ESTIMATES OF MONTHLY STREAMFLOW CHARACTERISTICS AT SELECTED SITES, WIND RIVER AND PART OF BIGHORN RIVER DRAINAGE BASINS, WYOMING

By James G. Rankl, Ellen Montague, and Bernard N. Lenz

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	4,047	square meter
cubic foot per second	0.02832	cubic meter per second
foot	0.3048	meter
foot per mile	0.1894	meter per kilometer
inch	2.54	centimeter
mile	1.609	kilometer
square mile	2.59	square kilometer

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 Mean Sea Level of 1929.

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ABSTRACT

Monthly characteristics of flow of selected streams in central and western Wyoming were estimated by various methods. Streamflow-gaging stations in and near the study area with more than 5 years of streamflow record were divided into two groups, perennial and ephemeral. For each group, a record-extension procedure was used to extend the monthly record to a 50-year base period, 1941-90. The extended streamflow records from perennial streams were used to estimate the monthly streamflow characteristics at ungaged sites of interest and at streamflow-gaging stations with fewer than 5 years of streamflow record.

Four statistical methods were used to make the estimates. The first method is based on basin characteristics--physical-basin and climatic--as independent (explanatory) variables in a multiple regression model. The significant variables were drainage area, basin slope, maximum basin relief, mean basin elevation, and mean annual precipitation. Monthly streamflow characteristics from 21 stations were used in the analysis. Coefficients of determination ranged from 0.74 to 0.93, and the standard errors of estimate ranged from 37 to 83 percent.

The second method is based on the active-channel width as the independent variable in a linear regression model. Monthly streamflow characteristics, in cubic feet per second, exceeded 90, 70, 50 and 10 percent of the time, from the same 21 stations used in the basin-characteristics method were used in the active channel-width method. Coefficients of determination ranged from 0.65 to 0.95 and the standard errors of estimate ranged from 34 to 100 percent. The standard errors of estimate increased with larger exceedence probabilities.

The third method is based on the concurrent-measurement method. Discharge was measured at 11 ungaged sites and at 5 streamflow-gaging stations with fewer than 5 years of record. Discharge was measured in the middle of the month for 9 months to make the measurements representative of the monthly mean streamflow. A MOVE.1 (Maintenance of variance extension, Type 1) curve-fitting technique was used to relate the discharge measurements from 8 of the ungaged sites and discharge from 5 streamflow-gaging stations with fewer than 5 years of record with discharge data from streamflow-gaging stations with extended records. Relations between discharge at three of the ungaged sites and the monthly streamflow data at nearby gages could not be established because of substantial effects of ground water and irrigation withdrawals on the discharge. Errors for the concurrent-discharge method were analyzed by using 14 pairs of data from streamflow-gaging stations. Daily discharges for the 15th day of the month were selected for both the pseudo-ungaged sites and the index sites. The standard error of estimate was computed from the residuals between the known and the estimated discharge. Standard errors of estimates ranged from 27 to 151 percent.

The fourth method is based on the weighted average of estimates from the first three methods or of estimates from any combination of two of the methods. The standard error of estimate of the weighted average was less than the error of any individual method. The standard error of estimates of the weighted-average method ranged from 18 to 82 percent.

Application of the equations for estimating monthly streamflow characteristics is limited to perennial streams with physical-basin, climatic, and active-channel-width characteristics that are within the range of values used in this study. The equations are not be applicable for estimating flow for ephemeral streams.

INTRODUCTION

The Wind River and part of the Bighorn River, at the confluence with Owl Creek, drains 3,600 square miles of mountains and intermontane valleys and supplies irrigation water for about 210,000 acres of land in the drainage basins in central and western Wyoming. The Wind and the Bighorn are virtually the same river. Four miles south of Thermopolis at the mouth of the Wind River Canyon, the name of the river changes from Wind River to Bighorn River. The point of change is known as the "Wedding of the Waters." Many species of fish, both native and introduced, live in the rivers and streams of the basins. Serious shortages of water can occur during years of less rainfall and runoff. To balance the needs of irrigators with other natural resource considerations, difficult decisions have to be made about the allocation of the water resources. To facilitate making decisions about water resources in the area, the U.S. Geological Survey undertook a cooperative project with the Shoshone Tribe and Northern Arapahoe Tribe of the Wind River Indian Reservation. The objective of this project was to estimate monthly streamflow characteristics at selected sites in the Wind River and part of the Bighorn River drainage basins. These selected sites included both gaged and ungaged sites. These estimates will be used by the Tribes' Wind River Environmental Quality Commission in their development of a streamflow-management model.

Purpose and Scope

This report describes the methods that were used to estimate the monthly streamflow characteristics and the associated reliability and limitations of these estimates. The streamflow characteristics for each month of interest were the mean monthly discharge (the arithmetic mean of discharges for all Octobers of record, for instance) and the monthly mean discharges (the mean discharge for one specific month, October 1980) that were exceeded 90, 70, 50, and 10 percent of the time for that given month for the period of record. Extended records for a common base period of 50 years, 1941-90, were created for gaging stations with at least 5 years of streamflow record, using a record-extension procedure developed by Alley and Burns (1983). These extended records were used in the rest of the study. Monthly streamflow characteristics for the gaging stations of interest were developed from these extended records.

Four methods were used to estimate the monthly streamflow characteristics at ungaged sites. All four methods included information available at streamflow-gaging stations in the area. The first method, basin characteristics, was based on multiple-regression equations for each month that related various basin and climatic characteristics with the monthly streamflow characteristics of the gaging stations. The second method, channel width, was based on regression equations for each month relating the active-channel width with the monthly streamflow characteristics of the gaging stations. The third method, concurrent measurement, requires that discharge be regularly measured over a 9-month period at the ungaged sites. These measurements then were related to known discharges at nearby gaging stations. In the fourth method, weighted average, estimates from the three preceding methods were weighted by their errors and averaged to develop estimates of the streamflow characteristics. Five of the gaged sites of interest had fewer than 5 years of gaged record and so were unsuited for the record-extension procedure. These stations were treated as if they had been ungaged. Following the procedures of the third method, discharge values from their gaged record were related to nearby gaged stations with longer records. The reliability and limitations of all of these estimates are described. The procedures for using the methods for basin characteristics, channel widths, concurrent measurement, and weighted-average estimates outlined in Parrett and Cartier (1990) and Parrett and others (1989), were followed in this report.

The study area included the mainstem and tributaries to the Wind River and part of the Bighorn River, both within and adjoining the Wind River Indian Reservation, upstream from the confluence of Owl Creek and the Bighorn River, north of Thermopolis, Wyoming. Only data from streams whose drainage basins were not substantially regulated were used in this study. Within the study area, streamflow records were limited in length and number. Therefore, some hydrologically similar gaging stations with longer records from outside the study area also were used.

Description of Study Area

The Wind River drains principally the northeastern slope of the Wind River Range, the southern slope of the Absaroka Range, the southern slope of the Owl Creek Mountains, and the basin of the Wind River. Owl Creek drains the northern slope of the Owl Creek Mountains and flows into the Bighorn River north of Thermopolis about 11 miles downstream from the point where the name of the river changes from Wind River to Bighorn River.

Mean annual precipitation ranges from 7 inches in the central part of Wind River drainage basin to about 30 inches in the Wind River Range. Mean annual precipitation in the part of the Absaroka Range within the study area ranges from 14 to 25 inches (Lowham, 1988).

Most of the streams draining the mountains of the study area are perennial. Several of the tributaries draining the southeastern slope of the Wind River Range flow into sinks in limestones. On some of these streams, the flow reappears in a downstream channel. Continental glaciers, which lie along the upper southeastern slope of the Wind River Range, are a source of sustained summer runoff for some of the tributaries flowing into the Wind River.

Streams that originate in the center of the basin of the Wind River generally are ephemeral and flow only in response to rainfall or snowmelt. Flows in these streams are highly variable and are regulated by small dams and water-spreader systems. Return flows from irrigation projects have changed a few of the ephemeral streams to perennial. The stream-flow gaging stations and ungaged sites of interest are shown in figure 1 and are listed in table 1.

Streamflow Data

Data from 38 streamflow-gaging stations in the study area and hydrologically similar stations in adjoining drainages were designated as perennial or ephemeral streams (table 2). Fifteen perennial streamflow-gaging stations in the Wind River and part of the Bighorn River drainage basins, unaffected by regulation, had 5 or more years of gaged records. Records from 10 hydrologically similar streamflow-gaging stations from outside the study area were included to expand the data base to 25 records. Twenty-three of the 25 records were extended. Monthly streamflow data prior to 1930 for Dinwoody Creek near Burris (site 10) and prior to 1939 for Bull Lake Creek near Lenore (site 17) were used in the extension procedure; however, the records were not extended because the streams have been regulated since the 1930's. Estimates of streamflow characteristics developed from 12 extended records in the study area, along with estimates of streamflow characteristics from 9 streamflow-gaging stations outside of the study area, were used for the basin-characteristics and channel-width methods. Monthly streamflow records for Wind River near Burris (site 11) and Green River at Warren Bridge, near Daniel (site 50) were extended; however, the extended records were not used for the basin-characteristics and channel-width methods because of the large size of their drainage areas.

Monthly streamflow data from 8 ephemeral streams in the Wind River drainage that have moderate regulation by small earthen dams and water-spreader systems, 5 ephemeral streams from outside the study area, and the 25 perennial streams previously mentioned were used to extend records for 5 ephemeral streams in the study area (table 2). Data for three of the ephemeral streams in the study area were not extended by the mixed-station model, because a statistically significant relation was not determined with any other stream. The results of this extension were not used to develop equations for any of the three estimating methods. The number of stations used in the record-extension procedure for both perennial and ephemeral streams are summarized in table 2. The periods of record for each of the stations are shown in figure 2.

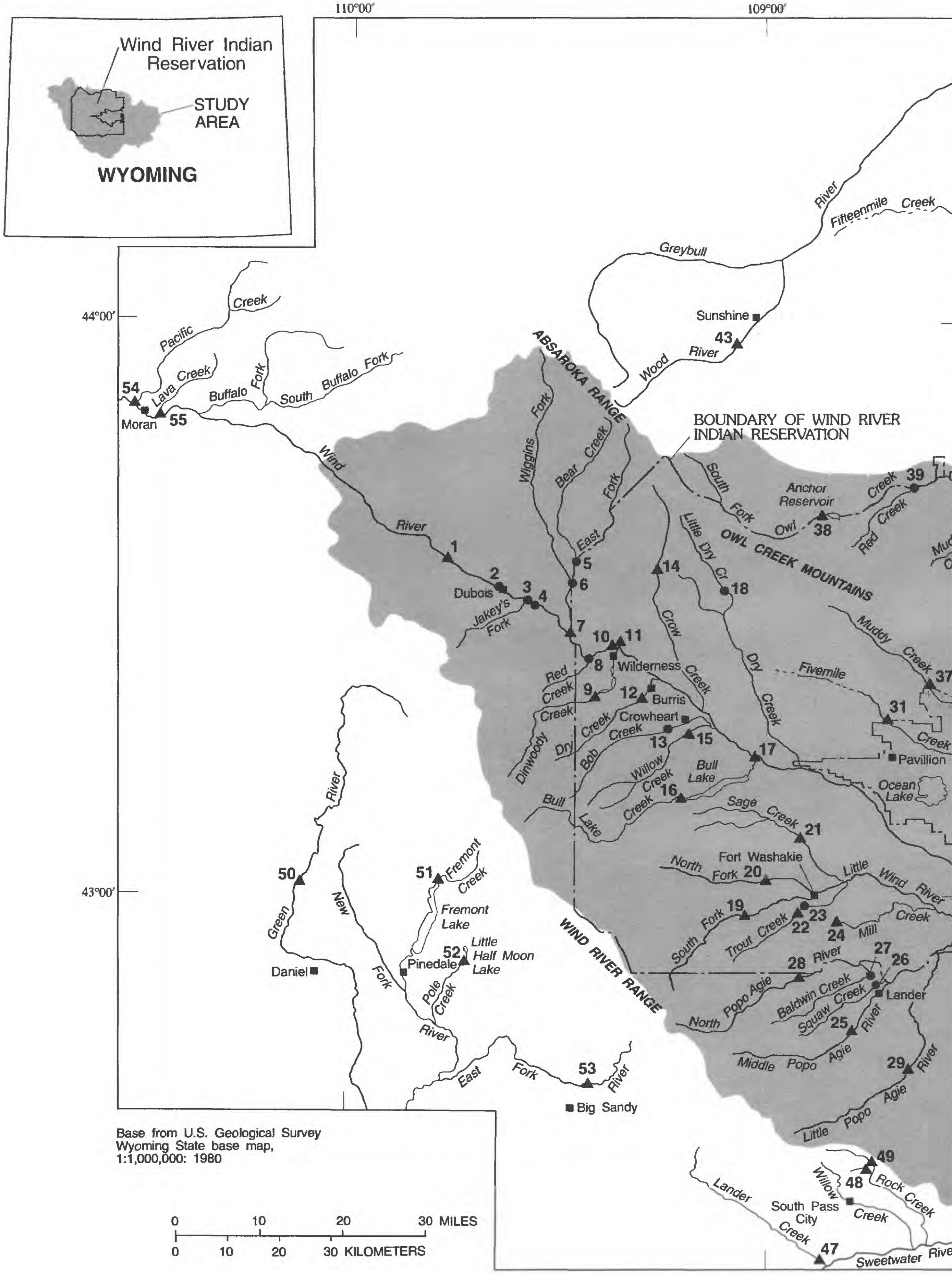

Figure 1. Location of streamflow-gaging stations and ungaged sites.

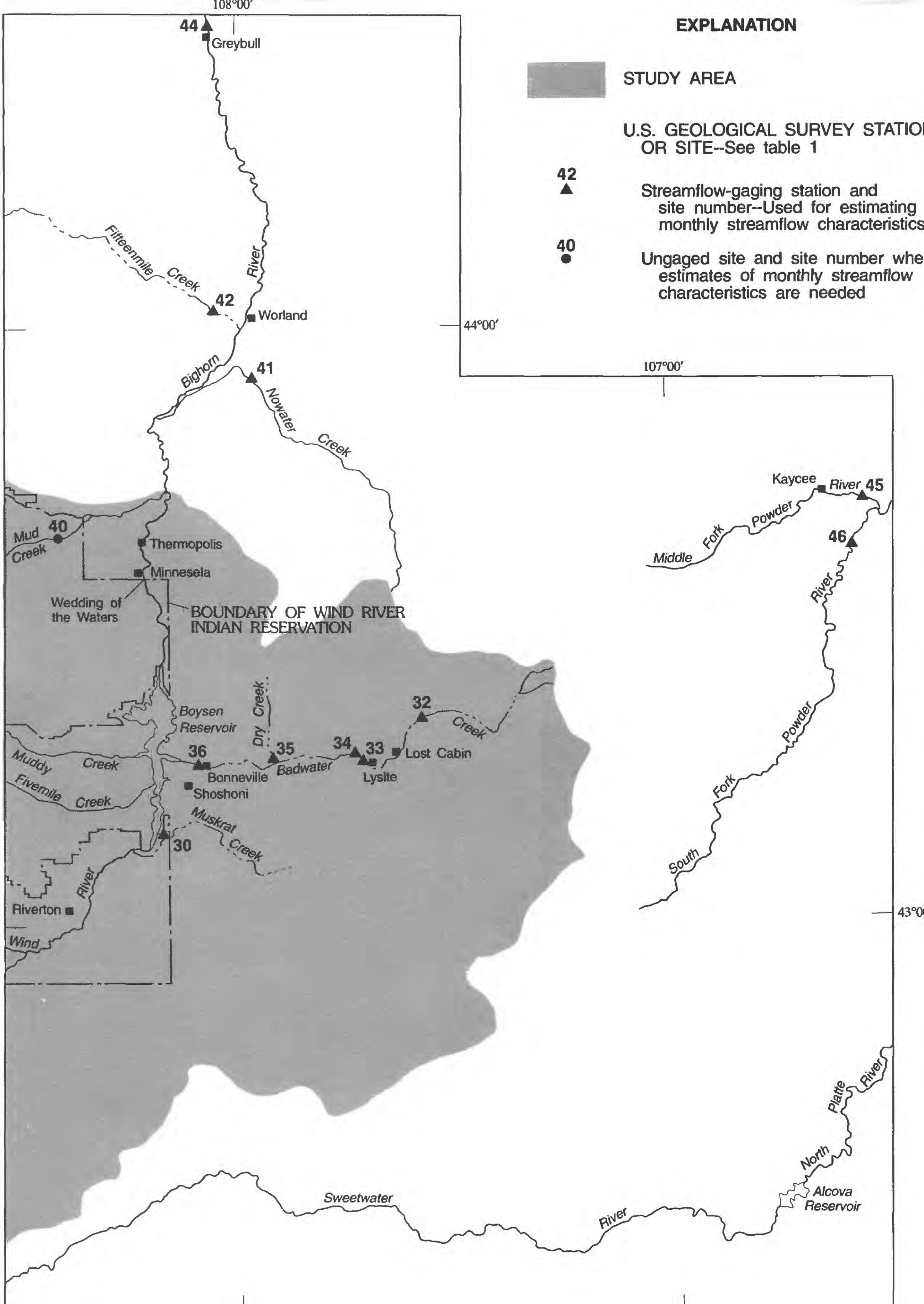

Figure 1. Location of streamflow-gaging stations and ungaged sites-continued.

Table 1. *Sites in Wyoming and methods used for estimating monthly streamflow characteristics*

[>5, streamflow-gaging stations with at least 5 years of record; >5‘, monthly streamflow characteristics based on record prior to construction of Bull Lake; --, no data; x, basin-characteristics and channel-width data used in regression analysis; e, methods used to estimate monthly streamflow characteristics at ungaged sites and at streamflow-gaging stations with less than 5 years of record]

Site	Station name	Station number	Record length (years)	Basin charac-teristics	Channel width	Concurrent measure-ment	Weighted average
1	Wind River near Dubois	06218500	>5	x	x	--	--
2	Horse Creek near Dubois	06219500	--	e	e	e	e
3	Jakey's Fork near Dubois	--	--	e	e	e	e
4	Torrey Creek near Dubois	--	--	e	e	e	e
5	Bear Creek near Dubois	--	--	e	e	e	e
6	Wiggins Fork near Dubois	--	--	e	e	e	e
7	East Fork Wind River near Dubois	06220500	>5	x	x	--	--
8	Red Creek near Wilderness	--	--	e	--	e[1]	--
9	Dinwoody Creek above lakes, near Burris	06221400	>5	x	x	--	--
10	Dinwoody Creek near Burris	06221500	>5	--	--	--	--
11	Wind River near Burris	06222000	>5	--	--	--	--
12	Dry Creek near Burris	06222500	>5	x	x	--	--
13	Meadow Creek near Crowheart	--	--	e	e	--	e
14	Crow Creek near Tipperary	06222700	>5	x	x	--	--
15	Willow Creek near Crowheart	06223500	>5	x	x	--	--
16	Bull Lake Creek above Bull Lake	06224000	>5	x	x	--	--
17	Bull Lake Creek near Lenore	06225000	>5‘	--	--	--	--
18	Dry Creek near Tipperary	--	--	e	e	e	e
19	South Fork Little Wind River above Washakie Reservoir, near Fort Washakie	06228350	>5	x	x	--	--
20	North Fork Little Wind River near Fort Washakie	06228800	--	e	e	e	e
21	Sage Creek above Norkok Meadows	06229680	--	--	e	e	e
22	Trout Creek near Fort Washakie	06229900	--	e	e	e	e
23	Crooked Creek near Fort Washakie	--	--	e	--	e	e
24	Mill Creek above Ray Canal outlet	06230190	--	--	e	e	e
25	Middle Popo Agie River below The Sinks, near Lander	06231600	>5	x	x	--	--
26	Squaw Creek near Lander	--	--	e	e	e	e
27	Baldwin Creek near Lander	--	--	e	e	e[1]	e
28	North Popo Agie River near Milford	06232000	>5	x	x	--	--
29	Little Popo Agie River near Lander	06233000	>5	x	x	--	--
30	Muskrat Creek near Shoshoni	06239000[2]	>5	--	--	--	--
31	Fivemile Creek above Wyoming Canal, near Pavillion	06244500[2]	>5	--	--	--	--
32	Badwater Creek at Lybyer Ranch, near Lost Cabin	06256000[2]	>5	--	--	--	--
33	Badwater Creek at Lysite	06256650[2]	>5	--	--	--	--

Table 1. *Sites in Wyoming and methods used for estimating monthly streamflow characteristics--Continued*

Site	Station name	Station number	Record length (years)	Basin charac-teristics	Channel width	Concurrent measure-ment	Weighted average
34	Bridger Creek near Lysite	06256800[2]	>5	--	--	--	--
35	Dry Creek near Bonneville	06256900[2]	>5	--	--	--	--
36	Badwater Creek at Bonneville	06257000[2]	>5	--	--	--	--
37	Muddy Creek near Pavillion	06257500[2]	>5	--	--	--	--
38	South Fork Owl Creek near Anchor	06260000	>5	x	x	--	--
39	Red Creek near Embar	--	--	--	e	e[1]	--
40	Mud Creek near Minnesela	--	--	--	e	e	e
41	East Fork Nowater Creek near Colter	06267400[2]	>5	--	--	--	--
42	Fifteenmile Creek near Worland	06268500[2]	>5	--	--	--	--
43	Wood River at Sunshine	06275000	>5	x	x	--	--
44	Dry Creek at Greybull	06278000[2]	>5	--	--	--	--
45	Powder River near Kaycee	06312500[2]	>5	--	--	--	--
46	South Fork Powder River near Kaycee	06313000[2]	>5	--	--	--	--
47	Sweetwater River near South Pass City	06637550	>5	x	x	--	--
48	Rock Creek above Rock Creek Reservoir	06637750	>5	x	x	--	--
49	Slate Creek near Atlantic City	06637900	>5	x	x	--	--
50	Green River at Warren Bridge, near Daniel	09188500	>5	--	--	--	--
51	Pine Creek above Fremont Lake	09196500	>5	x	x	--	--
52	Pole Creek below Little Half Moon Lake, near Pinedale	09198500	>5	x	x	--	--
53	East Fork River near Big Sandy	09203000	>5	x	x	--	--
54	Pacific Creek at Moran	13011500	>5	x	x	--	--
55	Buffalo Fork above Lava Creek, near Moran	13011900	>5	x	x	--	---

[1]Nine streamflow-discharge measurements were made at these sites, but the data are not suitable for the concurrent-measurement method.
[2]Streamflow-gaging stations from which most flow is from direct runoff (ephemeral).

Table 2. *Summary of number of streamflow-gaging stations used in record-extension procedure*

<table>
<tr><td colspan="4">Perennial streams</td><td colspan="4">Ephemeral streams</td><td>Total</td></tr>
<tr><td colspan="4">25</td><td colspan="4">13</td><td>38</td></tr>
<tr><td colspan="2">Streams inside study area</td><td colspan="2">Streams outside study area</td><td colspan="2">Streams inside study area</td><td colspan="2">Streams outside study area</td><td></td></tr>
<tr><td colspan="2">15</td><td colspan="2">10</td><td colspan="2">8</td><td colspan="2">5</td><td>38</td></tr>
<tr><td>Records not extended</td><td>Records extended</td><td>Records extended</td><td>Records not extended</td><td>Records not extended</td><td>Records extended</td><td>Records extended</td><td>Records not extended</td><td></td></tr>
<tr><td>2</td><td>13</td><td>10</td><td>0</td><td>3</td><td>5</td><td>0</td><td>5</td><td>38</td></tr>
<tr><td></td><td colspan="2">Total extended records</td><td></td><td></td><td colspan="2">Total extended records</td><td></td><td></td></tr>
<tr><td></td><td>Extended record used for regression analysis</td><td>Extended record not used for regression analysis</td><td></td><td></td><td>Extended record used for regression analysis</td><td>Extended record not used for regression analysis</td><td></td><td></td></tr>
<tr><td></td><td>21</td><td>2</td><td></td><td></td><td>0</td><td>5</td><td></td><td></td></tr>
</table>

Streamflow at 11 ungaged sites of interest, 8 of which were used in the concurrent-measurement method, was measured nine times during 1991 and 1992. Discharge data collected at five streamflow-gaging stations with fewer than 5 years of record also were used in the concurrent-measurement method. Instantaneous discharge at one ungaged site of interest, Meadow Creek near Crowheart (site 13), could not be measured because of lack of access.

Common Base Period Development

To obtain an unbiased estimate of the monthly streamflow characteristics, a common base period of 50 water years, 1941-90, was established. The mixed-station extension model developed by Alley and Burns (1983) was used to fill in the missing months of record for the stations that did not have a complete record for the 50-year period. This mixed-station model selects the best record from all available stations to fill in each month of missing record; therefore, for a site with several missing months of record, the model may use several different stations to compute the missing values of monthly runoff. The model searches for the smallest standard error of prediction to determine the best station for a given month. Only data from months with actual records were used to estimate the discharges for months with no record; that is, no estimated record was used to estimate the discharge for a missing month of another record.

The record-extension model also has two options: cyclic and non cyclic. If the stations have concurrent monthly discharges for 5 or more years, the model runs the cyclic option and develops 12 linear relations, one for each month. If the stations do not have concurrent monthly discharges for 5 or more years, or if the non-cyclic option produces the smallest standard error of prediction, the model chooses the non-cyclic option. This option uses all of the concurrent-monthly discharge values to develop one linear relation.

The mixed-station record-extension model (Alley and Burns, 1983) uses four types of regression equations to fill in the missing monthly streamflow records. The four methods are described by Hirsch (1982) as follows: (1) Ordinary least squares (OLS); (2) Maintenance of variance extension, type 1 (MOVE.1); (3) Maintenance of variance extension, type 2 (MOVE.2); and (4) Regression plus noise (RPN). Hirsch (1982) discusses each method and its properties, and evaluates the bias and error in estimating means, variances, and order statistics. In this study, the MOVE.1 method was used to extend all records.

A common base period, 1941-90, was developed using streamflow records from 38 continuous-record streamflow-gaging stations (fig. 2). The longest continuous streamflow record, Green River at Warren Bridge, near Daniel (site 50), ranged from 1934 to 1990. The earliest continuous streamflow records started in 1918 (sites 10 and 17). Except for 1924 and 1925, the record for site 17, Bull Lake near Lenore, is continuous through 1990. However, a dam was constructed at the mouth of Bull Lake in 1938 making the streamflow record after 1938 unsuitable for this study. Record-extension procedures were run on five ephemeral streams (sites 30, 31, 35-37) that are on or adjacent to the Wind River Indian Reservation. To extend records for the five ephemeral streams, ephemeral streams to the north and east of the study area (fig. 1) were used as base stations. The extended records for the five ephemeral streams were used to compute the monthly statistics for those five sites, but were not used to develop the basin-characteristics and channel-width methods. The streamflow characteristics developed from the extended record are listed in table 14 at the back of this report.

METHODS FOR ESTIMATING MONTHLY STREAMFLOW CHARACTERISTICS

Four statistical techniques were used to estimate monthly streamflow characteristics at ungaged sites and at streamflow-gaging stations with fewer than 5 years of record. The methods used to estimate streamflow data at each site of interest are identified in table 1 and are described as follows.

Basin Characteristics

Basin characteristics considered for this study were determined by examining characteristics used in streamflow studies in Montana (Parrett and Johnson, 1989; Parrett and others, 1989; and Parrett and Cartier, 1990) and in Wyoming (Lowham, 1988). Five physical-basin characteristics and one climatic characteristic were chosen as potential independent variables. The variables chosen were drainage area, in square miles; mean basin elevation, in feet above sea level; basin slope, in feet per mile; basin perimeter, in miles; maximum basin relief, in feet per 10,000 feet, and mean annual precipitation, in inches. Drainage area, in square miles, was measured by a planimeter or digitizer on the best available topographic maps. Mean basin elevation, in feet above sea level was measured on 1:250,000 scale topographic maps. The measurements were made by laying a grid over the map, determining the elevation for at least 25 evenly spaced intersections within the basin, and averaging those elevations (Lowham, 1988). Basin perimeter, in miles, was determined by measuring the length of drainage area boundary (Craig and Rankl, 1978). Basin slope, in feet per mile, was determined by measuring the lengths, in miles, of elevation contour lines within the drainage boundary, multiplying by the contour interval, in feet, and dividing by the drainage area, in square miles (Lowham, 1988). Maximum relief, in feet per 10,000 feet, was determined by computing the difference between the elevation of the channel at the gage and the elevation of the highest point in the basin, then dividing the difference by 10,000. Mean annual precipitation, in inches, was determined from Lowham, 1988, plate 1b. Correlation analysis indicated a correlation coefficient of 0.98 between basin perimeter and drainage area; therefore, basin perimeter was not used as an independent variable in this study. The data for drainage area, mean basin elevation, basin slope, basin perimeter, maximum basin relief, and mean annual precipitation for selected streamflow-gaging stations and ungaged sites of interest are listed in table 3.

The basin-characteristics method is based on a linear-regression model with multiple variables. For each of the 21 streamflow-gaging stations used in the method, the calculated monthly streamflow characteristics, the four physical-basin characteristics, and the one climatic characteristic were transformed into logarithmic space. All of the possible subsets of independent variables were calculated by using the following regression equation:

$$\text{Log}\, Q_{xx} = \log a + b_1 \cdot X_1 + b_2 \cdot X_2 + \ldots + b_n \cdot \log X_n, \quad (1)$$

where

Q_{xx} is the monthly mean streamflow, in cubic feet per second, exceeded 90, 70, 50, and 10 percent of the time for the 50 years of record (Q.90, Q.70, Q.50, Q.10), or the mean monthly streamflow (Qm);

a is the multiple-regression constant;

$b_1, b_2, \ldots b_n$ are the regression coefficients; and

$X_1, X_2, \ldots X_n$ are the independent explanatory variables.

Site	Station	Station name
1	06218500	Wind River near Dubois
7	06220500	East Fork Wind River near Dubois
9	06221400	Dinwoody Creek above lakes, near Burris
10	06221500	Dinwoody Creek near Burris
11	06222000	Wind River near Burris
12	06222500	Dry Creek near Burris
14	06222700	Crow Creek near Tipperary
15	06223500	Willow Creek near Crowheart
16	06224000	Bull Lake Creek above Bull Lake
17	06225000	Bull Lake Creek near Lenore
19	06228350	South Fork Little Wind River above Washakie Reservoir, near Fort Washakie
25	06231600	Middle Popo Agie River below The Sinks, near Lander
28	06232000	North Popo Agie River near Milford
29	06233000	Little Popo Agie River near Lander
30	06239000	Muskrat Creek near Shoshoni
31	06244500	Fivemile Creek above Wyoming Canal, near Pavillion
32	06256000	Badwater Creek at Lybyer Ranch, near Lost Cabin
33	06256650	Badwater Creek at Lysite
34	06256800	Bridger Creek near Lysite

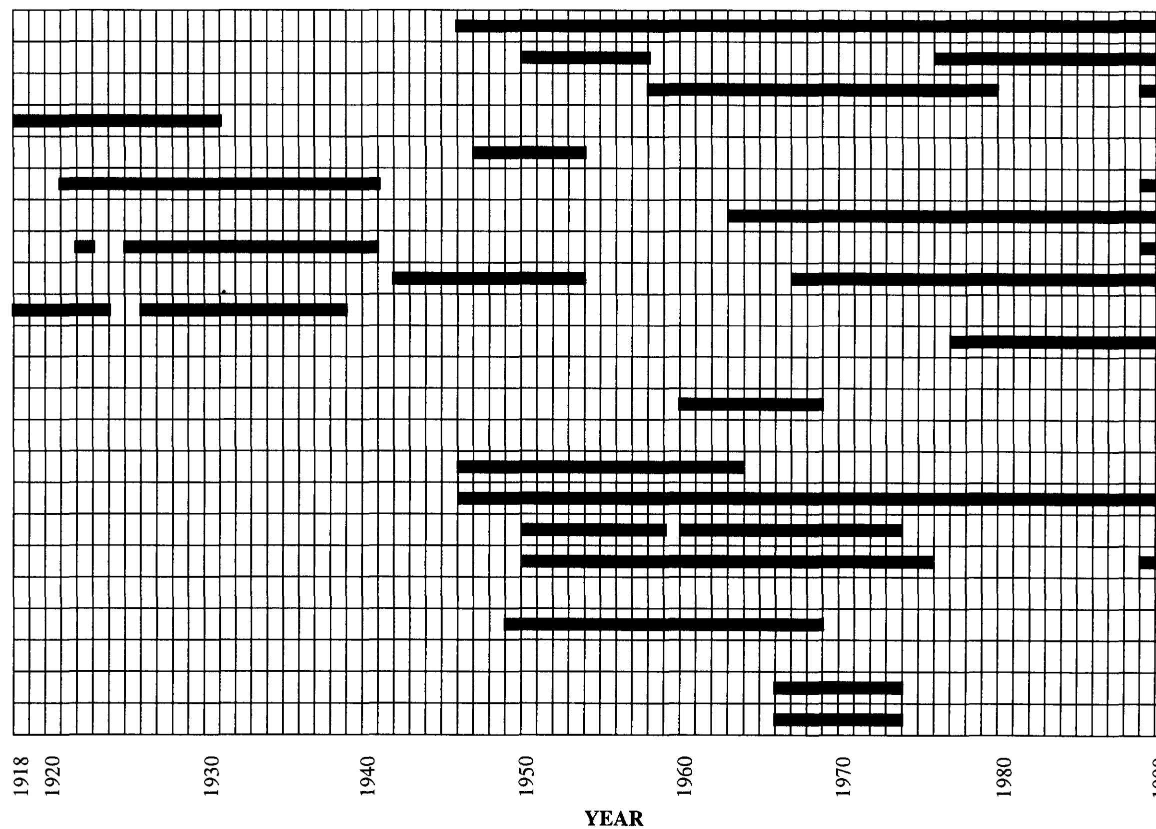

Figure 2. Streamflow-gaging stations in Wyoming used in the record-extension procedure.

Site	Station	Station name
35	06256900	Dry Creek near Bonneville
36	06257000	Badwater Creek at Bonnevile
37	06257500	Muddy Creek near Pavillion
38	06260000	South Fork Owl Creek near Anchor
41	06267400	East Fork Nowater Creek near Colter
42	06268500	Fifteenmile Creek near Worland
43	06275000	Wood River at Sunshine
44	06278000	Dry Creek at Greybull
45	06312500	Powder River near Kaycee
46	06313000	South Fork Powder River near Kaycee
47	06637550	Sweetwater River near South Pass City
48	06637750	Rock Creek above Rock Creek Reservoir
49	06637900	Slate Creek near Atlantic City
50	09188500	Green River at Warren Bridge, near Daniel
51	09196500	Pine Creek above Fremont Lake
52	09198500	Pole Creek below Little Half Moon Lake, near Pinedale
53	09203000	East Fork River near Big Sandy
54	13011500	Pacific Creek at Moran
55	13011900	Buffalo Fork above Lava Creek, near Moran

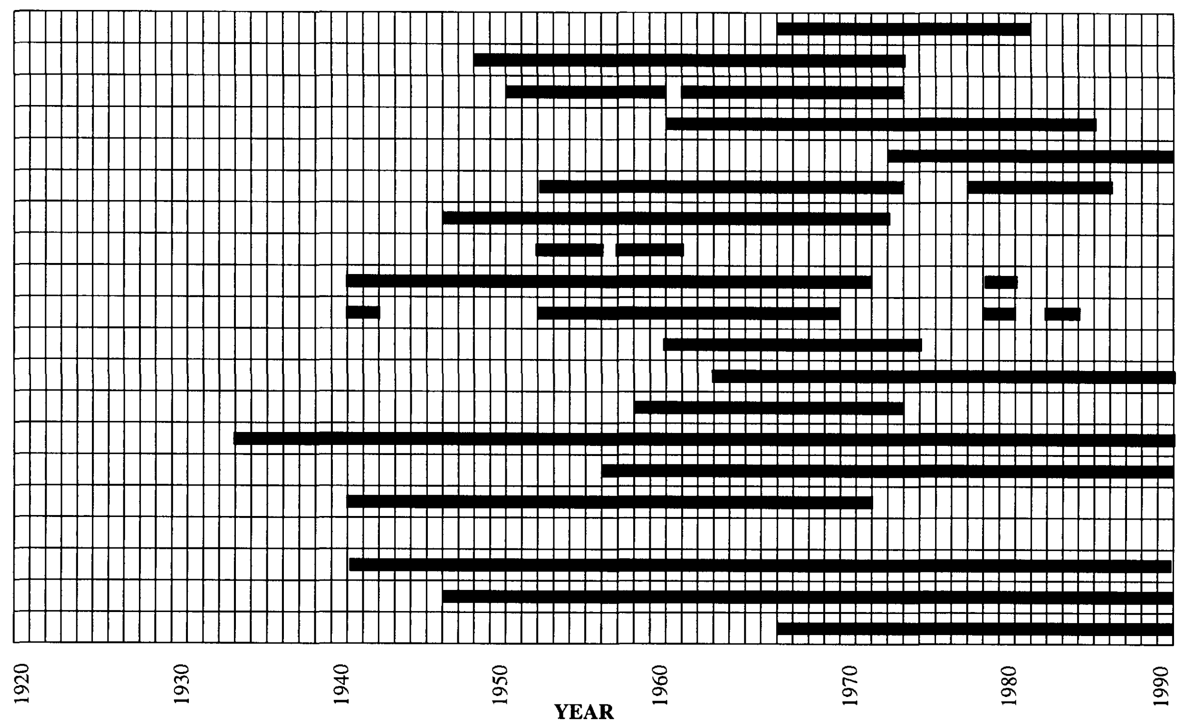

Figure 2. Streamflow-gaging stations in Wyoming used in the record-extension procedure--Continued.

Table 3. *Basin and climatic characteristics and channel widths for each gaging station and ungaged site in Wyoming, used in the basin-characteristics and channel-width methods*

[--, ungaged site, A, drainage area, in square miles; E, mean basin elevation, in feet above sea level; BSL, basin slope, in feet per mile; BP, basin perimeter, in miles; BR, maximum basin relief, in feet per 10, 000 feet; P, mean annual precipitation, in inches; W, active channel width, in feet

Site	Station name	Station number	A	E	BSL	BP	BR	P	W
1	Wind River near Dubois[1]	06218500	232	8,920	1,010	76.5	0.445	20	54
2	Horse Creek near Dubois	06219500	119	8,730	1,090	56.9	.470	15	39
3	Jakeys Fork near Dubois	--	51.6	9,900	1,380	38.5	.604	23	48
4	Torrey Creek near Dubois	--	66.0	9,850	1,450	40.0	.648	21	35
5	Bear Creek near Dubois	--	63.9	9,210	1,330	45.8	.481	23	28
6	Wiggins Fork near Dubois	--	211	9,660	1,890	85.4	.575	20	81
7	East Fork Wind River near Dubois[1]	06220500	427	9,140	1,490	105	.603	20	124
8	Red Creek near Wilderness	--	15.0	8,880	1,500	20.6	.536	16	7
9	Dinwoody Creek above Lakes, near Burris[1]	06221400	88.2	10,500	1,570	49.1	.720	25	74
12	Dry Creek near Burris[1]	06222500	53.7	10,100	1,480	45.8	.658	22	34
13	Meadow Creek near Crowheart	--	41.7	8,920	1,300	39.8	.632	17	16
14	Crow Creek near Tipperary[1]	06222700	30.2	9,950	1,610	28.7	.364	18	24
15	Willow Creek near Crowheart[1]	06223500	55.4	8,720	1,150	38.1	.593	17	17
16	Bull Lake Creek above Bull Lake[1]	06224000	187	10,300	1,690	74.5	.787	25	116
18	Dry Creek near Tipperary	--	24.6	8,970	1,120	25.6	.469	16	14
19	South Fork Little Wind River above Washakie Reservoir, near Fort Washakie[1]	06228350	90.3	10,230	1,450	50.3	.608	25	65
20	North Fork Little Wind River near Fort Washakie	06228800	112	9,990	1,330	57.4	.661	23	62
21	Sage Creek above Norkok Meadows	06229680	115	7,170	757	49.8	.564	13	14
22	Trout Creek near Fort Washakie	06229900	16.1	9,620	1,290	21.0	.503	16	13
23	Crooked Creek near Fort Washakie	--	12.6	7,700	1,270	22.2	.402	15	5
24	Mill Creek above Ray Canal outlet	06230190	15.8	6,470	508	21.8	.320	14	6
25	Middle Popo Agie River below The Sinks, near Lander[1]	06231600	87.5	9,920	1,400	54.3	.704	20	61
26	Squaw Creek near Lander	--	23.5	6,890	1,350	28.9	.462	15	12
27	Baldwin Creek near Lander	--	27.9	7,850	1,060	34.0	.574	15	13
28	North Popo Agie River near Milford[1]	06232000	98.4	9,890	1,940	67.7	.665	22	58
29	Little Popo Agie River near Lander[1]	06233000	125	8,020	1,090	59.2	.705	18	46
38	South Fork Owl Creek near Anchor[1]	06260000	85.5	9,530	1,480	61.1	.600	21	37
39	Red Creek near Embar	--	24.6	7,290	1,220	27.0	.415	14	10
40	Mud Creek near Minnesela	--	76.6	6,380	1,010	41.0	.440	14	12
43	Wood River at Sunshine[1]	06275000	194	9,100	1,320	68.6	.611	20	50
47	Sweetwater River near South Pass City[1]	06637550	177	8,660	1,070	69.6	.489	16	33
48	Rock Creek above Rock Creek Reservoir[1]	06637750	9.07	8,990	778	14.9	.190	17	15
49	Slate Creek near Atlantic City[1]	06637900	5.92	8,620	572	13.2	.131	16	9
51	Pine Creek above Fremont Lake[1]	09196500	75.8	10,200	1,660	41.3	.620	23	67

Table 3. *Basin and climatic characteristics and channel widths for each gaging station and ungaged site in Wyoming, used in the basin-characteristics and channel-width methods--Continued*

Site	Station name	Station number	A	E	BSL	BP	BR	P	W
52	Pole Creek below Little Half Moon Lake, near Pinedale[1]	09198500	87.5	10,000	1,130	45.8	.559	22	62
53	East Fork River near Big Sandy[1]	09203000	79.2	9,580	1,130	49.9	.459	22	56
54	Pacific Creek at Moran[1]	13011500	169	8,160	902	76.6	.378	30	85
55	Buffalo Fork above Lava Creek, near Moran[1]	13011900	323	9,270	1,250	101	.460	29	131

[1] Streamflow-gaging station used for regression analysis

Several criteria were evaluated to select the best-fit model. These included the root-mean-square error, the adjusted R^2 (coefficient of determination), and Mallow's C_p for each subset of independent variables. Mallow's C_p was used as the primary statistical criterion for determining the best-fit model for each monthly streamflow characteristic. Mallow's C_p is an estimate of the average squared prediction error of the subset in relation to the estimated variance of all the variables in the set. The subset of variables with the minimum value of Mallow's C_p is considered to be the best model. Occasionally, two combinations of independent variables would provide nearly equal minimum values for Mallow's C_p. In that case, a procedure called Prediction Sum of Squares (PRESS) (Myers, 1990) was used to evaluate the best-fit model.

The PRESS procedure is used to compute the error of the data set similarly to a split-sample procedure. That is, one dependent observation and its associated independent observations are removed from the data set, and a residual is computed for the dependent observation by using the remaining data set to determine the estimated value. The procedure is repeated for each dependent observation in the data set to obtain the total residual mean-square error for the data set. The explanatory or independent variables that produce the minimum error constitute the best-fit model.

The best-fit equations were retransformed to the nonlinear form by taking antilogarithms of the values

$$Q_{xx} = aX_1^{b1}X_2^{b2}...X_n^{bn}. \qquad (2)$$

The results of the regression analysis--the nonlinear equation, R^2 (coefficient of determination), and the standard error of estimate (in log units and percent)--are listed in table 4. The standard errors ranged from 37 to 83 percent. The application range of the estimation equations used in the basin-characteristics method is listed in table 5.

As seen in table 4, the basin-characteristics method resulted in an adequate prediction model for all months, although the model performed better for lower exceedence probabilities (Qm, Q.10, and Q.50) than for larger exceedence probabilities (Q.70 and Q.90). The monthly streamflow characteristics were estimated, using the equations in table 4, for the 13 sites (table 1) where this method was considered to be appropriate.

Channel Width

Channel geometry of a stream can be attributed to the history and magnitude of flows from the basin. Numerous studies have related channel characteristics to a designated flow characteristic; however, in most cases, the flow characteristic is a flood flow.

Several different definitions of channel width have been used: within-channel bar section, active-channel section, and main-channel section (Wahl, 1977). This study uses active-channel width to be consistent with the channel measurements made by Lowham (1988). The technique used to measure active-channel width is described by Hedman and others (1974) and by Rigg (1974)

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

[R^2, coefficient of determination; Q.90, 70, 50, and 10, monthly mean discharge exceeded 90, 70, 50, and 10 percent of the time during a specified month, in cubic feet per second; Qm, monthly mean streamflow for specified month, in cubic feet per second; A, drainage area, in square miles; P, mean annual precipitation, in inches; BSL, basin slope, in feet per mile; BR, maximum basin relief, in feet per 10,000 feet; E, mean basin elevation, in feet above sea level]

Month	Streamflow characteristic		Equation	R^2	Standard error (logarithm, base 10)	Standard error (percent)
October	Q.90	=	$0.000327\ A^{1.01}\ P^{2.04}$	0.84	0.237	59
	Q.70	=	$0.000659\ A^{0.97}\ P^{1.95}$	.87	.201	49
	Q.50	=	$0.000730\ A^{0.96}\ P^{2.02}$	.90	.176	42
	Q.10	=	$0.000807\ A^{0.97}\ P^{2.14}$	.90	.178	43
	Qm	=	$0.000514\ A^{0.96}\ P^{2.16}$	.90	.173	41
November	Q.90	=	$0.00139\ A^{1.01}\ P^{1.48}$	.80	.258	65
	Q.70	=	$0.00213\ A^{0.99}\ P^{1.46}$	.84	.223	55
	Q.50	=	$0.00201\ A^{0.96}\ P^{1.60}$	.86	.201	49
	Q.10	=	$0.00223\ A^{0.97}\ P^{1.68}$	.87	.198	48
	Qm	=	$0.00155\ A^{0.97}\ P^{1.68}$	.88	.188	45
December	Q.90	=	$0.000675\ A^{1.06}\ P^{1.56}$	.81	.263	67
	Q.70	=	$0.000911\ A^{1.00}\ P^{1.65}$	.83	.232	57
	Q.50	=	$0.00124\ A^{0.96}\ P^{1.67}$	.84	.222	55
	Q.10	=	$0.00258\ A^{0.95}\ P^{1.56}$	.86	.198	48
	Qm	=	$0.00124\ A^{0.97}\ P^{1.65}$	.85	.213	52
January	Q.90	=	$0.493\ A^{1.15}\ P^{1.70}\ BSL^{-1.07}$	.74	.314	83
	Q.70	=	$0.177\ A^{1.09}\ P^{1.64}\ BSL^{-0.82}$	.82	.244	61
	Q.50	=	$0.160\ A^{1.07}\ P^{1.65}\ BSL^{-0.77}$	.85	.213	52
	Q.10	=	$0.201\ A^{1.05}\ P^{1.57}\ BSL^{-0.70}$	.85	.209	51
	Qm	=	$0.207\ A^{1.07}\ P^{1.64}\ BSL^{-0.80}$	.84	.219	54
February	Q.90	=	$0.316\ A^{1.31}\ P^{1.36}\ BR^{-0.80}$	.75	.312	82
	Q.70	=	$0.443\ A^{1.28}\ P^{1.22}\ BR^{-0.74}$	.82	.244	61
	Q.50	=	$0.585\ A^{1.23}\ P^{1.26}\ BR^{-0.74}$	.84	.222	55
	Q.10	=	$0.318\ A^{1.07}\ P^{1.55}\ BSL^{-0.78}$	.87	.198	48
	Qm	=	$0.439\ A^{1.12}\ P^{1.49}\ BSL^{-0.88}$	.84	.225	55
March	Q.90	=	$1.24\ A^{1.34}\ P^{1.07}\ BR^{-0.85}$	0.84	0.231	57
	Q.70	=	$0.743\ A^{1.30}\ P^{1.12}\ BR^{-0.77}$	.87	.209	51
	Q.50	=	$1.02\ A^{1.26}\ P^{1.17}\ BR^{-0.78}$	.87	.203	49
	Q.10	=	$1.52\ A^{1.18}\ P^{1.13}\ BR^{-0.73}$	.90	.165	39
	Qm	=	$1.07\ A^{1.25}\ P^{1.15}\ BR^{-0.77}$	.88	.193	47

Table 4. *Results of the basin-characteristics regression analysis--Continued*

Month	Streamflow characteristic		Equation	R^2	Standard error (logarithm, base 10)	Standard error (percent)
April	Q.90	=	$8.62\ A^{1.30}\ P^{0.80}\ BR^{-0.89}$	.89	.178	43
	Q.70	=	$20.6\ A^{1.34}\ P^{0.78}\ BR^{-0.98}$	.90	.172	41
	Q.50	=	$19.7\ A^{1.26}\ P^{0.93}\ BR^{-0.95}$	.90	.159	38
	Q.10	=	$15.5\ A^{1.15}\ P^{1.25}\ BR^{-0.89}$	.88	.169	40
	Qm	=	$14.6\ A^{1.22}\ P^{1.04}\ BR^{-0.91}$	.91	.155	37
May	Q.90	=	$0.0238\ A^{0.85}\ P^{3.03}\ BR^{-0.57}$	.84	.204	50
	Q.70	=	$0.154\ A^{0.87}\ P^{2.77}\ BR^{-0.65}$	.81	.215	53
	Q.50	=	$0.291\ A^{0.88}\ P^{2.72}\ BR^{-0.69}$	.83	.204	50
	Q.10	=	$0.925\ A^{0.86}\ P^{2.54}\ BR^{-0.69}$	.80	.211	52
	Qm	=	$0.326\ A^{0.87}\ P^{2.68}\ BR^{-0.68}$	.82	.207	51
June	Q.90	=	$0.0000999\ A^{0.85}\ P^{3.54}\ E^{3.11}$	.89	.213	52
	Q.70	=	$0.000164\ A^{0.72}\ P^{3.63}$	.85	.221	54
	Q.50	=	$0.000423\ A^{0.71}\ P^{3.41}$	.83	.229	57
	Q.10	=	$0.00451\ A^{0.66}\ P^{2.87}$	.81	.211	52
	Qm	=	$0.000837\ A^{0.67}\ P^{3.26}$	.83	.214	52
July	Q.90	=	$0.000274\ A^{1.03}\ P^{2.66}\ E^{6.08}$	.91	.206	50
	Q.70	=	$0.000260\ A^{0.99}\ P^{2.91}\ E^{5.45}$	.93	.179	43
	Q.50	=	$0.000418\ A^{0.95}\ P^{2.90}\ E^{4.65}$	.92	.183	44
	Q.10	=	$0.00314\ A^{0.94}\ P^{2.46}\ E^{3.79}$	.91	.184	44
	Qm	=	$0.000708\ A^{0.94}\ P^{2.77}\ E^{4.51}$	.92	.179	43
August	Q.90	=	$0.0000319\ A^{1.19}\ P^{2.88}\ E^{6.06}$	0.89	0.259	65
	Q.70	=	$0.000110\ A^{1.00}\ P^{2.85}\ E^{4.86}$	.87	.245	61
	Q.50	=	$0.000442\ A^{1.02}\ P^{2.45}\ E^{5.29}$	.89	.217	53
	Q.10	=	$0.00126\ A^{0.99}\ P^{2.34}\ E^{5.49}$	.91	.192	46
	Qm	=	$0.000461\ A^{1.01}\ P^{2.48}\ E^{5.21}$	.90	.207	51
September	Q.90	=	$0.0000787\ A^{1.09}\ P^{2.53}\ E^{3.16}$	.85	.259	65
	Q.70	=	$0.000168\ A^{1.00}\ P^{2.51}\ E^{2.70}$	.86	.236	59
	Q.50	=	$0.000450\ A^{1.04}\ P^{2.21}\ E^{3.04}$	.89	.210	51
	Q.10	=	$0.00138\ A^{1.00}\ P^{2.09}\ E^{3.62}$	.90	.192	46
	Qm	=	$0.000532\ A^{1.01}\ P^{2.23}\ E^{3.19}$	.89	.206	50

Table 5. *Application range of the estimation equations used in the basin-characteristics and channel-width methods*

Drainage area (square miles)	Mean basin elevation (feet above sea level)	Basin slope (feet per mile)	Maximum basin relief (feet per 10,000 feet)	Mean annual precipitation (inches)	Active channel width (feet)
5.92-427	8,020-10,500	572-1,940	0.131-0.787	16-30	9-131

Regression analysis was used to relate the active-channel widths (table 3) to monthly streamflow characteristics for 21 streamflow-gaging stations. After variables were transformed into logarithms, the following linear relation between the channel width and monthly streamflow characteristics was developed:

$$\operatorname{Log} Q_{xx} = \log a + b \cdot \log W, \tag{3}$$

where

Q_{xx} is the monthly mean streamflow, in cubic feet per second, exceeded 90, 70, 50, and 10 percent of the time for the 50 years of record (Q.90, Q.70, Q.50, Q.10), or the mean monthly streamflow (Qm);

a is the regression constant;

b is the regression coefficient; and

W is the active-channel width.

The nonlinear form of the equation was determined by taking the antilogarithms of equation 3:

$$Q_{xx} = aW^b. \tag{4}$$

The nonlinear form of the equations, the coefficients of determination, and the standard error of estimate, in log units and percent, are listed in table 6. The coefficients of determination, R^2, ranged from 0.65 in January to 0.95 in July. Standard errors ranged from 34 percent in June and July to 100 percent in January and February. The low standard errors for May, June and July, and for high flows within any month (Q.10), indicate that the channels are primarily formed by flood flows, which is expected. These equations and on-site measurements of active-channel width at the ungaged sites were used to develop an estimate for each monthly streamflow characteristic at 15 sites of interest (table 1).

Concurrent Measurement

To improve estimates of monthly streamflow characteristics made by using the basin-characteristics and channel-width methods at ungaged sites and at streamflow-gaging stations with fewer than 5 years of record, the concurrent-measurement method was used. The method was described by Riggs (1969, p. 96), as follows: "The procedure is based on the assumption that the ratio of concurrent daily mean flows of two streams near the middle of the month equals the ratio of their means for that month." This assumption was expanded by Parrett and Cartier (1990) to include estimates of monthly streamflow characteristics.

Instantaneous discharge was determined near the middle of the month from June through November 1991 and from March through May 1992 at 11 ungaged sites and at 5 streamflow-gaging stations with fewer than 5 years of record. Normally, all discharge determinations would be made in the same water year; however, to complete this study, discharges were determined in both 1991 and 1992. On the basis of streamflow records for Bull Lake Creek above Bull Lake (site 16), a representative streamflow-gaging station for this study area, streamflow was above average for 1991 and below average for 1992. The use of instantaneous discharges from two different water years and seasonal effects could result in a loop curve. However, the effects of a loop relation between discharges at the ungaged sites and the hydrologically similar active streamflow-gaging station were not substantial.

A curve-fitting technique called Maintenance of Variance-Extension, Type 1 (MOVE.1) was used to develop the relation between the logarithms of measured discharge at ungaged sites and the logarithms of daily discharge at a nearby hydrologically similar

Table 6. *Results of channel-width regression analysis*

[R^2, coefficient of determination;Q.90, 70, 50, and 10 monthly mean discharge exceeded 90, 70, 50, and 10 percent of the time during a specified month, in cubic feet per second; Qm, mean monthly streamflow for specified month, in cubic feet per second; W, channel width, in feet]

Month	Streamflow characteristic		Equation	R^2	Standard error (logarithm, base 10)	Standard error (percent)
October	Q.90	=	$0.0165\ W^{1.76}$	0.79	0.271	69
	Q.70	=	$0.0264\ W^{1.71}$	.83	.229	57
	Q.50	=	$0.0335\ W^{1.71}$	.87	.201	49
	Q.10	=	$0.0422\ W^{1.78}$	.90	.173	41
	Qm	=	$0.0305\ W^{1.76}$	.89	.181	44
November	Q.90	=	$0.0206\ W^{1.64}$	.73	.300	78
	Q.70	=	$0.0305\ W^{1.60}$	.76	.273	70
	Q.50	=	$0.0368\ W^{1.62}$	.81	.235	58
	Q.10	=	$0.0437\ W^{1.67}$	.85	.211	52
	Qm	=	$0.0341\ W^{1.64}$	.83	.225	56
December	Q.90	=	$0.0121\ W^{1.70}$	.72	.317	84
	Q.70	=	$0.0195\ W^{1.67}$	.76	.277	71
	Q.50	=	$0.0270\ W^{1.63}$	.79	.255	64
	Q.10	=	$0.0434\ W^{1.60}$	.81	.234	58
	Qm	=	$0.0265\ W^{1.64}$	.79	.252	63
January	Q.90	=	$0.0122\ W^{1.65}$	.65	.361	100
	Q.70	=	$0.0196\ W^{1.62}$	.73	.296	77
	Q.50	=	$0.0251\ W^{1.60}$	.76	.272	69
	Q.10	=	$0.0379\ W^{1.59}$	.78	.254	64
	Qm	=	$0.0258\ W^{1.60}$	.75	.273	70
February	Q.90	=	$0.0107\ W^{1.69}$	.66	.362	100
	Q.70	=	$0.0180\ W^{1.64}$	.71	.309	80
	Q.50	=	$0.0252\ W^{1.59}$	.73	.290	75
	Q.10	=	$0.0361\ W^{1.58}$	.77	.262	66
	Qm	=	$0.0229\ W^{1.62}$	.74	.289	75
March	Q.90	=	$0.0171\ W^{1.62}$	.69	.325	87
	Q.70	=	$0.0205\ W^{1.62}$	.72	.301	79
	Q.50	=	$0.0275\ W^{1.58}$	.73	.287	74
	Q.10	=	$0.0602\ W^{1.48}$	.74	.261	66
	Qm	=	$0.0312\ W^{1.57}$	.73	.283	73
April	Q.90	=	$0.0477\ W^{1.51}$	.70	.292	76
	Q.70	=	$0.0595\ W^{1.52}$	.70	.299	78
	Q.50	=	$0.100\ W^{1.46}$	.72	.273	70
	Q.10	=	$0.252\ W^{1.42}$	.74	.250	63
	Qm	=	$0.122\ W^{1.45}$	.74	.259	65

Table 6. *Results of channel-width regression analysis--Continued*

Month	Streamflow characteristic		Equation	R^2	Standard error (logarithm, base 10)	Standard error (percent)
May	Q.90	=	$0.191\ W^{1.59}$	0.88	0.180	43
	Q.70	=	$0.355\ W^{1.54}$	.86	.184	44
	Q.50	=	$0.484\ W^{1.52}$	.86	.183	44
	Q.10	=	$0.984\ W^{1.45}$	.84	.189	46
	Qm	=	$0.525\ W^{1.50}$	.86	.183	44
June	Q.90	=	$0.0693\ W^{2.03}$	.94	.150	36
	Q.70	=	$0.237\ W^{1.81}$	.93	.144	34
	Q.50	=	$0.372\ W^{1.75}$	.92	.153	36
	Q.10	=	$1.34\ W^{1.55}$	.90	.156	37
	Qm	=	$0.555\ W^{1.67}$	.92	.144	34
July	Q.90	=	$0.0155\ W^{2.15}$	.90	.212	52
	Q.70	=	$0.0286\ W^{2.13}$	.94	.168	40
	Q.50	=	$0.0523\ W^{2.06}$	.94	.150	36
	Q.10	=	$0.173\ W^{1.93}$	.94	.142	34
	Qm	=	$0.0692\ W^{2.01}$	.95	.146	35
August	Q.90	=	$0.00314\ W^{2.36}$	.86	.290	75
	Q.70	=	$0.0132W^{2.08}$	.87	.247	62
	Q.50	=	$0.0194\ W^{2.05}$	.88	.224	55
	Q.10	=	$0.0403\ W^{2.00}$	.91	.192	46
	Qm	=	$0.0217\ W^{2.04}$	.89	.214	52
September	Q.90	=	$0.00623\ W^{2.07}$	.84	.267	68
	Q.70	=	$0.0138\ W^{1.95}$	.87	.228	56
	Q.50	=	$0.0178\ W^{1.94}$	.88	.214	52
	Q.10	=	$0.0345\ W^{1.91}$	.92	.172	41
	Qm	=	$0.0207\ W^{1.92}$	.90	.197	48

streamflow-gaging station. The MOVE.1 model was suggested by Hirsch (1982) to be used in place of ordinary least squares (OLS) where the variance of the estimates needs to be maintained. The MOVE.1 (eq. 5) and OLS (eq. 6) models from Hirsh and Gilroy (1984) are as follows:

$$y = \bar{y} + \left(\frac{S_y}{S_x}\right)(x - \bar{x}), \tag{5}$$

$$y = \bar{y} + R\left(\frac{S_y}{S_x}\right)(x - \bar{x}), \tag{6}$$

where

y is the dependent variable;

$\bar{y}$ is the mean of the dependent variable;

R is the correlation coefficient;

S_y is the sample standard deviation of the dependent variable;

S_x is the sample standard deviation of the independent variable;

x is the independent variable; and

$\bar{x}$ is the mean of the independent variable.

Comparisons of MOVE.1 and OLS fit to monthly streamflow measurements are shown in figure 3. The correlation coefficient computed from OLS is 0.78 for the relation in figure 3 A and 0.97 for figure 3 B. It can be seen from figure 3 B and equations 5 and 6 that the two models can produce similar results as R approaches 1. However, the MOVE.1 model is an unbiased estimator of monthly streamflow characteristics.

An estimate of monthly streamflow characteristics can be made using MOVE.1 by entering the selected value on the x-axis (horizontal), intersecting the MOVE.1 line, and then determining the corresponding value on the y-axis (vertical). In practice, the streamflow characteristics were computed from equation 5 for the MOVE.1 model. The site number, the stream name, the standard errors in logarithmic units and in percent, and the correlation coefficient (R) are listed in table 7. The standard errors in loga-rithmic units are estimated by the standard deviations of the residuals from the MOVE.1 model. The correlation coefficient is a measure of the degree of the linear relation between the discharge at the site of interest and the discharge at the nearby streamflow-gaging station used to estimate the monthly stream-flow characteristics. The standard errors of estimate and correlation coefficients listed in table 7 are used to evaluate the individual relations between stations for the 16 sites with 9 monthly discharge determinations and should not be confused with the errors computed for the concurrent-measurement method.

The discharges at two of the concurrent-measurement sites, Red Creek near Wilderness (site 8) and Red Creek near Embar (site 39) fluctuated little because a large component of the flow was from ground water. The discharges were not significantly correlated with the discharge at any other adjacent streamflow-gaging station, and so estimates of monthly streamflow characteristics for these two sites could not be made using the concurrent-measurement method. The best estimate of the monthly mean streamflow for

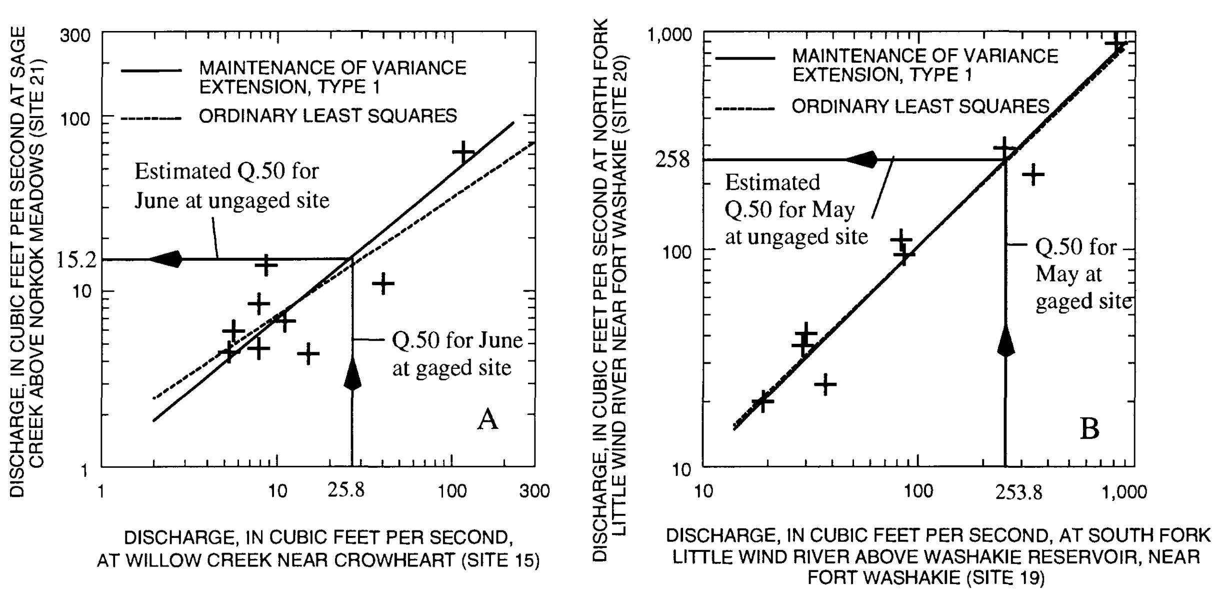

Figure 3. Two curve-fitting techniques for the concurrent-measurement method. A, correlation coefficient equal 0.78 and B, correlation coefficient equal 0.97. The monthly discharge Q.50 was exceeded 50 percent of the time during a specified month.

Table 7. *Summary of statistics used in the evaluation of ungaged sites in Wyoming for the concurrent-measurement method*

Site	Station name	Index site	Standard error (logarithm, base 10)	Standard error (percent)	Correlation coefficient (R)
2	Horse Creek near Dubois	1	0.044	10	0.99
3	Jakeys Fork near Dubois	16	.120	28	.98
4	Torrey Creek near Dubois	9	.527	183	.87
5	Bear Creek near Dubois	14	.113	26	.96
6	Wiggins Fork near Dubois	14	.075	17	.98
8	Red Creek near Wilderness	12	.139	33	.13
18	Dry Creek near Tipperary	14	.105	25	.96
20	North Fork Little Wind River near Fort Washakie	19	.120	28	.97
21	Sage Creek above Norkok Meadows	15	.223	55	.78
22	Trout Creek near Fort Washakie	48	.048	11	.98
23	Crooked Creek near Fort Washakie	48	.138	33	.84
24	Mill Creek above Ray Canal outlet	48	.169	40	.84
26	Squaw Creek near Lander	15	.125	29	.83
27	Baldwin Creek near Lander	1	.365	101	.55
39	Red Creek near Embar	14	.151	36	0
40	Mud Creek near Minnesela	31	.163	39	.77

Red Creek near Wilderness (site 8) and Red Creek near Embar (site 39) was the mean of the nine discharge measurements at each site. The mean discharge for Red Creek near Wilderness (site 8) was 2.55 cubic feet per second with a standard deviation of 1.11 cubic feet per second. The mean discharge for Red Creek near Embar (site 39) was 4.25 cubic feet per second with a standard deviation of 1.34 cubic feet per second. A similar problem with small correlation was evident in the data collected at Baldwin Creek near Lander (site 27). In this instance, the problem may be due to significantly larger irrigation withdrawls than were determined during the initial reconnaissance of the site; therefore, runoff was not estimated using the concurrent-measurement method.

The standard error of estimate for the MOVE.1 line for Torrey Creek near Dubois (site 4) was 183 percent. This error was caused by a large difference in discharge between Torrey Creek and its hydrologically similar gaged stream, Dinwoody Creek above lakes, near Burris (site 9), in the May 1992 measurements. The difference in discharge was the result of a delayed spring runoff on Torrey Creek due to storage in a system of natural lakes in the drainage basin. In spite of the large standard error in the relation between Torrey Creek and Dinwoody Creek, the relation was used to estimate the monthly streamflow characteristics using the concurrent-measurement method.

The error of computing monthly streamflow characteristics from the concurrent-measurement method can be estimated using daily discharges at selected long-term streamflow-gaging stations. Fourteen pairs of stations were used to obtain the estimated error. The first station of the pair was treated as if the site was ungaged (called a pseudo-ungaged site by Parrett and Cartier, 1990) and the second station of the pair was treated as the index-gaged site (table 8). Daily discharge for the 15th day of the month was selected for both the pseudo-ungaged sites and the index gaged sites. The same months that were used in the concurrent-measurement method, June through November and March through May, were selected. The years were selected at random. A MOVE.1 line was fit to the paired discharges at the pseudo-ungaged site and at the corresponding index-gaged site. These fitted lines were used to estimate the monthly streamflow characteristics at each pseudo-ungaged site listed in table 8.

Table 8. *Streamflow-gaging stations used to determine errors for the concurrent-measurement method and independence of the estimating methods*

Station used as pseudo-ungaged site (site number)	Station used as index-gaged site (site number)	Year of record used
7	1	1954
9	16	1970
11	1	1948
12	15	1927
19	16	1988
28	29	1960
38	14	1967
48	47	1964
49	47	1968
50	51	1980
52	51	1958
53	51	1985
54	1	1949
55	1	1990

Table 9. *Standard errors for the concurrent-measurement method, based on nine measurements*

[Q.90, 70, 50, and 10, monthly mean discharge exceeded 90, 70, 50, and 10 percent of the time during a specified month, in cubic feet per second; Qm, mean monthly discharge for a specified month, in cubic feet per second]

Month	Standard error, in percent, for specified monthly flow characteristics				
	Q.90	Q.70	Q.50	Q.10	Qm
October	65	59	54	33	44
November	82	74	65	47	59
December	90	92	89	65	79
January	147	111	101	79	97
February	151	113	102	87	100
March	112	99	99	89	95
April	83	87	84	77	73
May	60	52	57	65	57
June	28	44	56	77	58
July	29	27	35	49	34
August	44	36	38	34	34
September	52	53	42	37	40

The error for each monthly streamflow characteristic using this method was computed from differences (residuals) between the logarithms of the monthly streamflow characteristics for the pseudo-ungaged sites and the logarithms of the values estimated from the MOVE.1 lines. The errors, which ranged from 27 to 151 percent, were determined by computing the standard deviation of the residuals. Standard errors for each monthly streamflow used in the concurrent-measurement method are listed in table 9.

Weighted Average

The weighted-average method was originally developed by E.J. Gilroy (as cited by Parrett and Cartier, 1990) and was adapted for this study. Parrett and Cartier (1990, p. 12) assume "that a weighted average of the individual estimates might provide a better answer than any of the individual estimates." The weighted-average estimates are weighted inversely proportional to the variance of the individual methods and the degree of independence as measured by the cross-correlation coefficients. The weighted-average estimate will have a smaller variance than any of the individual methods.

Cross-correlation coefficients of residuals were computed to determine if the three estimating methods were independent, using 13 of the 14 pairs of streamflow-gaging stations listed in table 8 that were used to compute the errors for the concurrent-measurement method. One pair of stations (site 11 and site 1) used in the concurrent-measurement test could not be used to determine independence of methods because the physical-basin-characteristics data were not available for site 11. The residuals for each monthly streamflow characteristic for both physical-basin-characteristics and active-channel-width methods were computed as the difference between the logarithms of the monthly streamflow characteristic for the pseudo-ungage sites and logarithms of the values estimated from the equations (listed in tables 4 and 6) for each index site. The following equation was used to compute the cross-correlation coefficients:

$$r_{xy} = \frac{\sum_{i=1}^{n} (x_i y_i - N\bar{x}\bar{y})}{(N-1)\, S_x S_y}, \qquad (7)$$

where

r_{xy} is the correlation coefficient between the residuals from method x and method y (ranges from -1.0 to 1.0);

x_i and y_i are the ith residuals from methods x and y;

$\bar{x}$ and $\bar{y}$ are the mean values of the residuals from methods x and y;

N is the total number of samples; and

S_x and S_y are the standard deviations of the residuals from methods x and y.

The cross-correlation coefficients are listed in tables 10 through 12. If the values are larger than 0.634 (n=13 and $\alpha = 0.01$), either positive or negative, then the methods are not independent. In this study, the cross-correlation values for basin-characteristics and channel-width methods are significant for most months, except during high flows (April, May, June, and July), when cross-correlation coefficients are relatively small. The cross-correlation values are not significant for the channel-width and concurrent-measurement methods or for the basin-characteristics and concurrent-measurement methods, which have cross-correlation coefficients that are all relatively small.

To compute the weighted average of estimates from three estimating methods, the following equations developed by E.J. Gilroy, U.S. Geological Survey (as cited by Parrett and Cartier, 1990), are taken verbatim from Parrett and Cartier (1990, p. 13):

$$Z = a_1 \cdot x_1 + a_2 \cdot x_2 + a_3 \cdot x_3, \qquad (8)$$

where

Z is the unbiased, weighted estimate of a streamflow characteristic;

a_1, a_2, and a_3 are weights that result in a minimum-variance, unbiased, linear combination of x_1, x_2, and x_3; and

x_1, x_2, and x_3 are estimates of the streamflow characteristics from three different methods.

Table 10. *Cross-correlation coefficients between residuals from basin-characteristics and channel-width methods*

[Q.90, 70, 50, and 10, monthly mean discharge exceeded 90, 70, 50, and 10 percent of the time during the specified month, in cubic feet per second; Qm, mean monthly discharge, in cubic feet per second]

Month	Q.90	Q.70	Q.50	Q.10	Qm
October	0.83	0.76	0.62	0.49	0.52
November	.86	.80	.72	.65	.68
December	.84	.81	.80	.74	.78
January	.84	.76	.71	.69	.72
February	.80	.70	.69	.68	.72
March	.69	.65	.65	.63	.62
April	.62	.62	.62	.51	.54
May	.60	.57	.52	.56	.54
June	.41	.39	.43	.63	.50
July	.56	.41	.36	.50	.39
August	.73	.76	.68	.57	.66
September	.82	.79	.71	.57	.68

Table 11. *Cross-correlation coefficients between residuals from channel-width and concurrent-measurement methods*

[Q.90, 70, 50, and 10, monthly mean discharge exceeded 90, 70, 50, and 10 percent of the time during the specified month, in cubic feet per second; Qm, mean monthly discharge, in cubic feet per second]

Month	Q.90	Q.70	Q.50	Q.10	Qm
October	0.41	0.20	-0.01	-0.47	-0.19
November	.38	.23	.14	-.03	.08
December	.34	.25	.26	.18	.20
January	.49	.30	.28	.25	.28
February	.48	.35	.32	.23	.32
March	.42	.37	.37	.32	.34
April	.45	.49	.49	.39	.42
May	.36	.15	.13	.09	.14
June	.08	-.01	-.11	-.07	-.07
July	.30	.30	.32	.13	.22
August	.40	.32	.40	.36	.38
September	.38	.27	.14	-.05	.02

Table 12. *Cross-correlation coefficients between residuals from basin-characteristics and concurrent-measurement methods*

[Q.90, 70, 50, and 10, monthly mean discharge exceeded 90, 70, 50, and 10 percent of the time during the specified month, in cubic feet per second; Qm, mean monthly discharge, in cubic feet per second]

Month	Q.90	Q.70	Q.50	Q.10	Qm
October	0.52	0.36	0.19	-0.14	0.04
November	.54	.45	.38	.21	.33
December	.55	.50	.51	.45	.47
January	.55	.40	.41	.41	.39
February	.58	.50	.45	.36	.42
March	.54	.51	.52	.51	.49
April	.45	.53	.54	.27	.37
May	.14	.00	-.04	-.10	-.05
June	-.29	-.26	-.29	-.16	-.21
July	-.01	-.05	-.06	-.12	-.11
August	.24	.27	.37	.21	.29
September	.51	.44	.29	.07	.19

Equations for the weights are as follows:

$$a_1 = [C\,(SE_3^2 - S_{1,3}) - B\,(SE_3^2 - S_{2,3})]\,/\,(AC - B^2), \quad (9)$$

$$a_2 = [A\,(SE_3^2 - S_{2,3}) - B\,(SE_3^2 - S_{1,3})]\,/\,(AC - B^2), \quad (10)$$

$$a_3 = 1 - a_1 - a_2 \quad (11)$$

where

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

$S_{1,2} = r_{1,2}\,(SE_1 \cdot SE_2)$ and is the covariance of methods 1 and 2;

$S_{1,3} = r_{1,3}\,(SE_1 \cdot SE_3)$ and is the covariance of methods 1 and 3;

$S_{2,3} = r_{2,3}\,(SE_2 \cdot SE_3)$ and is the covariance of methods 2 and 3;

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

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

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

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

The estimated standard error of the weighted average, SE_z, is determined as follows:

$$SE_z = [\,(a_1 \cdot SE_1)^2 + (a_2 \cdot SE_2)^2 + (1 - a_1 - a_2)^2 SE_3^2 + 2 \cdot a_1 \cdot a_2 \cdot S_{1,2} + 2a_1\,(1 - a_1 - a_2) \cdot S_{1,3} + 2 \cdot a_2\,(1 - a_1 - a_2)\,S_{2,3}]^{0.5}, \quad (12)$$

where all terms are as previously defined.

If any two of the estimating methods are used, the following equations for computing weights and standard errors are applicable:

$$Z = a_1 \cdot x_1 + a_2 \cdot x_2, \text{ and} \quad (13)$$

$$SE_z = [\,(SE_1^2 SE_2^2 - S_{1,2}^2)/(SE_1^2 + SE_2^2 - 2S_{1,2})]^{0.5} \quad (14)$$

where

$$a_1 = (SE_2^2 - S_{1,2})\,/\,(SE_1^2 + SE_2^2 - 2S_{1,2})\text{; and}$$

$$a_2 = (SE_1^2 - S_{1,2})\,/\,(SE_1^2 + SE_2^2 - 2S_{1,2}).$$

Weighted estimates of monthly streamflow characteristics were made using three estimating methods at nine sites and two estimating methods at six sites. The weights used to compute the average estimated monthly streamflow characteristics, along with standard errors of estimate in log units and in percent, are listed in table 15 (see supplement at the end of this report) for three estimating methods and three combinations of two estimating methods. The standard error for the weighted average of all three methods for monthly streamflow characteristics ranged from 18 to 82 percent. The estimated monthly streamflow characteristics for ungaged sites of interest and for the streamflow-gaging stations with fewer than 5 years of record are listed in table 16 at the end of this report. The combination of methods used for each site of interest is identified in table 1.

RELIABILITY AND LIMITATIONS OF ESTIMATES

Data from streamflow-gaging stations on streams that had substantial change in hydrologic regulation in the last 50 years were edited to retain the unregulated part and then were used only in the record extension. No significant trends are assumed to have occurred in the hydrologic regime in the last 50 years at the stations used in this study. The estimates of the monthly streamflow characteristics are applicable in the future only if there are no significant changes or trends.

Records from only five streamflow-gaging stations in or near the study area included at least 40 years of monthly data. Because of the limited number of long-term streamflow records, an error analysis of the record-extension procedures could not be computed. Therefore, record-extension errors are cited from Parrett and others (1989, table 17, p. 102 and 103). They found that the accuracy of the record-extension procedure was dependent on the length of record being extended. For streamflow-gaging stations with 5 years of record, they computed an error of between 9 and 21 percent for extending the mean monthly streamflows to 50 years of record. To extend a record with between 25 and 35 years of record to 50 years, they computed an error of 2 to 7 percent for the mean monthly streamflow. Errors increase as the exceedence probability increases. The largest error that Parrett and others (1989) computed was 54 percent for extending a 5-year record of monthly streamflow, exceeded 90 percent of the time, to a 50-year record.

Four sites--Horse Creek near Dubois (site 2), Crooked Creek near Fort Washakie (site 23), Squaw Creek near Lander (site 26), and Baldwin Creek near Lander (site 27)-- had a mean annual precipitation of 15 inches, 1 inch less than the range of values used to define the equation for the basin-characteristics method. However, at least half of the area of each of these basins received a mean annual precipitation of 16 inches; therefore, monthly streamflow characteristics were estimated using the basin-characteristics method for the four sites.

Estimates of monthly flows at ungaged sites and at streamflow-gaging stations with fewer than 5 years of record can best be made using the weighted-average method of the three estimating techniques, which has a lower standard error than any individual method. The standard error for the weighted average of all three methods for monthly streamflow characteristic ranged from 18 to 82 percent. The basin-characteristics method generally had the smallest standard errors of the three individual methods, ranging from 37 to 83 percent for estimating monthly streamflow characteristics. The errors for estimating monthly streamflow characteristics for the channel-width method ranged from 34 to 100 percent. Errors for the concurrent-measurement method, which were computed using the 14 pseudo-ungaged sites, ranged from 27 to 151 percent.

The following statements are limiting conditions for application of equations for estimating monthly streamflow characteristics at ungaged sites. The equations can be applied to streams within the range of physical-basin, climatic, and channel-width characteristics identified in table 5. The equations can be applied to streams which are perennial and have little or no regulation.

Estimating equations were not developed for ephemeral streams; however, the record-extension procedure was used to develop extended records for five streams. Because an error analysis for extending records of ephemeral streams is not available and sufficient streamflow data are not available to make an analysis in this study, the standard error of prediction was used as an indicator of the accuracy of the extension method. The standard error of prediction computed by the record-extension model for the ephemeral streams is listed in table 13.

Table 13. *Standard error of prediction using record-extension model for ephemeral streams in Wyoming*

Site	Station name	Error of prediction, in percent
30	Muskrat Creek near Shoshoni	66
31	Fivemile Creek above Wyoming Canal, near Pavillion	55
35	Dry Creek near Bonneville	39
36	Badwater Creek at Bonneville	122
37	Muddy Creek near Pavillion	59

CONCLUSIONS

A common base period was established to provide an unbiased estimate of streamflow characteristics. The common base period was 1941-90--50 water years of actual and synthesized monthly streamflow records. Monthly streamflow data from 38 continuous-record streamflow gaging stations were used to extend 28 records to the common base period. Streamflow data from 25 of the 38 stations were used to extend records for 23 perennial streams. Streamflow data from all 38 stations were used to extend records for 5 streams with ephemeral flows. Of those 38 stations used, 25 streams had perennial flows and 13 streams had ephemeral flows. The monthly streamflow records used in the analysis and in development of the estimating equations were extended using a mixed-station model. The mixed-station model has four options for computing regression equations to estimate the missing record. The method used in this study was MOVE.1.

Four statistical methods were used to estimate monthly streamflow characteristics. The first method was based on physical-basin and climatic characteristics as independent variables in a multiple-regression model. The significant variables were drainage area, mean basin elevation, basin slope, maximum basin relief, and mean annual precipitation. Monthly streamflow characteristics from 21 stations were used in the analysis. Mallow's C_p was used to determine the best model with a minimum of independent variables. Where two models had a similar low value for Mallow's C_p, PRESS was used to determine the best-fit model. Coefficients of determination ranged from 0.74 to 0.93, and the standard errors of estimate ranged from 37 to 83 percent.

The second method was based on the active-channel width as the independent variable in a linear-regression model. Monthly streamflow characteristics, in cubic feet per second, exceeded 90, 70, 50 and 10 percent of the time, from the same 21 stations used in the basin-characteristics first method were used in the active channel-width method. Coefficients of determination ranged from 0.65 to 0.95, and the standard errors of estimate ranged from 34 to 100 percent. The standard errors of estimate increased with larger exceedence probabilities.

The third method was based on the concurrent-measurement method. Discharge was measured for 9 months at 11 ungaged sites and was determined from streamflow records at 5 gaging stations with fewer than 5 years of record. Discharge was measured near the middle of the month at ungaged sites to make the data representative of the monthly mean flow. A MOVE.1 curve-fitting technique was used to correlate discharge measurements from eight ungaged sites and discharge from five gaging stations with fewer than 5 years of record with discharge data from streamflow-gaging stations that had computed streamflow characteristics. Relations among discharge measurements at three of the ungaged sites and discharge data at nearby active gages could not be established owing to significant effects on streamflow at the ungaged sites because of ground-water discharge and irrigation withdrawls. Errors were analyzed for the concurrent-measurement method using data from 14 pseudo-ungaged sites matched with hydrologically similar streamflow-gaging stations; the standard errors of estimate ranged from 27 to 151 percent.

The fourth method was based on the weighted average of (1) estimates from the first three methods, or (2) estimates from any combination of estimates from two of the methods, if independent variables from one of the three methods were not available or were outside the accepted range used in the analysis. The error of the weighted averages was less than the error of any individual method. The standard error of estimates of the weighted-average method, using a combination of three methods, ranged from 18 to 82 percent.

Application of the equations for estimating monthly streamflow characteristics are limited to perennial streams with physical-basin, climatic, and active channel-width characteristics that are within the range of values used in this study. The equations should not be used to estimate monthly streamflow characteristics for ephemeral streams.

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Wahl, K.L, 1977, Accuracy of channel measurements and the implications in estimating streamflow characteristics: U.S. Geological Survey Journal of Research, v. 5, no. 6, p. 8Monthly streamflow characteristics for selected streamflow-gaging stations in Wyoming

SUPPLEMENTAL DATA

Table 14. *Monthly streamflow characteristics of selected streamflow-gaging stations in Wyoming*

[Q.90, 70, 50, and 10, monthly mean discharge exceeded 90, 70, 50, and 10 percent of the time during a specified month, in cubic feet per second; Qm, mean monthly discharge for a specified month, in cubic feet per second

Month	Q.90	Q.70	Q.50	Q.10	Qm
Site 1 -- 06218500 Wind River near Dubois					
October	63.7	73.8	84.8	116	89.1
November	50.0	64.6	71.9	89.3	71.7
December	46.9	55.4	61.3	83.0	62.3
January	41.8	49.4	56.7	76.1	56.9
February	44.2	52.1	55.1	70.9	56.2
March	50.2	55.1	59.8	73.5	61.5
April	65.2	84.6	99.4	156	106
May	190	304	362	534	363
June	381	502	682	1,080	661
July	135	221	317	555	327
August	83.0	108	130	202	141
September	67.1	83.9	94.7	137	100
Site 7 -- 06220500 East Fork Wind River near Dubois					
October	67.1	87.0	102	164	108
November	46.8	55.0	61.0	98.9	65.8
December	35.0	43.1	51.8	70.1	51.6
January	35.8	41.7	46.6	68.7	50.0
February	33.5	46.5	52.0	66.5	51.7
March	46.4	52.6	59.2	73.1	59.0
April	74.0	107	128	222	144
May	262	388	506	776	513
June	558	848	1,000	1,550	1,030
July	204	374	546	1,120	588
August	84.3	108	172	331	189
September	81.4	103	127	238	141
Site 9 -- 06221400 Dinwoody Creek above lakes, near Burris					
October	28.5	33.8	38.7	58.7	41.8
November	12.8	15.3	19.8	28.1	20.2
December	7.9	10.0	12.9	18.3	12.5
January	4.9	6.9	8.2	11.9	8.4
February	4.4	6.3	7.3	11.6	7.7
March	6.0	7.1	8.4	12.0	8.7
April	10.5	13.0	16.2	38.9	21.3
May	83.9	138	176	242	170
June	328	369	437	603	449
July	383	430	490	599	494
August	247	282	320	386	320
September	86.4	111	121	177	131

Table 14. *Monthly streamflow characteristics of selected streamflow-gaging stations in Wyoming--Continued*

Month	Q.90	Q.70	Q.50	Q.10	Qm
		Site 11 -- 06222000 Wind River near Burris			
October	266	311	361	494	375
November	238	269	310	365	303
December	204	223	246	292	247
January	155	186	220	305	218
February	195	204	207	222	208
March	193	208	216	250	219
April	254	310	375	643	418
May	749	1,220	1,470	2,300	1,460
June	2,090	2,680	3,130	3,990	3,050
July	1,030	1,480	1,950	3,260	1,990
August	410	608	772	1,300	834
September	306	404	437	640	465
		Site 12 -- 06222500 Dry Creek near Burris			
October	7.9	9.5	12.8	22.3	14.0
November	3.9	5.1	6.9	11.2	7.4
December	2.8	3.4	4.1	6.8	4.6
January	1.6	2.5	3.0	4.9	3.3
February	1.2	1.9	2.6	4.7	2.8
March	1.7	2.2	2.6	5.2	3.1
April	3.5	4.2	6.2	18.6	8.6
May	39.1	55.3	73.8	117	74.3
June	122	154	183	282	192
July	53.9	89.4	113	191	120
August	33.3	47.3	56.3	101	62.4
September	18.7	23.3	27.3	48.6	30.6
		Site 14 -- 06222700 Crow Creek near Tipperary			
October	3.6	4.5	5.6	7.8	5.8
November	3.2	3.6	4.3	5.9	4.4
December	2.2	2.7	3.3	5.3	3.5
January	1.9	2.3	2.8	4.3	2.9
February	2.1	2.4	2.7	3.6	2.7
March	2.4	2.9	3.4	5.2	3.6
April	4.5	6.1	9.0	21.8	10.8
May	27.3	40.9	56.5	80.9	53.7
June	35.5	69.4	90.9	167	99.6
July	11.0	22.9	35.5	81.4	39.5
August	4.0	6.0	9.9	18.5	10.6
September	3.5	5.3	6.4	10.2	6.6

Table 14. *Monthly streamflow characteristics of selected streamflow-gaging stations in Wyoming--Continued*

Month	Q.90	Q.70	Q.50	Q.10	Qm
Site 15 -- 06223500 Willow Creek near Crowheart					
October	3.0	4.5	6.5	9.1	6.2
November	2.7	4.3	5.6	7.3	5.2
December	2.8	4.4	4.9	6.1	4.8
January	3.2	4.1	4.6	5.5	4.5
February	3.5	3.9	4.3	6.4	4.5
March	3.6	3.9	4.4	5.8	4.5
April	4.4	5.1	6.5	9.6	6.7
May	11.8	14.7	18.0	29.4	19.2
June	20.5	23.0	25.8	54.7	33.4
July	12.2	14.9	18.4	44.1	22.5
August	6.1	7.5	9.4	16.1	10.3
September	4.1	5.1	6.9	10.4	7.1
Site 16 -- 06224000 Bull Lake Creek above Bull Lake					
October	58.6	72.1	89.7	156	101
November	33.1	40.9	55.2	80.6	55.0
December	25.0	31.5	36.4	52.0	37.6
January	19.4	24.2	27.3	38.2	28.3
February	18.0	20.6	24.0	35.0	25.2
March	18.7	22.0	25.0	35.3	26.4
April	30.8	37.8	55.0	131	64.8
May	220	354	468	715	463
June	821	935	1,110	1,620	1,140
July	480	725	860	1,310	903
August	298	349	412	625	420
September	130	155	182	281	198
Site 19 -- 06228350 South Fork Little Wind River above Washakie Reservoir, near Fort Washakie					
October	25.9	31.7	38.5	63.2	42.1
November	18.5	23.0	29.0	37.5	28.7
December	15.8	20.9	22.8	29.2	23.1
January	12.3	14.3	17.3	23.8	17.6
February	11.1	14.1	16.3	22.8	16.4
March	13.6	16.4	17.3	22.0	18.0
April	23.9	30.1	41.0	87.7	46.6
May	134	192	254	364	248
June	369	448	538	874	569
July	140	234	312	583	337
August	54.0	74.6	89.6	168	101
September	29.9	41.4	50.3	82.7	53.3

Table 14. *Monthly streamflow characteristics of selected streamflow-gaging stations in Wyoming--Continued*

Month	Q.90	Q.70	Q.50	Q.10	Qm
Site 25 -- 06231600 Middle Popo Agie River below The Sinks, near Lander					
October	30.1	34.7	42.9	61.5	43.4
November	21.2	26.4	33.6	52.1	34.1
December	17.5	23.4	26.0	33.3	26.0
January	10.6	18.3	21.1	29.5	20.8
February	14.1	16.8	18.4	25.1	19.3
March	15.5	18.4	20.4	27.0	21.0
April	26.8	34.7	42.2	73.3	47.3
May	158	218	243	307	241
June	371	481	557	794	562
July	129	196	271	547	297
August	56.2	76.4	103	155	104
September	37.7	44.9	53.0	90.8	57.9
Site 28 -- 06232000 North Popo Agie River near Milford					
October	23.3	31.7	38.5	64.2	41.8
November	18.8	22.8	27.0	41.1	28.6
December	11.9	17.6	19.9	26.4	19.6
January	9.5	13.4	15.6	21.3	15.7
February	10.6	13.3	15.1	19.3	15.1
March	11.5	13.6	15.1	18.6	15.0
April	19.4	24.1	29.3	73.2	37.8
May	133	212	260	390	261
June	366	458	579	850	595
July	135	217	271	564	312
August	56.5	73.7	85.7	150	97.1
September	33.7	44.4	51.0	80.0	54.5
Site 29 -- 06233000 Little Popo Agie River near Lander					
October	26.7	33.5	37.5	48.2	37.1
November	25.6	28.5	31.0	36.6	30.8
December	20.3	24.5	26.3	30.2	25.9
January	17.2	21.8	23.5	28.1	23.3
February	18.7	22.4	23.0	27.9	23.4
March	20.2	22.9	24.5	29.8	25.4
April	30.1	37.1	46.0	75.2	49.7
May	99.4	149	178	320	196
June	142	208	320	561	335
July	50.9	82.6	119	275	137
August	28.6	44.8	50.8	81.4	55.1
September	24.6	38.6	43.8	65.6	47.0

Table 14. *Monthly streamflow characteristics of selected streamflow-gaging stations in Wyoming--Continued*

Month	Q.90	Q.70	Q.50	Q.10	Qm
		Site 30 -- 06239000 Muskrat Creek near Shoshoni			
October	0	0	0	0.2	0.1
November	0	0	0	0	0
December	0	0	0	0	0
January	0	0	0	0	0
February	0	0	0	.1	6.4
March	0	0	.1	.6	.3
April	0	0	.1	1.3	2.4
May	0	.7	1.7	6.3	5.7
June	0	2.1	3.6	9.5	6.8
July	0	.1	1.2	4.0	2.0
August	0	0	0	1.1	.4
September	0	0	.1	1.9	.8
		Site 31 -- 06244500 Fivemile Creek above Wyoming Canal, near Pavillion			
October	0	1.8	2.8	4.1	2.6
November	.2	1.6	1.9	4.2	2.2
December	0	.9	1.6	2.5	1.5
January	0	.6	1.6	2.9	1.3
February	.8	1.7	2.6	5.7	2.8
March	1.3	2.4	4.2	8.6	4.6
April	1.6	2.4	3.7	6.2	3.7
May	1.4	2.8	3.5	6.8	4.5
June	.3	1.6	2.7	8.5	4.2
July	0	.2	.4	3.7	1.2
August	0	0	.6	3.6	1.1
September	0	.4	1.3	8.3	2.5
		Site 35 -- 06256900 Dry Creek near Bonneville			
October	0	0	0	0.1	0
November	0	0	0	0	0
December	0	0	0	.9	.1
January	0	0	0	0	0
February	0	0	0	1.0	.2
March	0	0	.1	1.4	.4
April	0	.7	1.6	6.1	2.9
May	.9	2.0	3.4	23.6	8.7
June	0	.5	2.7	12.0	4.8
July	0	0	.2	.9	.3
August	0	0	0	2.0	.5
September	0	0	0	.4	.1

Table 14. *Monthly streamflow characteristics of selected streamflow-gaging stations in Wyoming--Continued*

Month	Q.90	Q.70	Q.50	Q.10	Qm
Site 36 -- 06257000 Badwater Creek at Bonneville					
October	0	0	0	9.9	4.6
November	0	0	0	9.1	3.1
December	0	0	.3	3.7	1.3
January	0	0	0	5.5	1.3
February	0	0	2.5	11.1	8.7
March	4.7	15.7	28.1	72.2	39.0
April	.4	7.6	24.4	152	59.7
May	3.0	8.0	33.0	306	81.5
June	1.4	8.2	15.1	168	5.8
July	0	0	.4	38.8	12.7
August	0	0	.6	16.9	5.9
September	0	0	.4	14.6	5.4
Site 37 -- 06257500 Muddy Creek near Pavillion					
October	0.5	1.3	2.5	5.5	3.2
November	.9	1.9	3.3	7.6	3.7
December	.3	1.3	1.6	4.1	2.0
January	0	.3	.9	3.4	1.2
February	.1	1.6	2.9	5.7	2.9
March	4.7	6.7	7.9	11.3	8.3
April	4.4	6.6	9.2	22.7	1.8
May	2.1	3.7	6.1	2.0	8.3
June	1.2	3.4	6.5	2.4	9.4
July	.1	1.9	3.2	8.4	4.2
August	0	.4	1.3	4.2	1.8
September	0	.8	2.0	5.8	2.7
Site 38 -- 06260000 South Fork Owl Creek near Anchor					
October	7.2	8.7	1.7	15.1	1.9
November	5.1	6.1	6.9	9.2	6.9
December	2.2	3.7	4.6	7.2	4.7
January	.8	2.7	4.3	6.2	3.8
February	1.1	2.6	3.4	5.0	3.3
March	2.6	3.7	4.3	9.0	4.9
April	6.7	11.4	16.3	35.1	19.2
May	37.7	52.0	69.8	109	72.2
June	67.9	127	151	241	156
July	24.6	44.1	64.6	125	72.0
August	1.4	14.6	21.5	35.2	22.9
September	7.1	1.6	13.1	22.5	14.0

Table 14. *Monthly streamflow characteristics of selected streamflow-gaging stations in Wyoming--Continued*

Month	Q.90	Q.70	Q.50	Q.10	Qm
Site 43 -- 06275000 Wood River at Sunshine					
October	33.3	43.6	57.5	96.5	59.3
November	30.6	40.6	50.4	70.6	50.5
December	26.1	34.1	39.2	54.1	39.4
January	24.0	28.1	30.3	44.8	32.9
February	22.3	28.5	31.8	42.1	32.4
March	25.1	28.9	32.0	53.0	35.5
April	39.0	50.5	60.5	98.5	67.4
May	97.2	153	199	379	211
June	170	314	356	658	404
July	70.9	152	196	404	221
August	57.5	79.0	112	167	114
September	41.3	55.7	75.9	116	74.4
Site 47 -- 06637550 Sweetwater River near South Pass City					
October	11.8	15.9	19.2	36.4	21.8
November	10.1	13.7	18.4	30.2	18.9
December	7.2	9.2	11.5	21.8	12.4
January	4.9	7.4	9.8	17.1	10.1
February	4.8	8.2	10.2	15.3	10.5
March	9.0	11.3	12.6	19.2	13.5
April	30.0	43.1	51.2	167	73.6
May	77.0	146	208	323	206
June	93.2	168	242	463	257
July	37.7	56.2	86.6	194	97.3
August	15.0	20.6	27.3	47.2	30.1
September	9.9	13.3	19.3	31.7	20.4
Site 48 -- 06637750 Rock Creek above Rock Creek Reservoir					
October	1.2	1.9	2.2	3.3	2.2
November	1.3	1.6	1.9	2.6	1.9
December	.9	1.3	1.6	2.0	1.5
January	.8	1.2	1.4	2.0	1.4
February	.9	1.2	1.5	1.8	1.4
March	.8	1.1	1.4	1.8	1.4
April	1.9	2.3	3.5	8.2	4.4
May	18.8	26.4	31.6	51.7	33.7
June	1.6	2.0	3.7	64.7	36.4
July	2.7	4.7	6.9	13.4	7.6
August	1.5	2.4	2.7	4.6	3.0
September	1.2	2.0	2.1	3.4	2.3

Table 14. *Monthly streamflow characteristics of selected streamflow-gaging stations in Wyoming--Continued*

Month	Q.90	Q.70	Q.50	Q.10	Qm
		Site 49 -- 06637900 Slate Creek near Atlantic City			
October	.9	1.2	1.4	1.9	1.4
November	.8	1.1	1.3	1.6	1.3
December	.5	.7	1.0	1.5	.9
January	.6	.7	.8	1.2	.9
February	.4	.6	.8	1.1	.8
March	.7	.7	.9	1.8	1.0
April	1.4	1.9	2.8	6.2	3.2
May	6.0	13.0	17.6	34.8	18.8
June	7.2	2.2	27.5	69.1	34.9
July	1.3	3.0	5.6	14.5	6.7
August	.2	1.0	1.5	3.1	1.6
September	.4	.8	1.0	2.2	1.2
		Site 50 -- 09188500 Green River at Warren Bridge, near Daniel			
October	145	164	194	285	208
November	112	123	146	200	149
December	99.2	111	126	159	126
January	88.4	97.8	106	150	111
February	86.9	99.7	110	140	112
March	95.6	107	118	158	120
April	162	218	250	450	282
May	569	836	1,060	1,540	1,040
June	1,200	1,470	1,710	2,790	1,830
July	670	1,040	1,220	1,990	1,320
August	354	446	518	882	570
September	210	253	286	468	311
		Site 51 -- 09196500 Pine Creek above Fremont Lake			
October	18.8	28.0	44.8	92.1	54.8
November	11.8	18.9	32.7	58.8	33.4
December	10.7	19.5	26.2	41.8	25.5
January	10.8	17.0	19.5	33.8	20.8
February	10.9	15.3	17.5	26.7	18.5
March	12.0	14.3	17.0	23.4	17.3
April	18.2	25.0	31.8	68.7	39.5
May	140	217	248	562	297
June	625	695	811	1,160	833
July	233	377	522	874	552
August	89.6	117	152	306	166
September	45.2	57.3	78.7	152	88.9

Table 14. *Monthly streamflow characteristics of selected streamflow-gaging stations in Wyoming--Continued*

Month	Q.90	Q.70	Q.50	Q.10	Qm
Site 52 -- 09198500 Pole Creek below Little Half Moon Lake, near Pinedale					
October	5.1	9.7	18.6	54.0	27.3
November	3.9	7.6	19.6	42.0	20.3
December	4.8	11.1	17.5	30.6	17.1
January	6.8	10.6	15.4	29.7	16.4
February	7.3	11.2	13.4	26.3	15.8
March	8.2	10.7	14.0	24.0	15.3
April	13.9	19.2	27.0	68.1	34.0
May	123	182	219	381	247
June	359	454	541	709	552
July	98.0	184	246	466	267
August	32.8	43.2	61.3	144	69.9
September	10.6	15.7	23.2	61.0	30.7
Site 53 -- 09203000 East Fork River near Big Sandy					
October	6.2	11.0	16.0	42.6	20.9
November	5.9	9.1	13.2	28.7	15.0
December	4.4	8.3	11.1	20.0	11.8
January	4.2	7.2	10.0	18.0	10.5
February	4.5	8.5	9.8	15.8	10.3
March	6.0	8.6	10.5	16.9	11.3
April	12.3	15.8	25.0	72.8	35.7
May	155	262	326	477	330
June	256	458	552	878	568
July	51.0	109	154	381	187
August	16.8	24.0	33.3	81.1	40.4
September	6.4	12.5	18.7	49.8	22.7
Site 54 -- 13011500 Pacific Creek at Moran					
October	43.3	53.5	64.4	87.1	66.2
November	37.7	47.3	53.2	77.2	55.9
December	32.6	42.7	47.1	63.9	49.4
January	29.8	37.7	44.0	58.4	44.1
February	34.0	38.7	43.7	55.6	44.3
March	38.1	43.7	49.5	65.0	50.7
April	64.2	91.0	119	300	151
May	581	696	902	1,300	912
June	638	954	1,240	1,930	1,250
July	120	216	337	631	357
August	63.8	79.7	90.3	140	97.6
September	49.3	61.9	67.6	97.0	70.7

Table 14. *Monthly streamflow characteristics of selected streamflow-gaging stations in Wyoming--Continued*

Month	Q.90	Q.70	Q.50	Q.10	Qm
Site 55 -- 13011900 Buffalo Fork above Lava Creek, near Moran					
October	161	185	206	283	216
November	140	157	166	195	169
December	125	134	150	170	146
January	98.3	112	119	143	121
February	93.2	102	111	138	114
March	102	112	120	144	123
April	139	184	210	324	222
May	601	830	1,000	1,390	1,010
June	1,650	1,960	2,280	3,240	2,330
July	430	982	1,370	2,450	1,410
August	248	335	400	656	440
September	174	222	254	376	262

Table 15. *Weights and standard errors for combinations of estimating methods*

[Q.90, 70, 50, and 10, monthly mean discharge exceeded 90, 70, 50, and 10 percent of the time, in cubic feet per second; Qm, mean monthly streamflow for a specified month, in cubic feet per second; log, logarithm, base 10

Methods	Weights for specified month and monthly flow characteristics				
	Q.90	Q.70	Q.50	Q.10	Qm
OCTOBER					
Basin-characteristics method	0.460	0.377	0.326	0.075	0.197
Channel-width method	.124	.245	.311	.379	.365
Concurrent-measurement method	.416	.378	.363	.546	.438
Weighted standard error (log)	.213	.174	.140	.079	.112
Weighted standard error (percent)	52	42	33	18	26
Basin-characteristics method	.882	.764	.671	.472	.547
Channel-width method	.118	.236	.329	.528	.453
Weighted standard error (log)	.236	.198	.167	.152	.154
Weighted standard error (percent)	59	48	40	36	37
Basin-characteristics method	.585	.624	.630	.399	.525
Concurrent-measurement method	.415	.376	.370	.601	.475
Weighted standard error (log)	.214	.178	.149	.103	.128
Weighted standard error (percent)	52	43	35	24	30
Channel-width method	.457	.520	.541	.431	.501
Concurrent-measurement method	.543	.480	.459	.569	.499
Weighted standard error (log)	.221	.180	.147	.080	.115
Weighted standard error (percent)	54	43	35	19	27
NOVEMBER					
Basin-characteristics method	0.570	0.555	0.383	0.142	0.375
Channel-width method	.112	.146	.287	.362	.278
Concurrent-measurement method	.318	.299	.330	.496	.347
Weighted standard error (log)	.243	.208	.178	.139	.163
Weighted standard error (percent)	61	51	43	33	39
Basin-characteristics method	.989	.954	.766	.591	.773
Channel-width method	.011	.046	.234	.409	.227
Weighted standard error (log)	.258	.223	.197	.185	.184
Weighted standard error (percent)	65	55	48	45	44
Basin-characteristics method	.693	.719	.689	.487	.671
Concurrent-measurement method	.307	.281	.311	.513	.329
Weighted standard error (log)	.244	.209	.184	.152	.169
Weighted standard error (percent)	61	51	44	36	40
Channel-width method	.526	.533	.552	.459	.530
Concurrent-measurement method	.474	.467	.448	.541	.470
Weighted standard error (log)	.253	.220	.185	.141	.170
Weighted standard error (percent)	64	54	45	33	41

Table 15. *Weights and standard errors for combinations of estimating methods--Continued*

Methods	Weights for specified month and monthly flow characteristics				
	Q.90	Q.70	Q.50	Q.10	Qm
DECEMBER					
Basin-characteristics method	0.655	0.647	0.572	0.410	0.520
Channel-width method	.084	.170	.256	.281	.245
Concurrent-measurement method	.261	.183	.172	.309	.235
Weighted standard error (log)	.253	.225	.215	.181	.202
Weighted standard error (percent)	63	56	53	44	49
Basin-characteristics method	1.000	.923	.830	.809	.855
Channel-width method	0	.077	.170	.191	.145
Weighted standard error (log)	.263	.232	.220	.196	.212
Weighted standard error (percent)	67	57	54	47	52
Basin-characteristics method	.753	.842	.864	.725	.799
Concurrent-measurement method	.247	.158	.136	.275	.201
Weighted standard error (log)	.253	.227	.218	.186	.206
Weighted standard error (percent)	64	56	54	45	50
Channel-width method	.540	.635	.672	.557	.612
Concurrent-measurement method	.460	.365	.328	.443	.388
Weighted standard error (log)	.266	.240	.226	.188	.212
Weighted standard error (percent)	67	60	56	45	52
JANUARY					
Basin-characteristics method	0.818	0.725	0.767	0.588	0.716
Channel-width method	.063	.115	.113	.197	.130
Concurrent-measurement method	.119	.159	.119	.216	.154
Weighted standard error (log)	.310	.236	.208	.196	.211
Weighted standard error (percent)	82	59	51	48	52
Basin-characteristics method	.917	.878	.887	.803	.864
Channel-width method	.083	.122	.113	.197	.136
Weighted standard error (log)	.314	.243	.212	.206	.217
Weighted standard error (percent)	83	61	52	50	53
Basin-characteristics method	.878	.839	.881	.784	.845
Concurrent-measurement method	.122	.161	.119	.216	.155
Weighted standard error (log)	.310	.237	.209	.199	.213
Weighted standard error (percent)	82	59	51	48	52
Channel-width method	.738	.688	.693	.613	.674
Concurrent-measurement method	.262	.312	.307	.387	.326
Weighted standard error (log)	.343	.267	.244	.217	.243
Weighted standard error (percent)	93	68	61	53	61

Table 15. *Weights and standard errors for combinations of estimating methods--Continued*

Methods	Weights for specified month and monthly flow characteristics				
	Q.90	Q.70	Q.50	Q.10	Qm
FEBRUARY					
Basin-characteristics method	0.789	0.766	0.782	0.738	0.773
Channel-width method	.134	.135	.106	.105	.084
Concurrent-measurement method	.077	.099	.112	.157	.144
Weighted standard error (log)	.309	.240	.218	.191	.219
Weighted standard error (percent)	81	60	53	46	54
Basin-characteristics method	.860	.860	.886	.892	.906
Channel-width method	.140	.140	.114	.108	.094
Weighted standard error (log)	.311	.242	.221	.197	.224
Weighted standard error (percent)	82	60	54	48	55
Basin-characteristics method	.920	.899	.886	.842	.854
Concurrent-measurement method	.080	.101	.114	.158	.146
Weighted standard error (log)	.310	.241	.219	.192	.220
Weighted standard error (percent)	82	60	54	46	54
Channel-width method	.745	.680	.669	.642	.658
Concurrent-measurement method	.255	.320	.331	.358	.342
Weighted standard error (log)	.344	.280	.260	.226	.258
Weighted standard error (percent)	94	72	66	56	65
MARCH					
Basin-characteristics method	0.940	0.895	0.899	0.993	0.889
Channel-width method	.020	.050	.071	.007	.067
Concurrent-measurement method	.039	.055	.030	0	.044
Weighted standard error (log)	.231	.208	.202	.165	.192
Weighted standard error (percent)	57	51	49	39	46
Basin-characteristics method	.976	.945	.927	.993	.930
Channel-width method	.024	.055	.073	.007	.070
Weighted standard error (log)	.231	.209	.202	.165	.192
Weighted standard error (percent)	57	51	49	39	47
Basin-characteristics method	.960	.943	.967	1.000	.953
Concurrent-measurement method	.040	.057	.033	0	.047
Weighted standard error (log)	.231	.208	.203	.165	.192
Weighted standard error (percent)	57	51	49	39	47
Channel-width method	.656	.638	.674	.669	.652
Concurrent-measurement method	.344	.362	.326	.331	.348
Weighted standard error (log)	.296	.269	.261	.234	.253
Weighted standard error (percent)	77	68	66	58	63

Table 15. *Weights and standard errors for combinations of estimating methods--Continued*

Methods	Weights for specified month and monthly flow characteristics				
	Q.90	Q.70	Q.50	Q.10	Qm
APRIL					
Basin-characteristics method	0.918	1.00	1.00	0.778	0.887
Channel-width method	0	0	0	.072	.007
Concurrent-measurement method	.082	0	0	.150	.105
Weighted standard error (log)	.176	.172	.159	.161	.152
Weighted standard error (percent)	42	41	38	38	36
Basin-characteristics method	1.00	1.00	1.00	.857	.954
Channel-width method	0	0	0	.143	.046
Weighted standard error (log)	.178	.172	.159	.166	.155
Weighted standard error (percent)	43	41	38	40	37
Basin-characteristics method	.918	1.00	1.00	.832	.893
Concurrent-measurement method	.082	0	0	.168	.107
Weighted standard error (log)	.176	.172	.159	.161	.152
Weighted standard error (percent)	42	41	38	38	36
Channel-width method	.569	.582	.642	.640	.583
Concurrent-measurement method	.431	.418	.358	.360	.417
Weighted standard error (log)	.257	.268	.251	.225	.228
Weighted standard error (percent)	65	68	63	55	56
MAY					
Basin-characteristics method	0.330	0.264	0.321	0.342	0.322
Channel-width method	.399	.339	.335	.336	.328
Concurrent-measurement method	.271	.397	.344	.322	.350
Weighted standard error (log)	.156	.141	.139	.145	.140
Weighted standard error (percent)	37	33	33	34	33
Basin-characteristics method	.347	.321	.387	.375	.367
Channel-width method	.653	.679	.613	.625	.633
Weighted standard error (log)	.170	.174	.168	.175	.170
Weighted standard error (percent)	41	42	40	42	41
Basin-characteristics method	.598	.493	.556	.591	.550
Concurrent-measurement method	.402	.507	.444	.409	.450
Weighted standard error (log)	.166	.151	.150	.156	.150
Weighted standard error (percent)	40	36	35	37	36
Channel-width method	.718	.583	.627	.665	.630
Concurrent-measurement method	.282	.417	.373	.335	.370
Weighted standard error (log)	.166	.149	.152	.159	.152
Weighted standard error (percent)	40	35	36	38	36

Table 15. *Weights and standard errors for combinations of estimating methods--Continued*

Methods	Weights for specified month and monthly flow characteristics				
	Q.90	Q.70	Q.50	Q.10	Qm
JUNE					
Basin-characteristics method	0.216	0.202	0.206	0.158	0.176
Channel-width method	.163	.405	.456	.604	.530
Concurrent-measurement method	.621	.394	.338	.238	.293
Weighted standard error (log)	.085	.104	.112	.131	.114
Weighted standard error (percent)	20	24	26	31	27
Basin-characteristics method	.228	.186	.184	.134	.152
Channel-width method	.772	.814	.816	.866	.848
Weighted standard error (log)	.143	.138	.148	.154	.141
Weighted standard error (percent)	34	33	35	37	33
Basin-characteristics method	.288	.422	.495	.641	.537
Concurrent-measurement method	.712	.578	.505	.359	.463
Weighted standard error (log)	.088	.121	.135	.158	.140
Weighted standard error (percent)	21	28	32	38	33
Channel-width method	.374	.613	.669	.766	.713
Concurrent-measurement method	.626	.387	.331	.234	.287
Weighted standard error (log)	.096	.112	.120	.134	.119
Weighted standard error (percent)	22	26	28	31	28
JULY					
Basin-characteristics method	0.271	0.282	0.297	0.269	0.284
Channel-width method	0	.063	.228	.420	.240
Concurrent-measurement method	.729	.655	.475	.311	.476
Weighted standard error (log)	.107	.095	.107	.115	.101
Weighted standard error (percent)	25	22	25	27	24
Basin-characteristics method	.533	.447	.349	.255	.336
Channel-width method	.467	.553	.651	.745	.664
Weighted standard error (log)	.185	.145	.134	.135	.133
Weighted standard error (percent)	45	34	32	32	31
Basin-characteristics method	.271	.310	.399	.543	.405
Concurrent-measurement method	.729	.690	.601	.457	.595
Weighted standard error (log)	.107	.096	.111	.128	.106
Weighted standard error (percent)	25	22	26	30	25
Channel-width method	.173	.261	.486	.696	.493
Concurrent-measurement method	.827	.739	.514	.304	.507
Weighted standard error (log)	.120	.108	.121	.123	.113
Weighted standard error (percent)	28	25	28	29	27

Table 15. *Weights and standard errors for combinations of estimating methods--Continued*

Methods	Weights for specified month and monthly flow characteristics				
	Q.90	Q.70	Q.50	Q.10	Qm
AUGUST					
Basin-characteristics method	.283	.169	.196	.264	.226
Channel-width method	0	.045	.100	.106	.048
Concurrent-measurement method	.717	.785	.704	.629	.726
Weighted standard error (log)	.165	.141	.146	.125	.131
Weighted standard error (percent)	39	33	35	29	31
Basin-characteristics method	.705	.517	.549	.500	.549
Channel-width method	.295	.483	.451	.500	.451
Weighted standard error (log)	.252	.230	.202	.170	.192
Weighted standard error (percent)	63	57	49	41	46
Basin-characteristics method	.283	.203	.262	.325	.257
Concurrent-measurement method	.717	.797	.738	.675	.743
Weighted standard error (log)	.165	.141	.147	.126	.132
Weighted standard error (percent)	39	33	35	30	31
Channel-width method	.164	.178	.230	.288	.203
Concurrent-measurement method	.836	.822	.770	.712	.797
Weighted standard error (log)	.177	.144	.150	.133	.136
Weighted standard error (percent)	43	34	36	31	32
SEPTEMBER					
Basin-characteristics method	0.021	0	0.098	0.119	0.060
Channel-width method	.309	.468	.315	.367	.377
Concurrent-measurement method	.669	.532	.587	.514	.563
Weighted standard error (log)	.194	.177	.143	.111	.129
Weighted standard error (percent)	47	43	34	26	30
Basin-characteristics method	.584	.417	.532	.373	.430
Channel-width method	.416	.583	.468	.627	.570
Weighted standard error (log)	.251	.219	.196	.160	.184
Weighted standard error (percent)	63	54	48	38	44
Basin-characteristics method	.309	.428	.372	.393	.379
Concurrent-measurement method	.691	.572	.628	.607	.621
Weighted standard error (log)	.200	.192	.152	.126	.142
Weighted standard error (percent)	49	46	36	30	34
Channel-width method	.325	.468	.384	.456	.422
Concurrent-measurement method	.675	.532	.616	.544	.578
Weighted standard error (log)	.194	.177	.144	.113	.129
Weighted standard error (percent)	47	43	34	26	30

Table 16. *Estimated monthly streamflow characteristics in Wyoming*

[Q.90, 70, 50, and 10, monthly mean discharge exceeded 90, 70, 50, and 10 percent of the time, in cubic feet per second; Qm, mean monthly streamflow for a specified month, in cubic feet per second]

Site	Station name	Discharge for specified month and monthly flow characteristic				
		Q.90	Q.70	Q.50	Q.10	Qm
	OCTOBER					
2	Horse Creek near Dubois	14	17	21	34	23
3	Jakey's Fork near Dubois	11	14	19	31	21
4	Torrey Creek near Dubois	7	10	12	16	12
5	Bear Creek near Dubois	8	10	12	13	11
6	Wiggins Fork near Dubois	32	41	53	82	57
8	Red Creek near Wilderness	1	2	3	4	3
13	Meadow Creek near Crowheart	4	5	7	9	6
18	Dry Creek near Tipperary	2	2	3	3	3
20	North Fork Little Wind River near Fort Washakie	25	31	39	66	43
21	Sage Creek above Norkok Meadows	2	3	4	6	4
22	Trout Creek near Fort Washakie	3	3	4	6	4
23	Crooked Creek near Fort Washakie	.6	.9	1.2	1.2	1.1
24	Mill Creek above Ray Canal outlet	.6	.8	1.0	1.5	1.0
26	Squaw Creek near Lander	3	3	4	6	4
27	Baldwin Creek near Lander	2	3	4	5	4
39	Red Creek near Embar	.9	1.4	1.7	2.5	1.8
40	Mud Creek near Minnesela	.6	1.3	1.7	2.2	1.6
	NOVEMBER					
2	Horse Creek near Dubois	11	14	17	25	17
3	Jakey's Fork near Dubois	7	10	14	19	14
4	Torrey Creek near Dubois	6	8	10	10	9
5	Bear Creek near Dubois	7	9	10	10	10
6	Wiggins Fork near Dubois	26	32	40	57	41
8	Red Creek near Wilderness	1	2	2	3	2
13	Meadow Creek near Crowheart	4	5	6	8	6
18	Dry Creek near Tipperary	2	2	3	3	2
20	North Fork Little Wind River near Fort Washakie	18	23	29	41	30
21	Sage Creek above Norkok Meadows	2	3	3	5	3
22	Trout Creek near Fort Washakie	2	3	3	5	3
23	Crooked Creek near Fort Washakie	.7	1.0	1.2	1.2	1.1
24	Mill Creek above Ray Canal outlet	.6	.8	.9	1.2	.9
26	Squaw Creek near Lander	2	3	4	5	4
27	Baldwin Creek near Lander	2	3	3	4	3
39	Red Creek near Embar	.9	1.2	1.5	2.0	1.5
40	Mud Creek near Minnesela	.7	1.2	1.5	1.9	1.4

Table 16. *Estimated monthly streamflow characteristics in Wyoming--Continued*

Site	Station name	Discharge for specified month and monthly flow characteristic				
		Q.90	Q.70	Q.50	Q.10	Qm
	DECEMBER					
2	Horse Creek near Dubois	9	11	12	19	13
3	Jakey's Fork near Dubois	6	8	11	15	10
4	Torrey Creek near Dubois	5	7	9	11	8
5	Bear Creek near Dubois	6	8	9	11	9
6	Wiggins Fork near Dubois	20	26	31	45	31
8	Red Creek near Wilderness	1	1	2	3	2
13	Meadow Creek near Crowheart	3	4	5	7	5
18	Dry Creek near Tipperary	1	2	2	3	2
20	North Fork Little Wind River near Fort Washakie	14	19	22	31	22
21	Sage Creek above Norkok Meadows	2	2	3	4	3
22	Trout Creek near Fort Washakie	2	2	2	4	3
23	Crooked Creek near Fort Washakie	.5	.8	1.1	1.4	1.0
24	Mill Creek above Ray Canal outlet	.4	.6	.7	1.0	.7
26	Squaw Creek near Lander	2	2	3	4	3
27	Baldwin Creek near Lander	2	2	3	4	3
39	Red Creek near Embar	.6	.9	1.2	1.7	1.2
40	Mud Creek near Minnesela	.4	.9	1.3	1.7	1.2
	JANUARY					
2	Horse Creek near Dubois	7	10	11	17	12
3	Jakey's Fork near Dubois	4	6	8	11	8
4	Torrey Creek near Dubois	4	5	7	9	7
5	Bear Creek near Dubois	5	6	8	11	8
6	Wiggins Fork near Dubois	12	18	22	34	22
8	Red Creek near Wilderness	0	1	1	2	1
13	Meadow Creek near Crowheart	2	3	4	5	4
18	Dry Creek near Tipperary	1	2	2	3	2
20	North Fork Little Wind River near Fort Washakie	11	15	18	26	18
21	Sage Creek above Norkok Meadows	1	2	2	3	2
22	Trout Creek near Fort Washakie	1	2	2	3	2
23	Crooked Creek near Fort Washakie	.4	.6	.8	1.1	.7
24	Mill Creek above Ray Canal outlet	.3	.5	.6	.9	.6
26	Squaw Creek near Lander	1	2	2	3	2
27	Baldwin Creek near Lander	1	2	2	3	2
39	Red Creek near Embar	.5	.8	1.0	1.5	1.0
40	Mud Creek near Minnesela	.5	.9	1.1	1.6	1.1

Table 16. *Estimated monthly streamflow characteristics in Wyoming--Continued*

Site	Station name	Discharge for specified month and monthly flow characteristic Q.90	Q.70	Q.50	Q.10	Qm
	FEBRUARY					
2	Horse Creek near Dubois	8	11	12	16	12
3	Jakey's Fork near Dubois	4	6	7	10	7
4	Torrey Creek near Dubois	4	5	6	9	6
5	Bear Creek near Dubois	5	7	8	11	8
6	Wiggins Fork near Dubois	20	26	29	29	21
8	Red Creek near Wilderness	0	1	1	1	1
13	Meadow Creek near Crowheart	2	2	3	5	3
18	Dry Creek near Tipperary	1	1	2	3	2
20	North Fork Little Wind River near Fort Washakie	10	13	16	24	17
21	Sage Creek above Norkok Meadows	1	2	2	3	2
22	Trout Creek near Fort Washakie	1	1	2	2	2
23	Crooked Creek near Fort Washakie	.4	.6	.8	1.0	.7
24	Mill Creek above Ray Canal outlet	.3	.5	.6	.8	.6
26	Squaw Creek near Lander	1	2	2	3	2
27	Baldwin Creek near Lander	1	1	2	3	2
39	Red Creek near Embar	.5	.8	1.0	1.4	1.0
40	Mud Creek near Minnesela	.6	.9	1.2	1.7	1.2
	MARCH					
2	Horse Creek near Dubois	10	12	13	19	14
3	Jakey's Fork near Dubois	4	5	7	10	7
4	Torrey Creek near Dubois	5	6	7	11	7
5	Bear Creek near Dubois	7	8	10	15	10
6	Wiggins Fork near Dubois	25	28	33	45	34
8	Red Creek near Wilderness	1	1	1	2	1
13	Meadow Creek near Crowheart	2	3	3	5	3
18	Dry Creek near Tipperary	1	2	2	3	2
20	North Fork Little Wind River near Fort Washakie	11	14	16	22	17
21	Sage Creek above Norkok Meadows	2	2	2	3	3
22	Trout Creek near Fort Washakie	1	1	1	2	1
23	Crooked Creek near Fort Washakie	.6	.7	.9	1.5	.9
24	Mill Creek above Ray Canal outlet	.4	.5	.6	.9	.7
26	Squaw Creek near Lander	1	2	2	3	2
27	Baldwin Creek near Lander	1	1	2	3	2
39	Red Creek near Embar	.7	.9	1.0	1.8	1.2
40	Mud Creek near Minnesela	.8	1.0	1.3	2.2	1.4

Table 16. *Estimated monthly streamflow characteristics in Wyoming--Continued*

Site	Station name	Discharge for specified month and monthly flow characteristic				
		Q.90	Q.70	Q.50	Q.10	Qm
	APRIL					
2	Horse Creek near Dubois	20	26	33	58	37
3	Jakey's Fork near Dubois	7	9	13	32	16
4	Torrey Creek near Dubois	9	11	16	31	18
5	Bear Creek near Dubois	12	15	22	43	25
6	Wiggins Fork near Dubois	44	57	73	147	86
8	Red Creek near Wilderness	1	1	2	5	3
13	Meadow Creek near Crowheart	4	5	7	16	9
18	Dry Creek near Tipperary	3	3	5	10	6
20	North Fork Little Wind River near Fort Washakie	20	24	33	75	41
21	Sage Creek above Norkok Meadows	3	4	5	9	5
22	Trout Creek near Fort Washakie	2	2	3	7	4
23	Crooked Creek near Fort Washakie	1.2	1.5	2.2	4.5	2.5
24	Mill Creek above Ray Canal outlet	.9	1.1	1.6	3.4	1.9
26	Squaw Creek near Lander	3	3	4	9	5
27	Baldwin Creek near Lander	3	3	4	10	5
39	Red Creek near Embar	1.5	2.0	2.9	6.6	3.4
40	Mud Creek near Minnesela	1.4	1.9	2.8	6.0	3.1
	MAY					
2	Horse Creek near Dubois	58	102	124	199	126
3	Jakey's Fork near Dubois	66	94	119	190	120
4	Torrey Creek near Dubois	44	64	85	142	86
5	Bear Creek near Dubois	51	72	97	160	98
6	Wiggins Fork near Dubois	197	319	408	614	400
8	Red Creek near Wilderness	8	13	16	29	17
13	Meadow Creek near Crowheart	17	28	36	62	37
18	Dry Creek near Tipperary	11	16	22	37	22
20	North Fork Little Wind River near Fort Washakie	130	195	244	371	244
21	Sage Creek above Norkok Meadows	11	16	21	36	22
22	Trout Creek near Fort Washakie	13	21	24	37	25
23	Crooked Creek near Fort Washakie	5.0	7.6	9.7	18.1	1.3
24	Mill Creek above Ray Canal outlet	4.5	7.5	9.0	14.7	9.5
26	Squaw Creek near Lander	10	14	18	30	18
27	Baldwin Creek near Lander	11	18	23	40	24
39	Red Creek near Embar	7.4	12.3	16.0	27.7	16.6
40	Mud Creek near Minnesela	7.3	9.9	13.6	24.6	14.2

Table 16. *Estimated monthly streamflow characteristics in Wyoming--Continued*

Site	Station name	Discharge for specified month and monthly flow characteristic				
		Q.90	Q.70	Q.50	Q.10	Qm
	JUNE					
2	Horse Creek near Dubois	131	180	239	409	249
3	Jakey's Fork near Dubois	142	208	265	458	293
4	Torrey Creek near Dubois	118	154	198	336	213
5	Bear Creek near Dubois	68	124	161	270	171
6	Wiggins Fork near Dubois	364	623	785	1,283	840
8	Red Creek near Wilderness	13	27	37	77	43
13	Meadow Creek near Crowheart	24	42	56	109	64
18	Dry Creek near Tipperary	12	25	34	73	41
20	North Fork Little Wind River near Fort Washakie	359	433	524	823	553
21	Sage Creek above Norkok Meadows	13	23	30	68	38
22	Trout Creek near Fort Washakie	15	25	33	67	39
23	Crooked Creek near Fort Washakie	2.6	9.6	15.1	39.6	19.1
24	Mill Creek above Ray Canal outlet	4.0	6.8	9.5	21.5	11.7
26	Squaw Creek near Lander	10	19	26	56	31
27	Baldwin Creek near Lander	12	26	35	75	42
39	Red Creek near Embar	7.4	15.3	2.9	47.5	26.0
40	Mud Creek near Minnesela	4.2	13.3	19.6	48.7	25.4
	JULY					
2	Horse Creek near Dubois	40	70	100	199	108
3	Jakey's Fork near Dubois	68	107	138	259	147
4	Torrey Creek near Dubois	118	142	155	227	162
5	Bear Creek near Dubois	21	42	66	138	72
6	Wiggins Fork near Dubois	112	230	360	782	396
8	Red Creek near Wilderness	3	6	10	23	11
13	Meadow Creek near Crowheart	9	15	21	46	24
18	Dry Creek near Tipperary	4	7	11	28	13
20	North Fork Little Wind River near Fort Washakie	145	239	306	550	329
21	Sage Creek above Norkok Meadows	8	9	12	27	14
22	Trout Creek near Fort Washakie	7	10	13	25	14
23	Crooked Creek near Fort Washakie	.3	.8	1.8	6.2	2.2
24	Mill Creek above Ray Canal outlet	1.4	2.1	2.7	5.6	3.1
26	Squaw Creek near Lander	7	7	8	17	9
27	Baldwin Creek near Lander	3	6	10	24	11
39	Red Creek near Embar	2.2	3.9	6.0	14.7	7.1
40	Mud Creek near Minnesela	.6	1.6	4.4	14.9	5.3

Table 16. *Estimated monthly streamflow characteristics in Wyoming--Continued*

Site	Station name	Discharge for specified month and monthly flow characteristic				
		Q.90	Q.70	Q.50	Q.10	Qm
	AUGUST					
2	Horse Creek near Dubois	22	32	39	65	43
3	Jakey's Fork near Dubois	40	50	58	91	60
4	Torrey Creek near Dubois	59	77	87	117	91
5	Bear Creek near Dubois	9	11	16	34	19
6	Wiggins Fork near Dubois	47	61	101	192	106
8	Red Creek near Wilderness	1	3	3	6	4
13	Meadow Creek near Crowheart	4	6	9	15	10
18	Dry Creek near Tipperary	1	2	3	6	3
20	North Fork Little Wind River near Fort Washakie	61	80	97	179	109
21	Sage Creek above Norkok Meadows	4	5	6	10	7
22	Trout Creek near Fort Washakie	4	6	6	9	7
23	Crooked Creek near Fort Washakie	.1	.2	.3	.8	.3
24	Mill Creek above Ray Canal outlet	.8	1.2	1.4	2.1	1.5
26	Squaw Creek near Lander	4	5	6	7	6
27	Baldwin Creek near Lander	1	2	3	6	4
39	Red Creek near Embar	.7	1.6	2.2	4.0	2.4
40	Mud Creek near Minnesela	.2	.4	1.0	2.4	1.1
	SEPTEMBER					
2	Horse Creek near Dubois	18	22	27	42	29
3	Jakey's Fork near Dubois	20	25	29	48	32
4	Torrey Creek near Dubois	13	18	23	40	25
5	Bear Creek near Dubois	4	7	10	17	10
6	Wiggins Fork near Dubois	37	57	67	116	72
8	Red Creek near Wilderness	1	2	2	4	3
13	Meadow Creek near Crowheart	3	4	6	10	6
18	Dry Creek near Tipperary	1	2	2	4	2
20	North Fork Little Wind River near Fort Washakie	32	43	54	90	57
21	Sage Creek above Norkok Meadows	3	3	4	6	4
22	Trout Creek near Fort Washakie	3	4	5	6	5
23	Crooked Creek near Fort Washakie	.2	.4	.4	.8	.5
24	Mill Creek above Ray Canal outlet	.6	.9	1.0	1.5	1.1
26	Squaw Creek near Lander	4	4	5	6	5
27	Baldwin Creek near Lander	1	2	3	5	3
39	Red Creek near Embar	.7	1.2	1.6	2.8	1.7
40	Mud Creek near Minnesela	.3	1.0	1.2	2.8	1.5

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