains Region. These 40 ungaged estimation sites and their corresponding correlating gaged sites are identified in table 11.

Weighted-Average-Estimate Method

When different methods are available for estimating streamflow characteristics, it seems reasonable to assume that a weighted average of the individual estimates might provide a better answer than any of the individual estimates. The following equation can be used to weight three estimates:

$$Z = a1 \cdot X1 + a2 \cdot X2 + a3 \cdot X3, \quad (5)$$



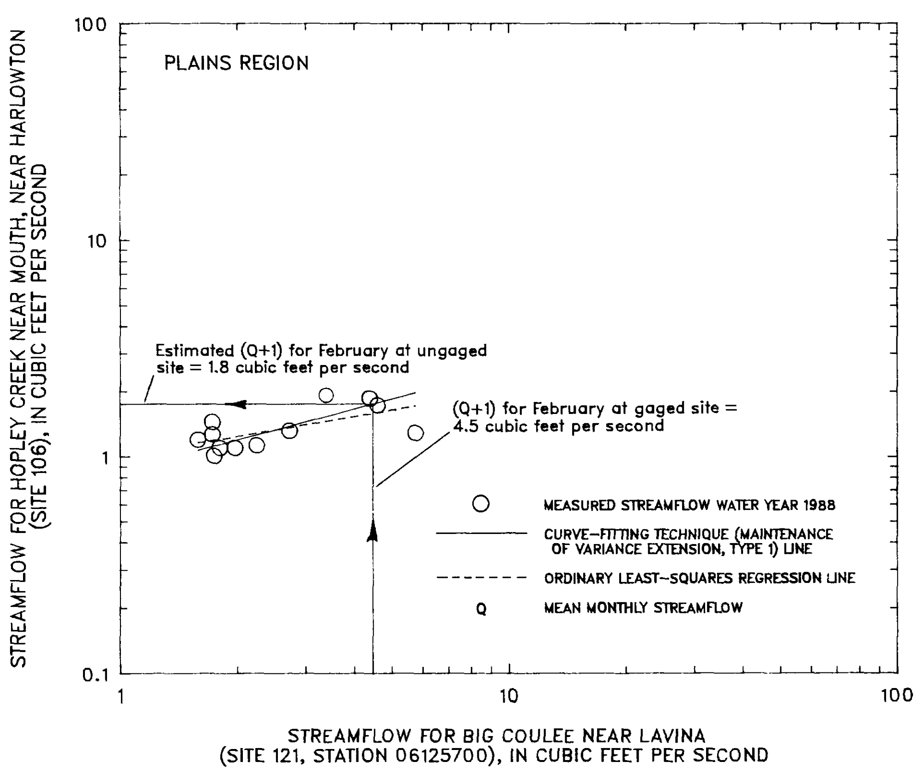


Figure 2.--Lines for the curve-fitting technique and ordinary least-squares regression in the Mountain and Plains Regions.

where

Z is the weighted estimate of mean monthly streamflow;

$a1$, $a2$, and $a3$ are weights; and

$X1$, $X2$, and $X3$ are estimates of the mean monthly streamflow from the three individual estimation methods.

The resulting weighted estimate Z will be unbiased and have minimum variance if the weights are computed from the following equations (E.J. Gilroy, U.S. Geological Survey, written commun., 1987):

$$a1 = [C\ (SE_3{}^2 - S_{1,3}) - B\ (SE_3{}^2 - S_{2,3})]/(A\ C - B^2), \qquad (6)$$

$$a2 = [A\ (SE_3{}^2 - S_{2,3}) - B\ (SE_3{}^2 - S_{1,3})]/(A\ C - B^2), \qquad (7)$$

$$a3 = 1 - a1 - a2, \qquad (8)$$

where

$C = SE_2{}^2 + SE_3{}^2 - 2\ S_{2,3}$;

SE_1, SE_2, SE_3 are the standard errors of the three different estimating methods;

$S_{i,j} = r_{i,j}\ (SE_i \cdot SE_j)$ and is the covariance of methods i and j;

$r_{i,j}$ is the cross-correlation coefficient between the residuals from estimating methods i and j;

$A = SE_1{}^2 + SE_3{}^2 - 2\ S_{1,3}$; and

$B = SE_3{}^2 + S_{1,2} - S_{1,3} - S_{2,3}$.

The estimated standard error of the weighted estimate, SE_Z, is determined from the following equation:

$$SE_Z = [(a1 \cdot SE_1)^2 + (a2 \cdot SE_2)^2 + (1 - a1 - a2)^2\ SE_3{}^2 + 2\ a1 \cdot a2 \cdot S_{1,2} + 2\ a1\ (1 - a1 - a2)\ S_{1,3} + 2\ a2\ (1 - a1 - a2)\ S_{2,3}]^{0.5}, \qquad (9)$$

where all terms are as previously defined.

The preceding equations, and a similar set for the case where only two methods were weighted, were used to calculate weights and standard errors for all combinations of the three methods. In the Mountain Region, the weights and standard errors previously calculated for the upper Missouri River basin were used. In the Plains Region, the standard errors used in the calculations for the basin-characteristics and channel-width methods are based on data from 31 gaged sites, whereas the standard errors for the concurrent-measurement method are based on data from 20 gaged sites. The resultant weights and standard errors for the weighted-average estimates for each combination of individual estimates used for the Mountain and Plains Regions are given in tables 12 and 13, respectively. The standard errors, when using the three individual estimates, ranged from 25 to 55 percent in the Mountain Region and from 71 to 97 percent in the Plains Region. In the Mountain Region, the standard errors of the weighted-average-estimate method generally are smaller than the standard errors determined by the other three methods. In the Plains Region, the standard errors of the weighted-average-estimate method are generally comparable to those of the channel-width estimation method and smaller than those of the basin-characteristics and the concurrent-measurement methods. The weighted-average-estimate method was used to estimate mean monthly streamflow at 7 ungaged sites in the Mountain Region and at 23 ungaged sites in the Plains Region.

RELIABILITY OF ESTIMATES

The most reliable estimates of mean monthly streamflow are those for the 17 gaged sites identified in table 1. If the gaged record is assumed to be correct, the only errors in the estimates are those resulting from the streamflow-record-extension procedure. Results from a previous study in the upper Missouri River basin (Parrett and others, 1989) indicate that the standard errors of the record-extension procedure for determining mean monthly streamflow range from 4 to 9 percent when only 5 years of actual record are available, and from 1 to 3 percent when 35 years of actual record are available.

For estimates of mean monthly streamflow made at ungaged sites in either the Mountain or the Plains Region, weighted-average estimates based on three methods are generally considered to be the most reliable. If only one estimation method was used, the most reliable estimates generally are determined by the concurrent-measurement method in the Mountain Region, and the channel-width method in the Plains Region.

In general, mean monthly estimates made at ungaged sites in the Mountain Region are substantially more reliable than estimates made at ungaged sites in the Plains Region. The large difference in reliability is attributed to the larger natural variability of streamflow and greater effect of irrigation on streamflow in the Plains Region.

SUMMARY

Estimates of mean monthly and mean annual streamflow were made at 56 selected sites in the Musselshell River basin in central Montana and at 1 site, used for streamflow correlation purposes, outside the basin. Of these sites, 17 have gaged record, and 40 are ungaged. The study area was divided into a Mountain Region and a Plains Region, and the methods used to estimate streamflow at the ungaged sites were applied separately in the two regions. In the Mountain Region, methods previously developed for a similar study in the mountainous area of the upper Missouri River basin were used.

Each method developed for estimating mean monthly streamflow was based on a common base period of record (water years 1937-86). The common base period ensured that estimates at ungaged sites would be unbiased and representative of a consistent hydrologic period. The base period was developed using a mixed-station monthly streamflow-extension procedure. Most of the same gaging stations previously used for the upper Missouri River basin study were used as potential base stations for the record-extension procedure for the Plains Region in this study.

Four methods were developed for estimating mean monthly streamflow at ungaged sites. The basin-characteristics method was used to estimate mean monthly streamflow at 7 ungaged sites in the Mountain Region and 23 ungaged sites in the Plains Region. The equations developed for the Mountain Region used drainage area and mean annual precipitation as explanatory variables, whereas only drainage area was used in equations developed for the Plains Region. For the Plains Region, meaningful regression equations could be developed only for February through July. The standard errors, in log units, ranged from 0.15 (35 percent) to 0.28 (71 percent) in the Mountain Region and from 0.36 (98 percent) to 0.48 (157 percent) in the Plains Region.

The channel-width method was used to estimate mean monthly streamflow at 7 ungaged sites in the Mountain Region and at 19 ungaged sites in the Plains Region. The equations used active-channel width as the explanatory variable. Standard errors, in log units, ranged from 0.16 (38 percent) to 0.31 (81 percent) in the Mountain Region and from 0.28 (71 percent) to 0.36 (98 percent) in the Plains Region.

The concurrent-measurement method was used to estimate mean monthly streamflow at 9 ungaged sites in the Mountain Region and at 31 ungaged sites in the Plains Region. All correlations were based on 12 streamflow measurements except for one, which was based on 7 streamflow measurements. Standard errors, in log units, ranged from 0.15 (36 percent) to 0.26 (66 percent) in the Mountain Region and from 0.39 (109 percent) to 0.68 (321 percent) in the Plains Region.

The weighted-average estimate method was used to estimate mean monthly streamflow at 7 ungaged sites in the Mountain Region and at 23 ungaged sites in the Plains Region. The weighted-average estimates were developed by weighting estimates from two or more of the individual estimation methods in accordance with the variance and degree of independence of the individual estimates. The standard errors, when using the three individual estimates, ranged from 25 to 55 percent in the Mountain Region and from 71 percent to 97 percent in the Plains Region. Standard errors for weighted-average estimates are substantially smaller in the Mountain Region than in the Plains Region. In the Mountain Region, the standard errors of the weighted-average estimate method generally are smaller than the standard errors of the other three methods. In the Plains Region, the standard errors of the weighted-average-estimate method are generally comparable to those of the channel-width method.

The most reliable estimates of mean monthly streamflow are for the 17 gaged sites. For the ungaged sites, estimates of mean monthly streamflow using the weighted-average-estimate method are considered to be more reliable than those determined by the other three methods. In general, estimates made at ungaged sites in the Mountain Region are substantially more reliable than estimates made at ungaged sites in the Plains Region. The large difference in reliability is attributed to the larger natural variability of streamflow and greater effect of irrigation on streamflow in the Plains Region. Also, of the first three estimation methods, the concurrent-measurement method was the most reliable in the Mountain Region, whereas the channel-width method was most reliable in the Plains Region.

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Table 1.--*Sites and methods used for estimation*

[--, -, not applicable]

Site No.	Stream name	Streamflow-gaging station No.	Method for estimating mean monthly streamflow at ungaged sites: Basin characteristics	Channel width	Concurrent measurement	Weighted average estimate
50	Sheep Creek near White Sulphur Springs[1]	06077000	-	-	-	-
88	North Fork Musselshell River near Delpine[1]	06115500	-	-	-	-
89	Checkerboard Creek at Checkerboard[1]	--	X	X	X	X
90	Sourdough Creek at mouth, near Checkerboard[1]	--	X	X	X	X
91	Trail Creek at mouth, near Checkerboard[1]	--	-	-	X	-
92	Flagstaff Creek at mouth, near Checkerboard[1]	--	X	X	X	X
93	Spring Creek at mouth, near Checkerboard[1]	--	-	-	X	-
94	Whetstone Creek at mouth, near Checkerboard[1]	--	X	X	X	X
95	Cooper Creek at mouth, near Checkerboard[1]	--	X	X	X	X
96	Mud Creek at mouth, near Martinsdale	--	X	X	X	X
97	Alabaugh Creek at mouth, near Lennep[1]	--	X	X	X	X
98	Cottonwood Creek at mouth, near Martinsdale[1]	--	X	X	X	X
99	South Fork Musselshell River above Martinsdale[1]	06118500	-	-	-	-
100	Daisy Dean Creek at mouth, near Twodot	--	X	X	X	X
101	Willis Coulee at mouth, near Twodot	--	X	X	X	X
102	Miller Creek near mouth, near Twodot	--	X	X	X	X
103	Haymaker Creek at mouth, at Twodot	--	X	X	X	X
104	Big Elk Creek at Twodot	06120000	-	-	-	-
105	Mexican John Creek at mouth, near Harlowton	--	X	X	X	X
106	Hopley Creek near mouth, near Harlowton	--	X	X	X	X
107	Musselshell River at Harlowton	06120500	-	-	-	-
108	Antelope Creek above Alkali Creek, near Harlowton	--	X	X	X	X
109	American Fork near Harlowton	06121000	-	-	-	-
110	Lebo Creek near Harlowton	06121500	-	-	-	-
111	American Fork below Lebo Creek, near Harlowton	06122000	-	-	-	-
112	Timber Creek at mouth, near Harlowton	--	X	X	X	X
113	Mud Creek near mouth, near Shawmut	--	X	X	X	X
114	Fish Creek near mouth, near Ryegate	--	X	X	X	X
115	Musselshell River near Ryegate	06123500	-	-	-	-
117	Careless Creek at Wallum	06125500	-	-	-	-
118	Careless Creek at mouth, near Ryegate	--	-	-	X	-
119	Ninemile Coulee at mouth, near Cushman	--	-	-	X	-
120	Fivemile Creek at mouth, near Lavina	--	-	-	X	-
121	Big Coulee near Lavina	06125700	-	-	-	-
122	Painted Robe Creek at mouth, near Lavina	--	X	-	X	X
123	Dean Creek near mouth, near Lavina	--	-	-	X	-
124	Stanley Creek at mouth, near Roundup	--	-	-	X	-
125	Goulding Creek at mouth, near Roundup	--	-	-	X	-
126	Currant Creek near Roundup	--	X	X	X	X
127	Horsethief Creek at mouth, near Roundup	--	X	X	X	X
128	Halfbreed Creek near Klein	06126470	-	-	-	-
129	Musselshell River near Roundup	06126500	-	-	-	-
130	Willow Creek at mouth, near Roundup	--	X	X	X	X
131	Parrot Creek at mouth, near Roundup	--	X	-	X	X
132	Fattig Creek near mouth, near Delphia	--	X	-	X	X
133	Musselshell River at Musselshell	06127500	-	-	-	-
134	Hawk Creek at Musselshell	--	X	X	X	X
135	McLean Coulee at mouth, near Musselshell	--	X	X	X	X
136	Carpenter Creek at mouth, near Musselshell	--	-	-	X	-
137	Lost Horse Creek near mouth, near Melstone	--	-	-	X	-
138	Home Creek near mouth, near Melstone	--	X	-	X	X
139	Rattlesnake Creek at mouth, near Mosby	--	X	X	X	X
140	North Willow Creek at mouth, near Mosby	--	X	X	X	X
142	Box Elder Creek near Winnett	06129000	-	-	-	-
143	McDonald Creek at Winnett	06129500	-	-	-	-
144	Flatwillow Creek at mouth, near Mosby	--	X	X	X	X
145	Musselshell River at Mosby	06130500	-	-	-	-
Totals		17	30	26	40	30

[1]Mountain Region stream.

Table 2.--*Estimated mean monthly and mean annual streamflow*

[Mean monthly streamflow for specified month and mean annual streamflow, in cubic feet per second. Weighted-average-estimate method used unless otherwise indicated]

Site No.	Stream name	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
50	Sheep Creek near White Sulphur Springs	16	13	11	9	9	9	21
88	North Fork Musselshell River near Delpine	7	7	6	6	6	9	19
89	Checkerboard Creek at Checkerboard	4	4	3	3	3	6	14
90	Sourdough Creek at mouth, near Checkerboard	.4	.4	.3	.3	.3	.5	1
91	Trail Creek at mouth, near Checkerboard[1]	.6	.5	.7	.5	.5	.6	.7
92	Flagstaff Creek at mouth, near Checkerboard	2	2	2	2	2	2	5
93	Spring Creek at mouth, near Checkerboard[1]	3	2	2	1	2	3	12
94	Whetstone Creek at mouth, near Checkerboard	.5	.5	.4	.3	.3	.4	2
95	Cooper Creek at mouth, near Checkerboard	.3	.3	.2	.2	.2	.2	1
96	Mud Creek at mouth, near Martinsdale	.6	.5	.4	.5	1	2	.8
97	Alabaugh Creek at mouth, near Lennep	4	3	3	2	2	2	11
98	Cottonwood Creek at mouth, near Martinsdale	15	14	10	8	8	21	73
99	South Fork Musselshell River above Martinsdale	31	28	22	18	21	37	110
100	Daisy Dean Creek at mouth, near Twodot	.4	.4	.4	.4	.2	.9	.5
101	Willis Coulee at mouth, near Twodot	.4	.4	.4	.4	.4	.8	.5
102	Miller Creek near mouth, near Twodot	1	1	1	1	2	4	4
103	Haymaker Creek at mouth, at Twodot	.5	.4	.4	.4	.5	1	.6
104	Big Elk Creek at Twodot	8	9	7	5	6	7	15
105	Mexican John Creek at mouth, near Harlowton	.9	.9	.8	.8	2	3	2
106	Hopley Creek near mouth, near Harlowton	.8	.8	.8	.7	1	3	2
107	Musselshell River at Harlowton	76	81	72	61	70	110	170
108	Antelope Creek above Alkali Creek, near Harlowton	.4	.3	.3	.3	.2	1	.4
109	American Fork near Harlowton	3	2	3	2	2	2	4
110	Lebo Creek near Harlowton	16	18	15	12	12	24	15
111	American Fork below Lebo Creek, near Harlowton	16	15	16	15	19	24	23
112	Timber Creek at mouth, near Harlowton	.6	.6	.5	.6	.9	2	1
113	Mud Creek near mouth, near Shawmut	.8	.7	.6	.7	1	2	1
114	Fish Creek near mouth, near Ryegate	2	3	3	2	4	16	25
115	Musselshell River near Ryegate	57	63	80	59	76	150	150
117	Careless Creek at Wallum	3	2	3	2	5	26	7
118	Careless Creek at mouth, near Ryegate[1,2]	3	2	3	2	5	26	7
119	Ninemile Coulee at mouth, near Cushman[1]	.2	.2	.1	.1	.1	.2	.3
120	Fivemile Creek at mouth, near Lavina[1]	0	0	0	0	0	0	0
121	Big Coulee near Lavina	2	3	3	2	3	10	7
122	Painted Robe Creek at mouth, near Lavina	.8	.9	.7	.6	6	11	5
123	Dean Creek near mouth, near Lavina[1]	0	0	0	0	0	.1	.1
124	Stanley Creek at mouth, near Roundup[1]	0	0	0	0	0	0	0
125	Goulding Creek at mouth, near Roundup[1]	.1	.1	.1	.1	.1	.2	.2
126	Currant Creek near Roundup	2	3	2	2	6	12	13
127	Horsethief Creek at mouth, near Roundup	.5	.5	.4	.5	.6	3	.7
128	Halfbreed Creek near Klein	1	1	1	.9	1	1	1
129	Musselshell River near Roundup	73	74	71	69	110	220	200
130	Willow Creek at mouth, near Roundup	.7	.9	.8	.8	.7	3	2
131	Parrot Creek at mouth, near Roundup	.3	.3	.3	.2	3	5	3
132	Fattig Creek near mouth, near Delphia	.4	.5	.5	.2	4	8	4
133	Musselshell River at Musselshell	76	74	73	72	120	260	210
134	Hawk Creek at Musselshell	.5	.5	.5	.5	.5	2	1
135	McLean Coulee at mouth, near Musselshell	.7	.6	.5	.6	1	2	1
136	Carpenter Creek at mouth, near Musselshell[1]	.2	.3	.2	.2	.3	.4	.4
137	Lost Horse Creek near mouth, near Melstone[1]	0	0	0	0	0	.1	.1
138	Home Creek near mouth, near Melstone	0	0	0	0	0	0	.2
139	Rattlesnake Creek at mouth, near Mosby	3	3	2	2	13	31	13
140	North Willow Creek at mouth, near Mosby	2	2	2	2	9	21	9
142	Box Elder Creek near Winnett	0	.2	.2	.5	14	56	12
143	McDonald Creek at Winnett	3	4	3	4	6	8	10
144	Flatwillow Creek at mouth, near Mosby	4	6	4	4	21	63	30
145	Musselshell River at Mosby	82	87	82	86	220	550	350

[1]Estimates made using concurrent-measurement method only.

[2]Estimates for Careless Creek at mouth, near Ryegate are for natural flow only and do not include reservoir releases.

Table 2.--*Estimated mean monthly and mean annual streamflow*--Continued

Site No.	Stream name	May	June	July	Aug.	Sept.	Mean annual
50	Sheep Creek near White Sulphur Springs	96	110	43	23	18	32
88	North Fork Musselshell River near Delpine	26	29	15	9	8	12
89	Checkerboard Creek at Checkerboard	27	32	12	5	4	6
90	Sourdough Creek at mouth, near Checkerboard	3	4	.9	.5	.4	3
91	Trail Creek at mouth, near Checkerboard[1]	1	3	.8	.4	.4	.8
92	Flagstaff Creek at mouth, near Checkerboard	13	18	5	2	2	4
93	Spring Creek at mouth, near Checkerboard[1]	41	45	8	2	2	10
94	Whetstone Creek at mouth, near Checkerboard	5	6	1	.5	.4	1
95	Cooper Creek at mouth, near Checkerboard	3	4	.8	.3	.3	.9
96	Mud Creek at mouth, near Martinsdale	1	2	1	.6	.9	.9
97	Alabaugh Creek at mouth, near Lennep	47	54	15	6	5	13
98	Cottonwood Creek at mouth, near Martinsdale	290	350	58	13	10	73
99	South Fork Musselshell River above Martinsdale	320	340	78	27	25	88
100	Daisy Dean Creek at mouth, near Twodot	.6	.6	.3	.3	.4	.5
101	Willis Coulee at mouth, near Twodot	.7	.8	.4	.4	.5	.5
102	Miller Creek near mouth, near Twodot	6	7	3	1	1	3
103	Haymaker Creek at mouth, at Twodot	.9	.9	.5	.4	.6	.6
104	Big Elk Creek at Twodot	43	62	15	4	6	16
105	Mexican John Creek at mouth, near Harlowton	3	3	2	.9	1	2
106	Hopley Creek near mouth, near Harlowton	2	3	1	.9	.9	1
107	Musselshell River at Harlowton	390	510	170	83	70	160
108	Antelope Creek above Alkali Creek, near Harlowton	.5	.5	.3	.3	.4	.4
109	American Fork near Harlowton	7	56	5	1	.9	7
110	Lebo Creek near Harlowton	26	28	9	13	17	17
111	American Fork below Lebo Creek, near Harlowton	77	120	31	13	12	32
112	Timber Creek at mouth, near Harlowton	1	2	1	.6	.8	1
113	Mud Creek near mouth, near Shawmut	2	2	1	.7	1	1
114	Fish Creek near mouth, near Ryegate	44	97	6	4	2	17
115	Musselshell River near Ryegate	410	650	250	120	86	180
117	Careless Creek at Wallum	9	20	9	3	3	8
118	Careless Creek at mouth, near Ryegate[1,2]	9	20	9	3	3	8
119	Ninemile Coulee at mouth, near Cushman	.5	.6	.3	.1	.1	.2
120	Fivemile Creek at mouth, near Lavina[1]	0	0	0	0	0	0
121	Big Coulee near Lavina	11	20	7	4	4	6
122	Painted Robe Creek at mouth, near Lavina	8	10	5	1	.9	4
123	Dean Creek near mouth, near Lavina[1]	.1	.1	.1	0	0	0
124	Stanley Creek at mouth, near Roundup[1]	0	0	0	0	0	0
125	Goulding Creek at mouth, near Roundup[1]	.3	.3	.3	.1	.2	.2
126	Currant Creek near Roundup	17	17	6	3	3	7
127	Horsethief Creek at mouth, near Roundup	1	1	.7	.5	.6	.8
128	Halfbreed Creek near Klein	1	1	1	.9	1	1
129	Musselshell River near Roundup	440	720	290	170	120	210
130	Willow Creek at mouth, near Roundup	4	3	1	.7	.7	2
131	Parrot Creek at mouth, near Roundup	4	5	3	.4	.4	2
132	Fattig Creek near mouth, near Delphia	6	8	4	.7	.8	3
133	Musselshell River at Musselshell	430	690	270	140	110	210
134	Hawk Creek at Musselshell	1	1	.6	.5	.6	.8
135	McLean Coulee at mouth, near Musselshell	2	2	1	.6	.8	1
136	Carpenter Creek at mouth, near Musselshell[1]	.4	.6	.4	.3	.3	.3
137	Lost Horse Creek near mouth, near Melstone[1]	.1	.2	.1	.1	.1	.1
138	Home Creek near mouth, near Melstone	.4	.3	.2	0	0	.1
139	Rattlesnake Creek at mouth, near Mosby	21	35	14	4	4	12
140	North Willow Creek at mouth, near Mosby	14	21	9	3	3	8
142	Box Elder Creek near Winnett	34	50	37	1	2	17
143	McDonald Creek at Winnett	38	47	30	3	8	13
144	Flatwillow Creek at mouth, near Mosby	61	81	24	6	6	26
145	Musselshell River at Mosby	630	1000	350	120	130	310

Table 3.--*Streamflow-gaging stations used for record-extension analysis of the Plains Region*

Site No.	Stream name	Streamflow-gaging station No.	Period of record (since water year 1906)
1	Red Rock River near Kennedy Ranch, near Lakeview	06011000	1936-67
2	Red Rock River below Lima Reservoir, near Monida	06012500	1911-19;1925-69;1974-82;1985-86
3	Big Sheep Creek below Muddy Creek, near Dell	06013500	1936;1946-53;1961-80
4	Red Rock River at Red Rock	06014500	1974-83
5	Horse Prairie Creek near Grant	06015000	1928;1932;1935-36;1946-53
6	Beaverhead River near Grant	06015400	1963-84
7	Grasshopper Creek near Dillon	06015500	1921-33;1946-58;1960-61
8	Beaverhead River at Barretts	06016000	1908-86
9	Blacktail Deer Creek near Dillon	06017500	1946-66
10	Beaverhead River near Dillon	06018000	1951-52;1963-84
11	Ruby River above reservoir, near Alder	06019500	1938-86
12	Ruby River near Twin Bridges	06023000	1940-43;1946-65;1979-81
13	Big Hole River near Jackson	06023500	1948-54
14	Trail Creek near Wisdom	06024500	1948-54;1967-72
15	Wise River near Wise River	06024590	1972-85
16	Big Hole River near Melrose	06025500	1924-86
17	Jefferson River near Twin Bridges	06026500	1940-43;1958-72
18	Whitetail Creek near Whitehall	06029000	1950-68
19	Boulder River above Rock Creek, near Basin	06030500	1936;1946-58
20	Boulder River near Boulder	06033000	1929-73;1985-86
21	Jefferson River at Sappington	06034500	1938-70
22	Willow Creek near Harrison	06035000	1938-85
23	Norwegian Creek near Harrison	06035500	1938-43;1946-51
24	Willow Creek near Willow Creek	06036500	1919-33;1946-57
25	Jefferson River near Three Forks	06036650	1978-86
26	Madison River near West Yellowstone	06037500	1913-73;1983-86
27	Madison River below Hebgen Lake, near Grayling	06038500	1939-86
28	Madison River near Cameron	06040000	1952-63;1968-71
29	Jack Creek near Ennis	06040300	1973-85
30	Madison River below Ennis Lake, near McAllister	06041000	1939-86
31	Madison River near Three Forks	06042500	1929-32;1942-50
32	Gallatin River near Gallatin Gateway	06043500	1930-82;1985-86
33	East Gallatin River at Bozeman	06048000	1939-61
34	Bridger Creek near Bozeman	06048500	1946-72
35	Hyalite Creek at Hyalite Ranger Station, near Bozeman	06050000	1934-86
36	Gallatin River near Logan	06052500	1906;1928-86
37	Sixteenmile Creek near Ringling	06053000	1950-55
38	Missouri River near Toston	06054500	1911-17;1941-86
39	Crow Creek near Radersburg	06055500	1919-29;1966-72
40	Prickly Pear Creek near Clancy	06061500	1908-16;1921-33;1946-70;1979-86
41	Tenmile Creek near Rimini	06062500	1915-86
42	Tenmile Creek near Helena	06063000	1908-54
43	Missouri River below Holter Dam, near Wolf Creek	06066500	1946-86
44	Little Prickly Pear Creek near Marysville	06068500	1913-33
45	Little Prickly Pear Creek near Canyon Creek	06071000	1909-25
46	Dearborn River near Clemons	06073000	1921-23;1929-53
47	Dearborn River near Craig	06073500	1946-69
48	Smith River near White Sulphur Springs	06074500	1923-31;1934-36
49	Smith River near Fort Logan	06076690	1978-86
50	Sheep Creek near White Sulphur Springs	06077000	1941-73

Table 3.--*Streamflow-gaging stations used for record-extension analysis of the Plains Region*--Continued

Site No.	Stream name	Streamflow-gaging station No.	Period of record (since water year 1906)
51	Smith River near Eden	06077500	1951-70
52	Missouri River near Ulm	06078200	1957-86
53	North Fork Sun River near Augusta	06078500	1911-12;1946-68
54	Sun River near Augusta	06080000	1906-40
55	Sun River below diversion dam, near Augusta	06080900	1968-81
56	Willow Creek near Augusta	06081500	1906-25
57	Sun River below Willow Creek, near Augusta	06082200	1968-75
58	Smith Creek near Augusta	06082500	1906-13
59	Elk Creek near Augusta	06084500	1906-25
60	Sun River at Simms	06085800	1966-79
61	Muddy Creek near Vaughn	06088300	1968-86
62	Muddy Creek at Vaughn	06088500	1935-68;1971-86
63	Missouri River near Great Falls	06090300	1957-86
64	Belt Creek near Monarch	06090500	1951-83
65	Missouri River at Fort Benton	06090800	1906-86
66	Two Medicine River near Browning	06092000	1907-24;1951-77
67	Badger Creek near Browning	06092500	1951-73
68	Badger Creek below Four Horns Canal, near Browning	06093200	1974-86
69	Badger Creek near Family	06093500	1907-25
70	Birch Creek at Swift Dam, near Valier	06094500	1913-29
71	Birch Creek near Valier	06098100	1977-84
72	Cut Bank Creek at Cut Bank	06099000	1906-20;1923-24;1952-74;1978-79; 1982-86
73	Marias River near Shelby	06099500	1906-08;1911-22;1924-86
74	Teton River near Strabane	06103000	1908-25
75	Spring Creek near Choteau	06104000	1917-20
76	Deep Creek near Choteau	06106000	1911-25
77	Teton River near Dutton	06108000	1954-86
78	Missouri River at Virgelle	06109500	1935-86
79	Middle Fork Judith River near Utica	06109780	1972-80
80	South Fork Judith River near Utica	06109800	1958-79
81	Judith River near Utica	06110000	1920-76
82	Ross Fork near Hobson	06111000	1946-62
83	Big Spring Creek near Lewistown	06111500	1932-57
84	Cottonwood Creek near Moore	06112100	1957-63
85	Judith River near Winifred	06113500	1929-32
86	Wolf Creek near Stanford	06114500	1950-62
87	Missouri River near Landusky	06115200	1934-86
88	North Fork Musselshell River near Delpine	06115500	1940-80
99	South Fork Musselshell River above Martinsdale	06118500	1942-80
104	Big Elk Creek at Twodot	06120000	1953-56
107	Musselshell River at Harlowton	06120500	1907-86
109	American Fork near Harlowton	06121000	1907-14;1924-32
110	Lebo Creek near Harlowton	06121500	1907-14;1924-32
111	American Fork below Lebo Creek, near Harlowton	06122000	1946-67
115	Musselshell River near Ryegate	06123500	1946-80
116	Roberts Creek at Hedgesville	06125000	1920-23
117	Careless Creek at Wallum	06125500	1934-42
121	Big Coulee near Lavina	06125700	1957-72
128	Halfbreed Creek near Klein	06126470	1978-86
129	Musselshell River near Roundup	06126500	1946-86
133	Musselshell River at Musselshell	06127500	1928-32;1945-80;1983-86
141	Flatwillow Creek near Flatwillow	06127900	1911-32;1934-56
142	Box Elder Creek near Winnett	06129000	1930-38;1959-72
143	McDonald Creek at Winnett	06129500	1930-45;1953-56
145	Musselshell River at Mosby	06130500	1929-32;1934-86

Table 3.--*Streamflow-gaging stations used for record-extension analysis of the Plains Region*--Continued

Site No.	Stream name	Streamflow-gaging station No.	Period of record (since water year 1906)
146	Big Dry Creek near Van Norman	06131000	1940-47;1949-86
147	Timber Creek near Van Norman	06131120	1982-85
148	Nelson Creek near Van Norman	06131200	1976-85
149	Missouri River below Fort Peck Dam	06132000	1934-86
150	Boxelder Creek near Rocky Boy	06137570	1976-86
151	Peoples Creek near Hays	06154400	1967-86
152	Little Peoples Creek near Hays	06154410	1972-86
153	Willow Coulee near Dodson	06154490	1983-86
154	Peoples Creek near Dodson	06154500	1918-22;1951-74;1982-86
155	Little Warm Creek at reservation boundary, near Zortman	06164615	1983-86
156	Rock Creek below McEachern Creek, near international boundary	06170050	1983-86
157	Milk River at Nashua	06174500	1940-86
158	Prairie Elk Creek near Oswego	06175540	1976-85
159	Wolf Creek near Wolf Point	06176500	1908-14;1950-53;1982-86
160	Missouri River near Wolf Point	06177000	1929-86
161	Redwater River at Circle	06177500	1929-72;1974-86
162	Redwater River near Richey	06177650	1982-85
163	Redwater River near Vida	06177825	1976-85
164	Poplar River near Poplar	06181000	1908-25;1947-69;1975-79;1982-86
165	Big Muddy Creek near Antelope	06183450	1979-86
166	Big Muddy Creek near Culbertson	06185110	1982-86
167	Missouri River near Culbertson	06185500	1941-52;1958-86
168	Tower Creek at Tower Falls, Yellowstone National Park	06187500	1922-43
169	Big Creek near Emigrant	06191800	1973-80;1983-85
170	Shields River near Wilsall	06193000	1935-57
171	Shields River near Clyde Park	06193500	1921-23;1929-67
172	Brackett Creek near Clyde Park	06194000	1921-23;1934-57
173	Sweet Grass Creek above Melville	06200500	1913-25;1937-69
174	Pryor Creek near Huntley	06216900	1979-86
175	Owl Creek near Lodge Grass	06291000	1939-45;1980-86
176	Rosebud Creek at reservation boundary, near Kirby	06295113	1980-86
177	Rosebud Creek near Colstrip	06295250	1975-86
178	Rosebud Creek at mouth, near Rosebud	06296003	1975-86
179	Squirrel Creek near Decker	06306100	1975-85
180	Otter Creek at Ashland	06307740	1973-85
181	Pumpkin Creek near Miles City	06308400	1973-85
182	Yellowstone River at Miles City	06309000	1922-23;1928-86
183	Powder River at Moorhead	06324500	1929-72;1975-86
184	Mizpah Creek near Mizpah	06326300	1975-86
185	O'Fallon Creek near Ismay	06326600	1977-86
186	Clear Creek near Lindsay	06326952	1982-85
187	Lower Sevenmile Creek near Bloomfield	06328200	1982-85
188	Little Blackfoot River near Garrison	12324590	1972-86
189	Boulder Creek at Maxville	12330000	1939-86
190	Middle Fork Rock Creek near Philipsburg	12332000	1938-86
191	Blackfoot River near Helmville	12335000	1941-54
192	Nevada Creek above reservoir, near Helmville	12335500	1940-86
193	East Fork Bitterroot River near Conner	12343400	1956-73
194	Skalkaho Creek near Hamilton	12346500	1949-53;1957-80
195	Skyland Creek near Essex	12356000	1946-52
196	Twin Creek near Hungry Horse	12360000	1948-56;1965-67
197	Lower Twin Creek near Hungry Horse	12360500	1948-56

Table 4.--*Results of basin-characteristics regression analysis for the Mountain Region*

[R^2, coefficient of determination; Q, mean monthly streamflow for specified month, in cubic feet per second; A, drainage area, in square miles; P, mean annual precipitation, in inches]

Month	Streamflow characteristic	Equation	R^2	Standard error (logarithm, base 10)	Standard error (percent)
October	Q	$= 0.00234\ A^{0.935}\ P^{1.51}$	0.80	0.21	50
November	Q	$= 0.00145\ A^{0.972}\ P^{1.56}$	.79	.22	55
December	Q	$= 0.00069\ A^{0.974}\ P^{1.73}$	.77	.24	60
January	Q	$= 0.00079\ A^{0.980}\ P^{1.63}$	.73	.26	67
February	Q	$= 0.00123\ A^{0.990}\ P^{1.50}$	.72	.27	70
March	Q	$= 0.00316\ A^{0.992}\ P^{1.28}$	.71	.28	71
April	Q	$= 0.00631\ A^{0.905}\ P^{1.49}$	.71	.26	64
May	Q	$= 0.00457\ A^{0.854}\ P^{2.02}$	.84	.18	43
June	Q	$= 0.00324\ A^{0.906}\ P^{2.08}$	.89	.15	35
July	Q	$= 0.00155\ A^{0.936}\ P^{1.94}$	.85	.18	43
August	Q	$= 0.00282\ A^{0.876}\ P^{1.60}$	.70	.26	65
September	Q	$= 0.00316\ A^{0.912}\ P^{1.45}$	.73	.25	62

Table 5.--*Results of basin-characteristics regression analysis for the Plains Region*

[R^2, coefficient of determination; Q, mean monthly streamflow for specified month, in cubic feet per second; A, drainage area, in square miles. --, no data]

Month	Streamflow characteristic		Equation	R^2	Standard error (logarithm, base 10)	Standard error (percent)
October			No meaningful equation derived.	--	--	--
November			No meaningful equation derived.	--	--	--
December			No meaningful equation derived.	--	--	--
January			No meaningful equation derived.	--	--	--
February	(Q+1)	=	$0.6622\ A^{0.46}$	0.45	0.36	98
March	(Q+1)	=	$0.5420\ A^{0.64}$	.50	.44	134
April	(Q+1)	=	$0.9954\ A^{0.47}$	.35	.44	135
May	(Q+1)	=	$1.2503\ A^{0.46}$	.33	.46	142
June	(Q+1)	=	$1.0839\ A^{0.53}$	.37	.48	157
July	(Q+1)	=	$0.9616\ A^{0.40}$	.33	.39	112
August			No meaningful equation derived.	--	--	--
September			No meaningful equation derived.	--	--	--

Table 6.--*Results of channel-width regression analysis for the Mountain Region*

[R^2, coefficient of determination; Q, mean monthly streamflow for specified month, in cubic feet per second; W_{AC}, active-channel width, in feet]

Month	Streamflow characteristic		Equation	R^2	Standard error (logarithm, base 10)	Standard error (percent)
October	Q	=	$0.0525\ W_{AC}^{1.78}$	0.75	0.23	57
November	Q	=	$0.0380\ W_{AC}^{1.83}$	.72	.25	64
December	Q	=	$0.0309\ W_{AC}^{1.84}$	.69	.28	71
January	Q	=	$0.0251\ W_{AC}^{1.85}$	.67	.29	75
February	Q	=	$0.0245\ W_{AC}^{1.87}$	.67	.29	76
March	Q	=	$0.0355\ W_{AC}^{1.82}$	.64	.31	81
April	Q	=	$0.1102\ W_{AC}^{1.79}$	.71	.25	63
May	Q	=	$0.2985\ W_{AC}^{1.84}$	.87	.16	38
June	Q	=	$0.2979\ W_{AC}^{1.88}$	.86	.17	40
July	Q	=	$0.1127\ W_{AC}^{1.85}$	.79	.21	52
August	Q	=	$0.0933\ W_{AC}^{1.67}$	.64	.28	72
September	Q	=	$0.0631\ W_{AC}^{1.72}$	.67	.27	68

Table 7.--*Results of channel-width regression analysis for the Plains Region*

[R^2, coefficient of determination; Q, mean monthly streamflow for specified month, in cubic feet per second; W_{AC}, active-channel width, in feet]

Month	Streamflow characteristic		Equation	R^2	Standard error (logarithm, base 10)	Standard error (percent)
October	(Q+1)	=	$0.9397\ W_{AC}^{0.47}$	0.23	0.33	89
November	(Q+1)	=	$0.9141\ W_{AC}^{0.50}$	.24	.34	92
December	(Q+1)	=	$1.0233\ W_{AC}^{0.40}$	.17	.34	93
January	(Q+1)	=	$0.9661\ W_{AC}^{0.43}$	.21	.31	82
February	(Q+1)	=	$0.4819\ W_{AC}^{1.02}$	.66	.28	72
March	(Q+1)	=	$0.4150\ W_{AC}^{1.35}$	.67	.36	98
April	(Q+1)	=	$0.5649\ W_{AC}^{1.13}$	.62	.34	92
May	(Q+1)	=	$0.5875\ W_{AC}^{1.20}$	.67	.32	86
June	(Q+1)	=	$0.4677\ W_{AC}^{1.36}$	.73	.32	84
July	(Q+1)	=	$0.5035\ W_{AC}^{1.03}$	.67	.28	71
August	(Q+1)	=	$0.7998\ W_{AC}^{0.57}$	.37	.29	74
September	(Q+1)	=	$0.8551\ W_{AC}^{0.55}$	.27	.35	94

Table 8.--*Streamflow-gaging stations used in test of concurrent-measurement method in the Plains Region*

Stream used as pseudo-ungaged site			Stream used as correlating gaged site			
Site No.	Stream name	Station No.	Site No.	Stream name	Station No.	Water year of record
104	Big Elk Creek at Twodot	06120000	111	American Fork below Lebo Creek, near Harlowton	06122000	1955
110	Lebo Creek near Harlowton	06121500	109	American Fork near Harlowton	06121000	1931
111	American Fork below Lebo Creek, near Harlowton	06122000	88	North Fork Musselshell River near Delpine	06115500	1947
116	Roberts Creek at Hedgesville	06125000	107	Musselshell River at Harlowton	06120500	1921
117	Careless Creek at Wallum	06125500	142	Box Elder Creek near Winnett	06129000	1937
121	Big Coulee near Lavina	06125700	111	American Fork below Lebo Creek, near Harlowton	06122000	1959
128	Halfbreed Creek near Klein	06126470	152	Little Peoples Creek near Hays	06154410	1985
142	Box Elder Creek near Winnett	06129000	143	McDonald Creek at Winnett	06129500	1938
143	McDonald Creek at Winnett	06129500	146	Big Dry Creek near Van Norman	06131000	1940
153	Willow Coulee near Dodson	06154490	152	Little Peoples Creek near Hays	06154410	1983
154	Peoples Creek near Dodson	06154500	152	Little Peoples Creek near Hays	06154410	1985
155	Little Warm Creek at reservation boundary, near Zortman	06164615	151	Peoples Creek near Hays	06154400	1985
158	Prairie Elk Creek near Oswego	06175540	161	Redwater River at Circle	06177500	1979
159	Wolf Creek near Wolf Point	06176500	161	Redwater River at Circle	06177500	1952
165	Big Muddy Creek near Antelope	06183450	164	Poplar River near Poplar	06181000	1982
179	Squirrel Creek near Decker	06306100	176	Rosebud Creek at reservation boundary, near Kirby	06295113	1981
180	Otter Creek at Ashland	06307740	181	Pumpkin Creek near Miles City	06308400	1977
185	O'Fallon Creek near Ismay	06326600	184	Mizpah Creek near Mizpah	06326300	1979
186	Clear Creek near Lindsay	06326952	184	Mizpah Creek near Mizpah	06326300	1982
187	Lower Sevenmile Creek near Bloomfield	06328200	184	Mizpah Creek near Mizpah	06326300	1984

Table 9.--*Standard errors for three methods of estimation in the Mountain Region*

Month	Standard error, in specified units, for specified method					
	Concurrent-measurement		Basin-characteristics		Channel-width	
	Log units	Percent	Log units	Percent	Log units	Percent
October	0.18	43	0.21	50	0.23	57
November	.17	41	.22	55	.25	64
December	.18	43	.24	60	.28	71
January	.21	51	.26	67	.29	75
February	.15	36	.27	70	.29	76
March	.16	38	.28	71	.31	81
April	.26	66	.26	64	.25	63
May	.18	43	.18	43	.16	38
June	.20	49	.15	35	.17	40
July	.17	41	.18	43	.21	52
August	.24	60	.26	65	.28	72
September	.23	57	.25	62	.27	68

Table 10.--*Standard errors for three methods of estimation in the Plains Region*

[--, no data]

Month	Standard error, in specified units, for specified method					
	Concurrent-measurement		Basin-characteristics		Channel-width	
	Log units	Percent	Log units	Percent	Log units	Percent
October	0.61	249	--	--	0.33	89
November	.52	181	--	--	.34	92
December	.48	154	--	--	.34	93
January	.50	165	--	--	.31	82
February	.61	247	0.36	98	.28	72
March	.68	321	.44	134	.36	98
April	.39	109	.44	135	.34	92
May	.47	148	.46	142	.32	86
June	.55	196	.48	157	.32	84
July	.49	161	.39	112	.28	71
August	.39	113	--	--	.29	74
September	.53	185	--	--	.35	94

Table 11.--*Ungaged estimation sites with corresponding correlating gaged sites for the Mountain and Plains Regions*

Ungaged site		Correlating gaged site		
Site No.	Name	Site No.	Name	Station No.
89	Checkerboard Creek at Checkerboard	88	North Fork Musselshell River near Delpine	06115500
90	Sourdough Creek at mouth, near Checkerboard	117	Careless Creek at Wallum	06125500
91	Trail Creek at mouth, near Checkerboard	109	American Fork near Harlowton	06121000
92	Flagstaff Creek at mouth, near Checkerboard	109	American Fork near Harlowton	06121000
93	Spring Creek at mouth, near Checkerboard	99	South Fork Musselshell River above Martinsdale	06118500
94	Whetstone Creek at mouth, near Checkerboard	88	North Fork Musselshell River near Delpine	06115500
95	Cooper Creek at mouth, near Checkerboard	88	North Fork Musselshell River near Delpine	06115500
96	Mud Creek at mouth, near Martinsdale	117	Careless Creek at Wallum	06125500
97	Alabaugh Creek at mouth, near Lennep	50	Sheep Creek near White Sulphur Springs	06077000
98	Cottonwood Creek at mouth, near Martinsdale	99	South Fork Musselshell River above Martinsdale	06118500
100	Daisy Dean Creek at mouth, near Twodot	117	Careless Creek at Wallum	06125500
101	Willis Coulee at mouth, near Twodot	143	McDonald Creek at Winnett	06129500
102	Miller Creek near mouth, near Twodot	121	Big Coulee near Lavina	06125700
103	Haymaker Creek at mouth, at Twodot	121	Big Coulee near Lavina	06125700
105	Mexican John Creek at mouth, near Harlowton	88	North Fork Musselshell River near Delpine	06115500
106	Hopley Creek near mouth, near Harlowton	121	Big Coulee near Lavina	06125700
108	Antelope Creek above Alkali Creek, near Harlowton	88	North Fork Musselshell River near Delpine	06115500
112	Timber Creek at mouth, near Harlowton	143	McDonald Creek at Winnett	06129500
113	Mud Creek near mouth, near Shawmut	121	Big Coulee near Lavina	06125700
114	Fish Creek near mouth, near Ryegate	121	Big Coulee near Lavina	06125700
118	Careless Creek at mouth, near Ryegate	117	Careless Creek at Wallum	06125500
119	Ninemile Coulee at mouth, near Cushman	104	Big Elk Creek at Twodot	06120000
120	Fivemile Creek at mouth, near Lavina	121	Big Coulee near Lavina	06125700
122	Painted Robe Creek at mouth, near Lavina	88	North Fork Musselshell River near Delpine	06115500
123	Dean Creek near mouth, near Lavina	121	Big Coulee near Lavina	06125700
124	Stanley Creek at mouth, near Roundup	143	McDonald Creek at Winnett	06129500
125	Goulding Creek at mouth, near Roundup	143	McDonald Creek at Winnett	06129500
126	Currant Creek near Roundup	88	North Fork Musselshell River near Delpine	06115500
127	Horsethief Creek at mouth, near Roundup	121	Big Coulee near Lavina	06125700
130	Willow Creek at mouth, near Roundup	143	McDonald Creek at Winnett	06129500
131	Parrot Creek at mouth, near Roundup	121	Big Coulee near Lavina	06125700
132	Fattig Creek near mouth, near Delphia	121	Big Coulee near Lavina	06125700
134	Hawk Creek at Musselshell	121	Big Coulee near Lavina	06125700
135	McLean Coulee at mouth, near Musselshell	121	Big Coulee near Lavina	06125700
136	Carpenter Creek at mouth, near Musselshell	121	Big Coulee near Lavina	06125700
137	Lost Horse Creek near mouth, near Melstone	121	Big Coulee near Lavina	06125700
138	Home Creek near mouth, near Melstone	121	Big Coulee near Lavina	06125700
139	Rattlesnake Creek at mouth, near Mosby	143	McDonald Creek at Winnett	06129500
140	North Willow Creek at mouth, near Mosby	142	Box Elder Creek near Winnett	06129000
144	Flatwillow Creek at mouth, near Mosby	143	McDonald Creek at Winnett	06129500

Table 12.--*Weights and standard errors for various combinations of methods of estimation for the Mountain Region*

[Log, logarithm, base 10; pct, percent]

Combinations of methods	Weights and standard errors for specified month											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Basin-characteristics method	0.153	0.241	0.234	0.239	0.125	0.256	0.295	0.235	0.383	0.187	0.000	0.000
Channel-width method	.299	.147	.155	.178	.172	.000	.315	.472	.323	.269	.399	.424
Concurrent-measurement method	.548	.612	.611	.583	.703	.744	.391	.293	.294	.544	.601	.576
Weighted standard error (log)	.12	.12	.13	.15	.11	.14	.22	.13	.11	.13	.19	.17
Weighted standard error (pct)	28	29	30	34	25	34	55	32	26	31	47	40
Basin-characteristics method	.666	.751	.810	.726	.640	.681	.476	.397	.598	.695	.763	.683
Channel-width method	.334	.249	.190	.274	.360	.319	.524	.603	.402	.305	.237	.317
Weighted standard error (log)	.20	.22	.24	.26	.26	.27	.24	.14	.13	.17	.25	.24
Weighted standard error (pct)	47	54	59	65	67	68	59	34	31	41	64	60
Concurrent-measurement method	.555	.621	.613	.590	.718	.744	.491	.463	.337	.559	.573	.552
Basin-characteristics method	.445	.379	.387	.410	.282	.256	.509	.537	.663	.441	.427	.448
Weighted standard error (log)	.13	.13	.13	.15	.11	.14	.23	.15	.13	.14	.21	.19
Weighted standard error (pct)	31	30	31	35	26	34	57	36	29	33	51	46
Concurrent-measurement method	.591	.668	.659	.623	.729	.814	.475	.389	.408	.628	.601	.576
Channel-width method	.409	.332	.341	.377	.271	.186	.525	.611	.592	.372	.399	.424
Weighted standard error (log)	.12	.13	.13	.15	.11	.15	.23	.14	.13	.13	.19	.17
Weighted standard error (pct)	28	31	31	36	26	36	57	33	30	32	47	40

Table 13.--*Weights and standard errors for various combinations of methods of estimation for the Plains Region*

[Log, logarithm, base 10; pct, percent]

Combinations of methods	Weights and standard errors for specified month											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Basin-characteristics method	0.000	0.000	0.000	0.000	0.000	0.090	0.000	0.000	0.000	0.000	0.000	0.000
Channel-width method	.824	.744	.680	.794	1.000	.858	.581	.712	.856	.972	.832	1.000
Concurrent-measurement method	.176	.256	.320	.206	.000	.052	.419	.288	.144	.028	.168	.000
Weighted standard error (log)	.31	.31	.29	.29	.28	.35	.28	.29	.31	.28	.28	.35
Weighted standard error (pct)	82	81	76	76	72	97	72	73	81	71	72	94
Basin-characteristics method	.000	.000	.000	.000	.000	.102	.000	.000	.000	.000	.000	.000
Channel-width method	1.000	1.000	1.000	1.000	1.000	.898	1.000	1.000	1.000	1.000	1.000	1.000
Weighted standard error (log)	.33	.34	.34	.31	.28	.36	.34	.32	.32	.28	.29	.35
Weighted standard error (pct)	89	92	93	82	72	98	91	86	84	71	74	94
Concurrent-measurement method	1.000	1.000	1.000	1.000	.038	.186	.586	.483	.420	.314	1.000	1.000
Basin-characteristics method	.000	.000	.000	.000	.962	.814	.414	.517	.580	.686	.000	.000
Weighted standard error (log)	.37	.38	.37	.34	.36	.42	.32	.37	.41	.36	.31	.39
Weighted standard error (pct)	104	108	104	93	98	126	85	101	118	100	83	113
Concurrent-measurement method	.176	.256	.320	.206	.000	.056	.419	.288	.144	.028	.168	.000
Channel-width method	.824	.744	.680	.794	1.000	.944	.581	.712	.856	.972	.832	1.000
Weighted standard error (log)	.31	.31	.29	.29	.28	.36	.28	.29	.31	.28	.28	.35
Weighted standard error (pct)	82	81	76	76	72	98	72	73	81	71	72	94

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