COST EFFECTIVENESS OF THE STREAM-GAGING NETWORK IN IDAHO

By W. A. Harenberg, R. L. Moffatt, and R. W. Harper

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CONVERSION FACTORS

For readers who prefer to use metric units, conversions for terms used in this report are listed below:

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

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ABSTRACT

The stream-gaging network in Idaho was evaluated as part of a nationwide effort by the U.S. Geological Survey to define and document the most cost-effective means of furnishing streamflow information. Eleven sources of funding contribute to the Idaho network. Uses of streamflow data collected from 185 surface-water gaging stations compose nine categories. Analysis of the data-use categories identified 19 stations that could be discontinued.

Operation of Idaho's current (1982) network requires an annual budget of $781,000, which results in an average standard error of 22.7 percent. This overall level of record accuracy could be maintained with a minimum budget of $760,000, if allocation of manpower and equipment among the 185 gages was redistributed. Such redistribution would allow additional money for establishing gages in data-deficient areas.

At the minimum budget, the average standard error is 23.0 percent. At a maximum budget of $1,500,000, the average standard error is 13.4 percent. Upgrading equipment and developing strategies to minimize lost record would improve reliability and accuracy of streamflow data.

Future cost-effectiveness studies would be essential to identify changes in demand for streamflow information and to investigate ways of reducing the probabilities of lost correlative data.

INTRODUCTION

The Water Resources Division of the U.S. Geological Survey is the principal Federal agency for collecting surface-water data. Data-collection programs are conducted in cooperation with State and local governments and other Federal agencies. In 1982, the Survey operated about 8,000 continuous-record gaging stations throughout the Nation. Some have been in operation since the turn of the century. Activities of such duration should be reexamined periodically because objectives, technology, and external constraints constantly change. The last systematic, nationwide evaluation of the stream-gaging network was completed in 1970 and was documented by Benson and Carter (1973). The Survey presently is undertaking another nationwide evaluation of the stream-gaging network. The evaluation will be conducted over a 5-year period; 20 percent of the network will be evaluated each year. The objective of this evaluation is to define and document the most cost-effective means of furnishing streamflow information.

This objective will be accomplished in three steps:

1. Principal uses of data collected at each continuous-record gaging station will be identified and related to funding sources. Gaging stations from which data are inadequate or no longer needed will be identified. In addition, gaging stations will be categorized as to whether the data are available to users in a real-time sense, on a provisional basis, or after the end of the water year.

2. Less costly alternatives of furnishing needed information, such as flow-routing models and statistical methods, will be identified. Stream-gaging activity no longer is considered a network of observation points, but rather an integrated information system in which data are provided by both observation and synthesis.

3. Kalman-filtering and mathematical-programming techniques will be used to define strategies for operating the necessary stations that minimize uncertainty in streamflow records for given operating budgets. Kalman-filtering techniques are used to compute uncertainty functions (relating standard error of computation or estimation of streamflow records to frequency of station visits) for all stations evaluated. A steepest descent optimization program uses these

uncertainty functions, information on practical stream-gaging routes, various costs associated with stream gaging, and total operating budget to identify, for each station, the visit frequency that minimizes the overall uncertainty in the streamflow record. The standard errors of estimate given in the report are those that would occur if daily discharges were computed through the use of methods described in this study. No attempt has been made to estimate standard errors for discharges that are computed by other means. Such errors could differ from the errors computed in the report. The magnitude and direction of the differences would be a function of methods used to account for shifting controls and for estimating discharges during periods of missing record.

The first report in the current nationwide evaluation was produced for the State of Maine (Fontaine and others, 1984). The Idaho report is based on the Maine report.

The authors acknowledge the assistance of U. S. Geological Survey personnel, D. J. Langman and A. K. Lehmann, Idaho Office; F. E. Arteaga, Nevada Office; G. D. Tasker, Northeastern Region; and W. H. Doyle Jr., Southeastern Region.

HISTORY OF THE STREAM-GAGING NETWORK IN IDAHO

The following history of the stream-gaging network in Idaho was documented by Follansbee (dates unknown). The network of surface-water investigations in Idaho began in 1889 with the establishment of three gaging stations: Bear River near Preston, Snake River at Idaho Falls, and Big Wood River at Hailey.

During the period 1894 to 1905, five resident Survey hydrographers worked in cooperation with the State Engineer, who made reservoir and canal surveys along the Snake River. No State funds were provided for this work.

From 1906 to 1911, gaging stations were established throughout Idaho and part of western Wyoming. Because access to stations in northern Idaho was difficult, these stations were operated by the Columbia River and Montana Districts but were funded by the Idaho District, headquartered in Boise in 1911. For the same reason, stations in the Malheur basin were operated by the Idaho District but were funded by the Oregon District. Most of the 85 stations in the Great Basin were maintained cooperatively by the Great Basin and Idaho Districts. During 1912 and 1913, 36 additional stations were established; at the end of 1913, 100 stations were maintained.

In 1919, 25 stations in the upper Snake River basin were transferred to the newly established Idaho Falls District, which functioned as a separate District until 1959, when it once again became part of the Idaho District. The Idaho District continued to maintain about 50 stations, including a few in Yellowstone Park within the Idaho Falls District boundaries.

The period from 1919 to 1925 was one of intense irrigation activity and water-power development. Surface-water investigations expanded rapidly and, by 1925, the Idaho network included 138 gaging stations throughout the State.

By 1938, the number of gaging stations throughout the State increased to 181, owing to hydrologic investigations conducted by the Idaho District. At the end of 1939, 188 gaging stations were maintained by the two Districts, which brought the State total to 212.

Although the war effort during 1940-45 curtailed expansion, by 1948 the Idaho and Idaho Falls Districts operated 224 gaging stations throughout the State. This increase was due primarily to intensive studies by the U.S. Bureau of Reclamation for irrigation and power production projects. Upon completion of these construction projects, a large number of stations were discontinued, and the Idaho District network decreased to 203 stations in 1962.

Following an increase in State funding for various new irrigation projects, the Idaho District network increased to 228 gaging stations by 1967.

After 1967, State and Federal funding was curtailed and in 1970, the network was evaluated. These actions resulted in a reduction of the Idaho District network to 185 stations in 1982.

The history of gages on streams, reservoirs, canals, and lakes in Idaho and Wyoming is shown in figure 1.

Current Idaho Stream-Gaging Network

Idaho has a complex topography and occupies parts of four physiographic provinces--Northern Rocky Mountain,

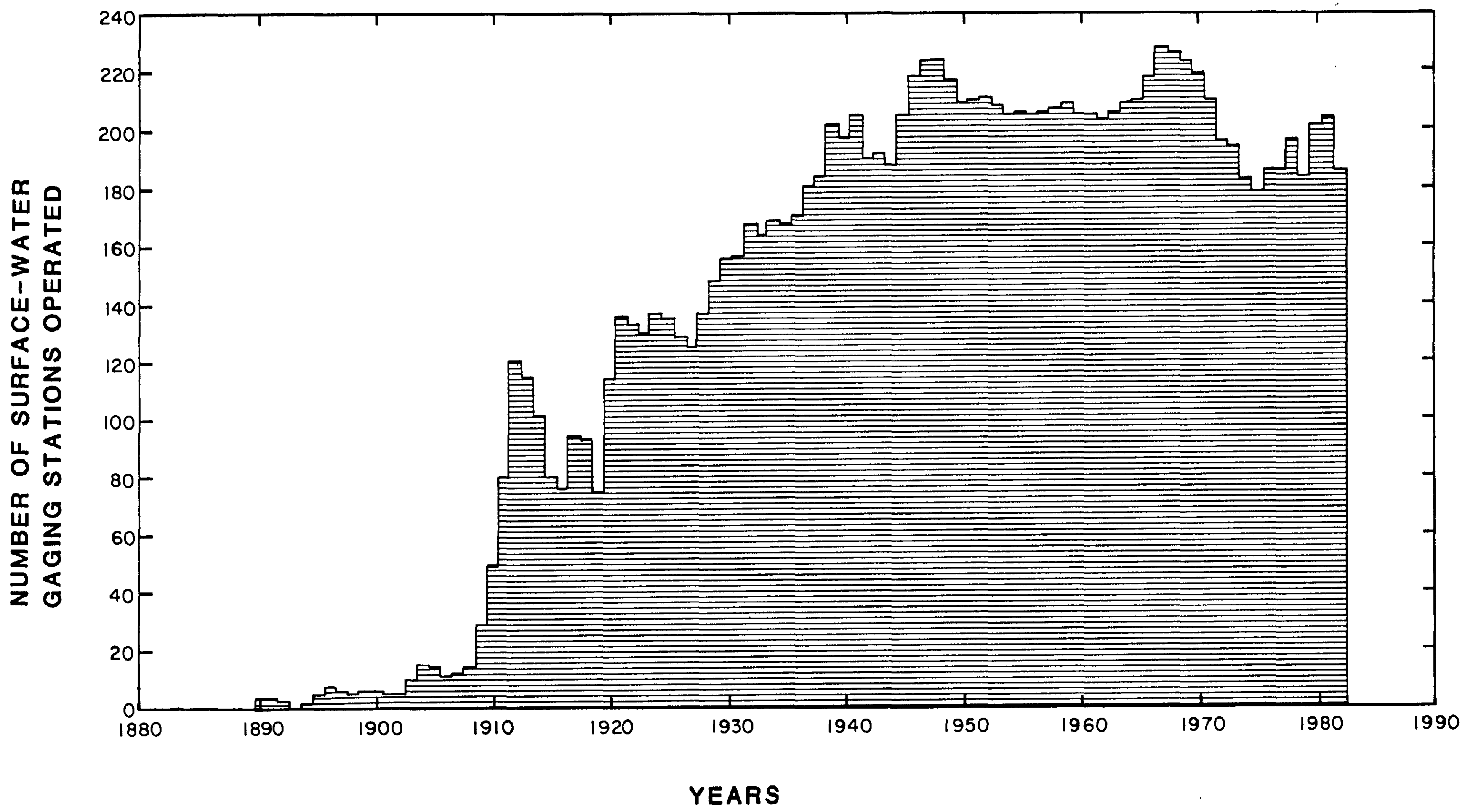

Figure 1.--History of stream gaging in Idaho.

Columbia Plateau, Middle Rocky Mountain, and Basin and Range (Fenneman, 1931). Locations of these provinces are shown in figure 2. Although most of Idaho lies within the Northern Rocky Mountain province, most of the gaging stations are in the Columbia Plateau province or near the boundary between the two. Distribution of the 185 surface-water gaging stations currently operated by the Idaho Office is shown in figures 3-9. Eighty-three stations are in the Columbia Plateau province, 81 in the Northern Rocky Mountain province, 14 in the Middle Rocky Mountain province, and 7 in the Basin and Range province. Large areas in the Northern Rocky Mountain province are ungaged. Many gaging stations on the Snake River Plain, which is the eastward extension of the Columbia Plateau province, are concentrated along the Snake River and its major tributaries. Operating costs for the 185 gaging stations in fiscal year 1982 were $781,000.

Of the 185 surface-water gaging stations, 156 are continuous stream-gaging stations; the remainder are gages on lakes and reservoirs or are stream-gaging stations where only gage heights are collected and published.

Selected hydrologic data for the 185 surface-water gaging stations are given in table 1. Eight-digit station identification numbers designated by the Survey in Idaho are used throughout this report. The first two digits represent the part numbers as follows: Part 10, the Great Basin; Part 12, the Upper Columbia River Basin; and Part 13, the Snake River basin. The last six digits represent sequential downstream order.

An additional 17 gaging stations are operated in Idaho by the Utah District under terms of the Bear River Compact. These stations, in the Basin and Range and the Middle Rocky Mountain provinces, are not included in this analysis. They will be included in a similar analysis and report by the Utah District.

USES OF STREAMFLOW DATA

Relevance of a gaging station is determined by uses made of the collected data. Uses of data collected from each station in the Idaho network were surveyed and grouped into nine categories: regional hydrology, hydrologic systems, legal obligations, planning and design, project operation, hydrologic forecasts, water-quality monitoring, research, and other. Sources of funding and frequency at which data are provided also were compiled. The survey documented the importance of each station and identified 19 that could be discontinued.

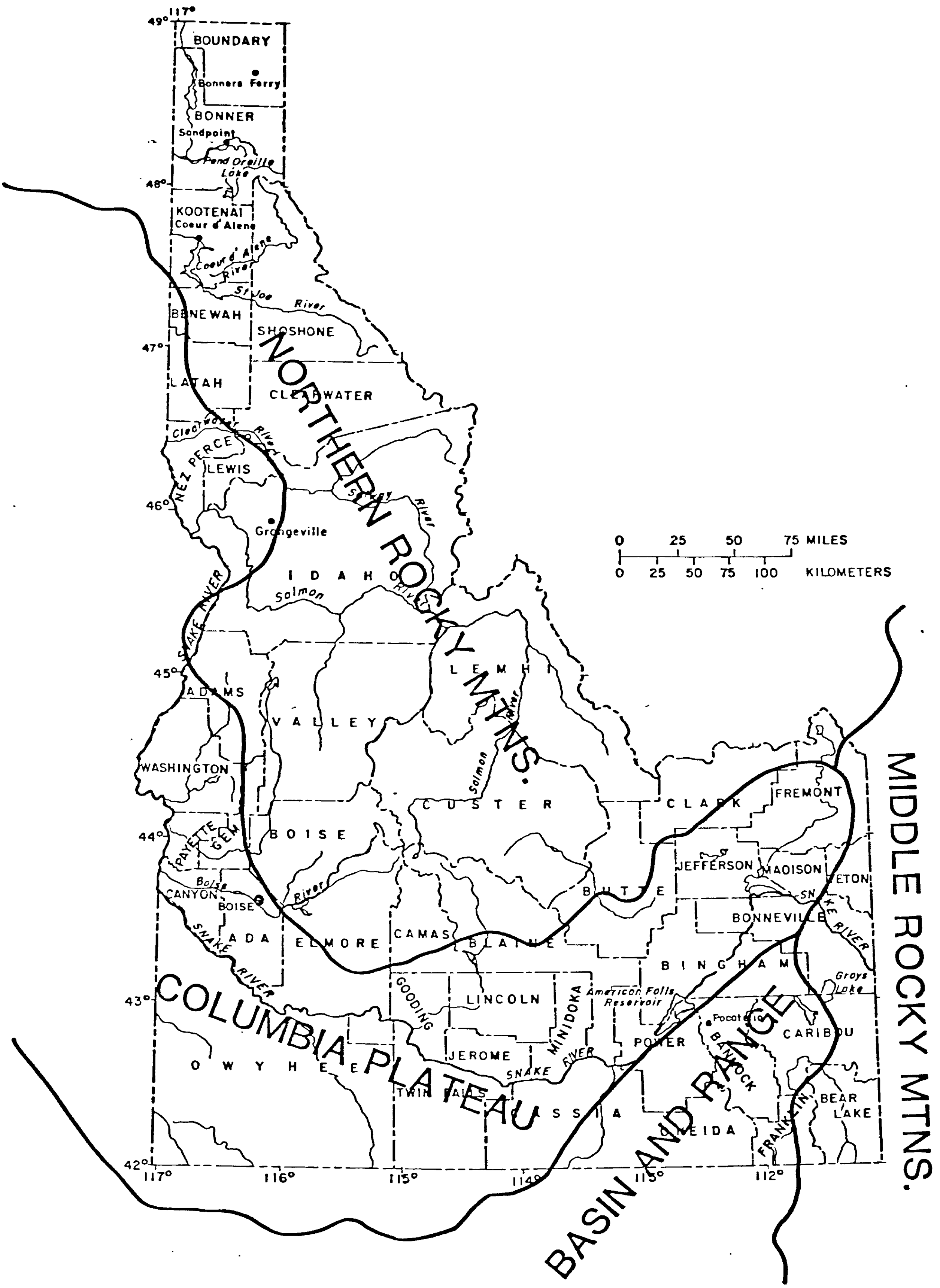

Figure 2. -- Locations of physiographic provinces in Idaho.

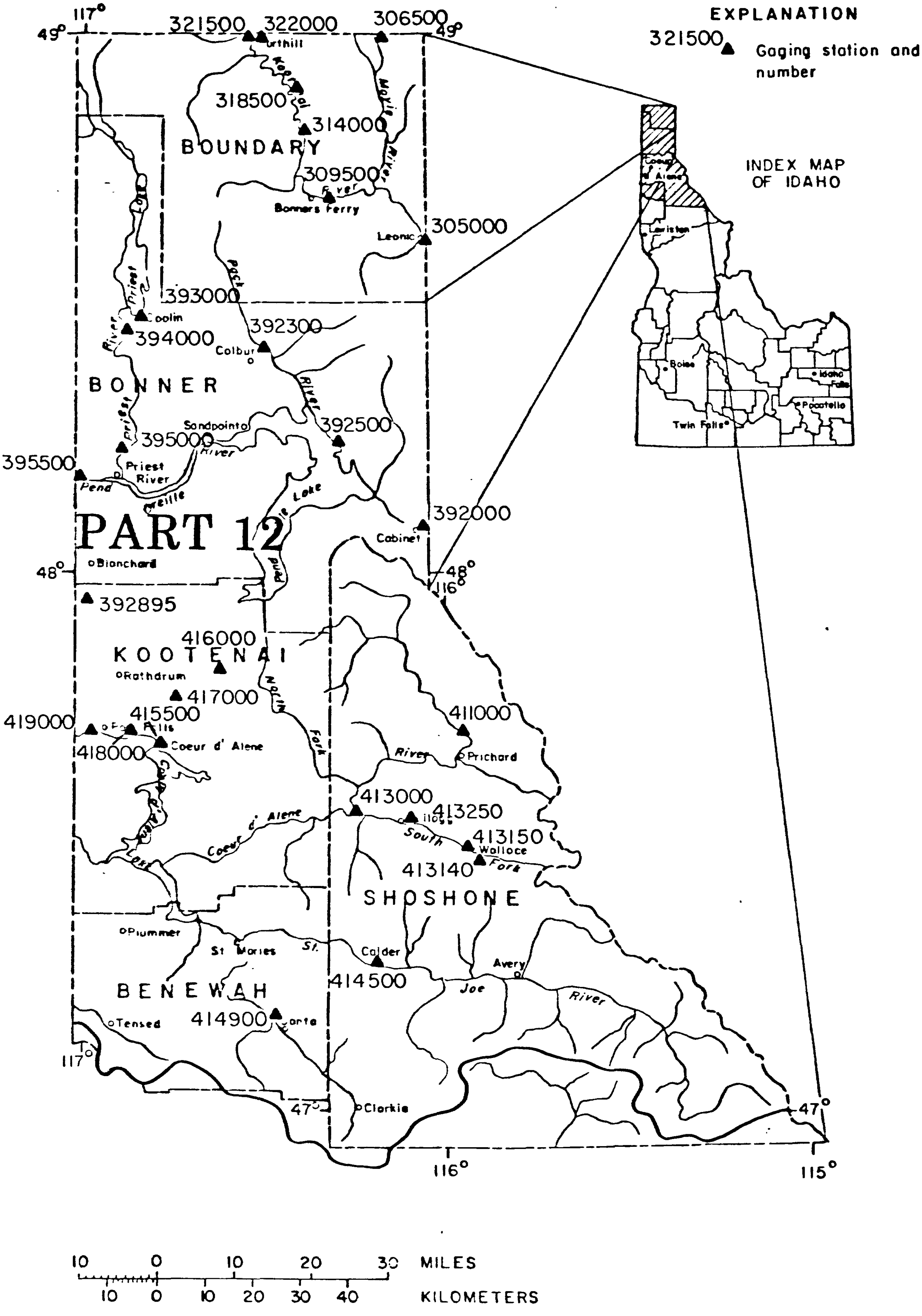

Figure 3. -- Location of surface-water stations in north Idaho.

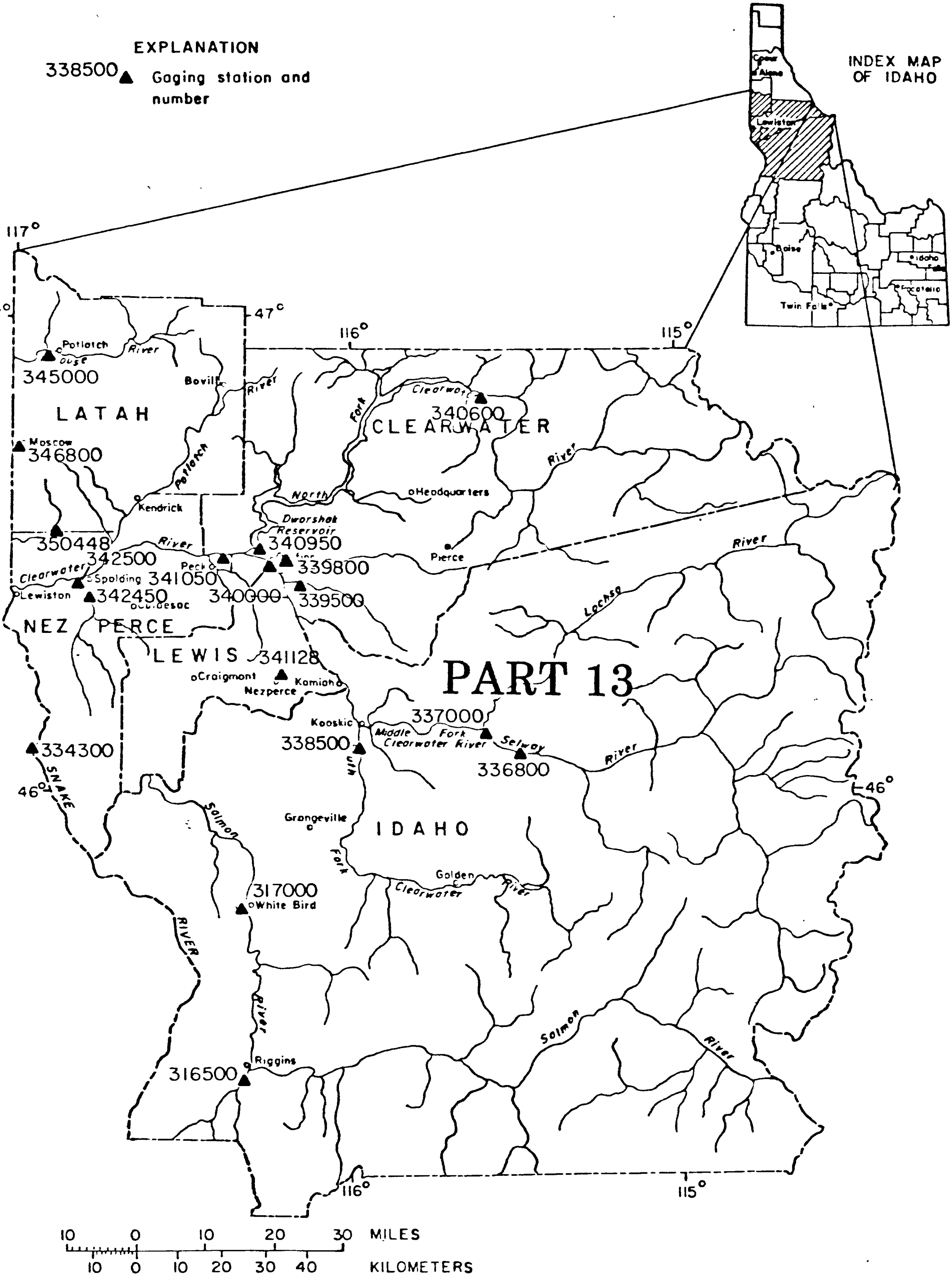

Figure 4. -- Location of surface-water stations in north-central Idaho.

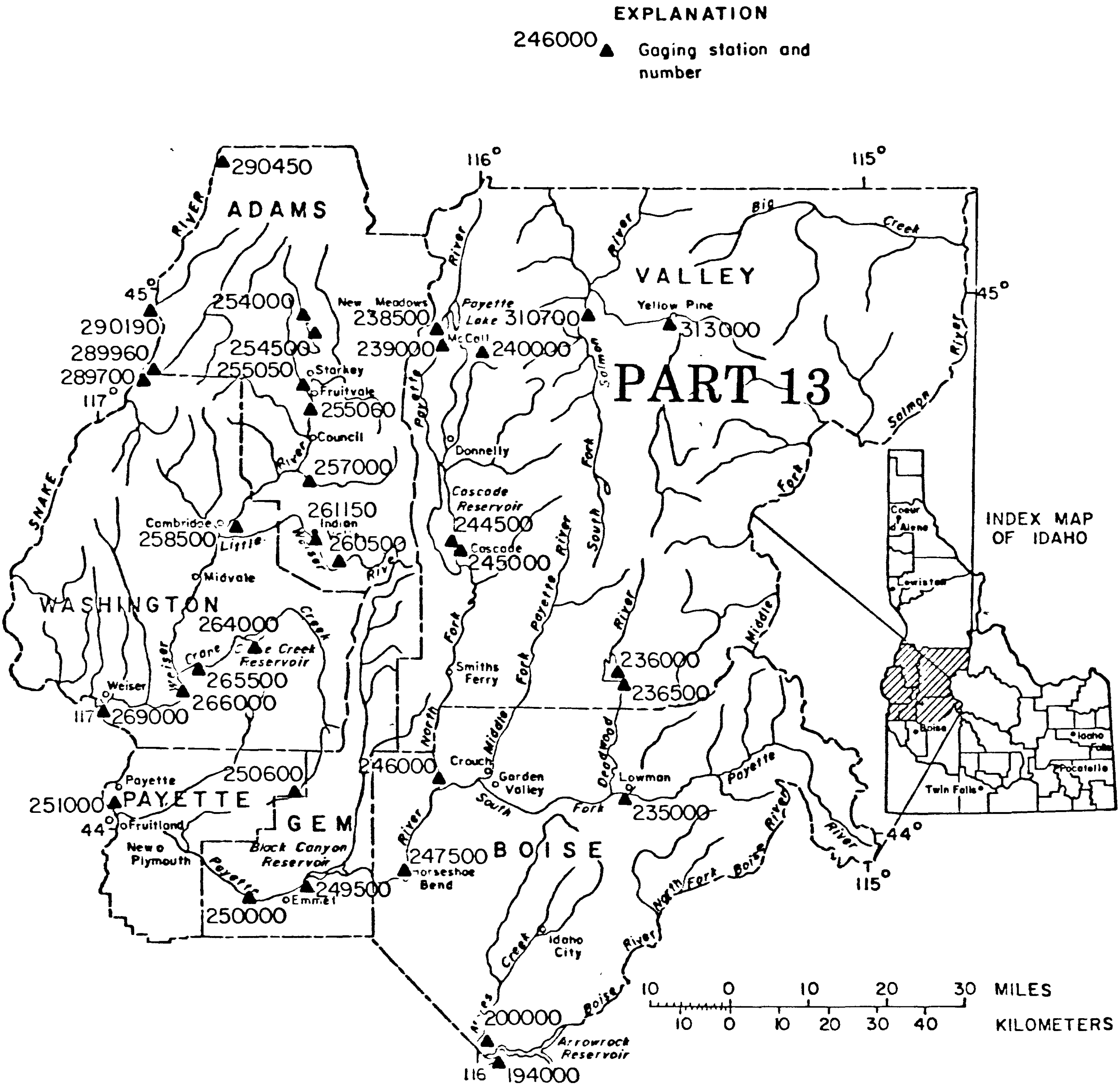

Figure 5. -- Location of surface-water stations in west-central Idaho.

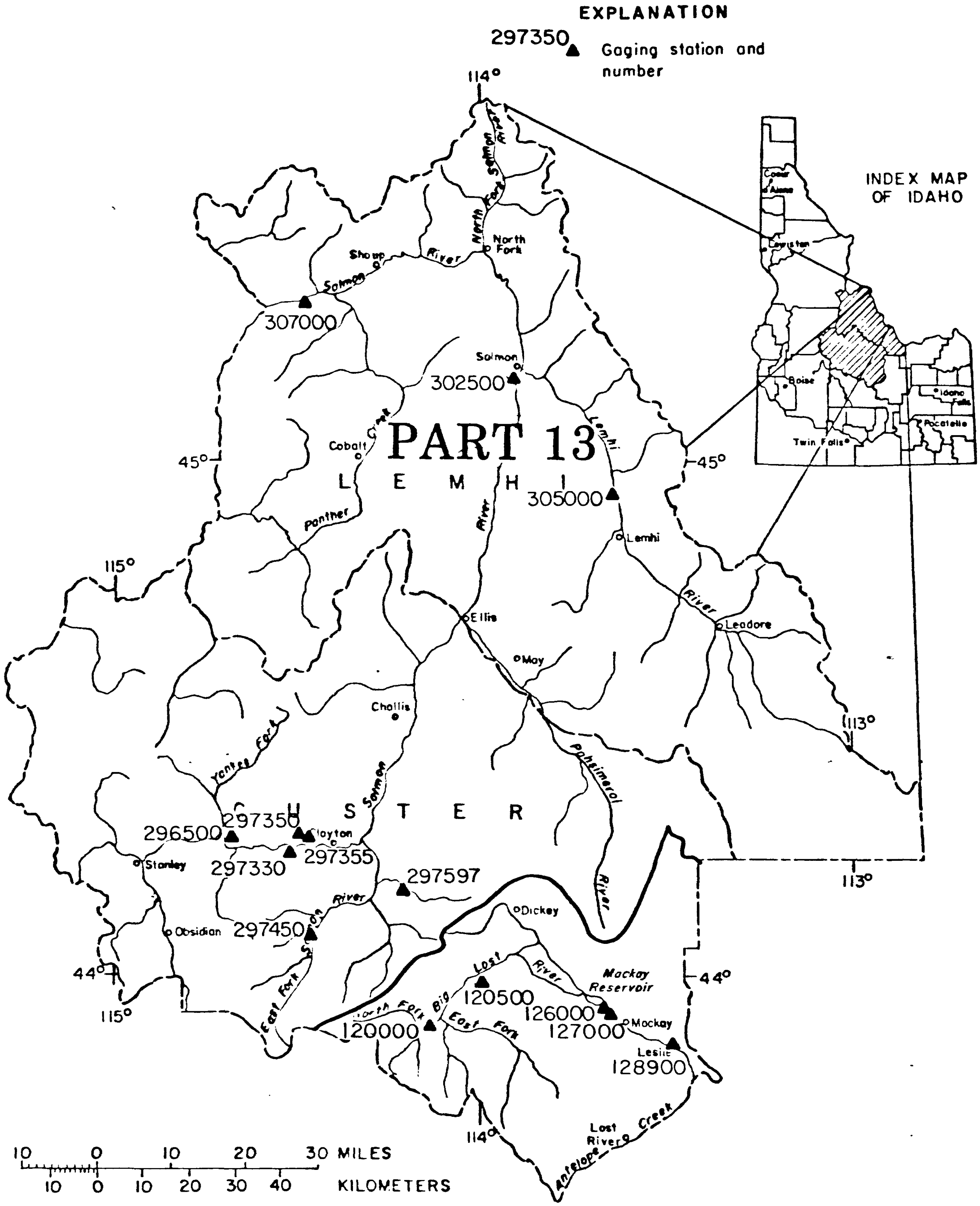

Figure 6. -- Location of surface-water stations in east-central Idaho.

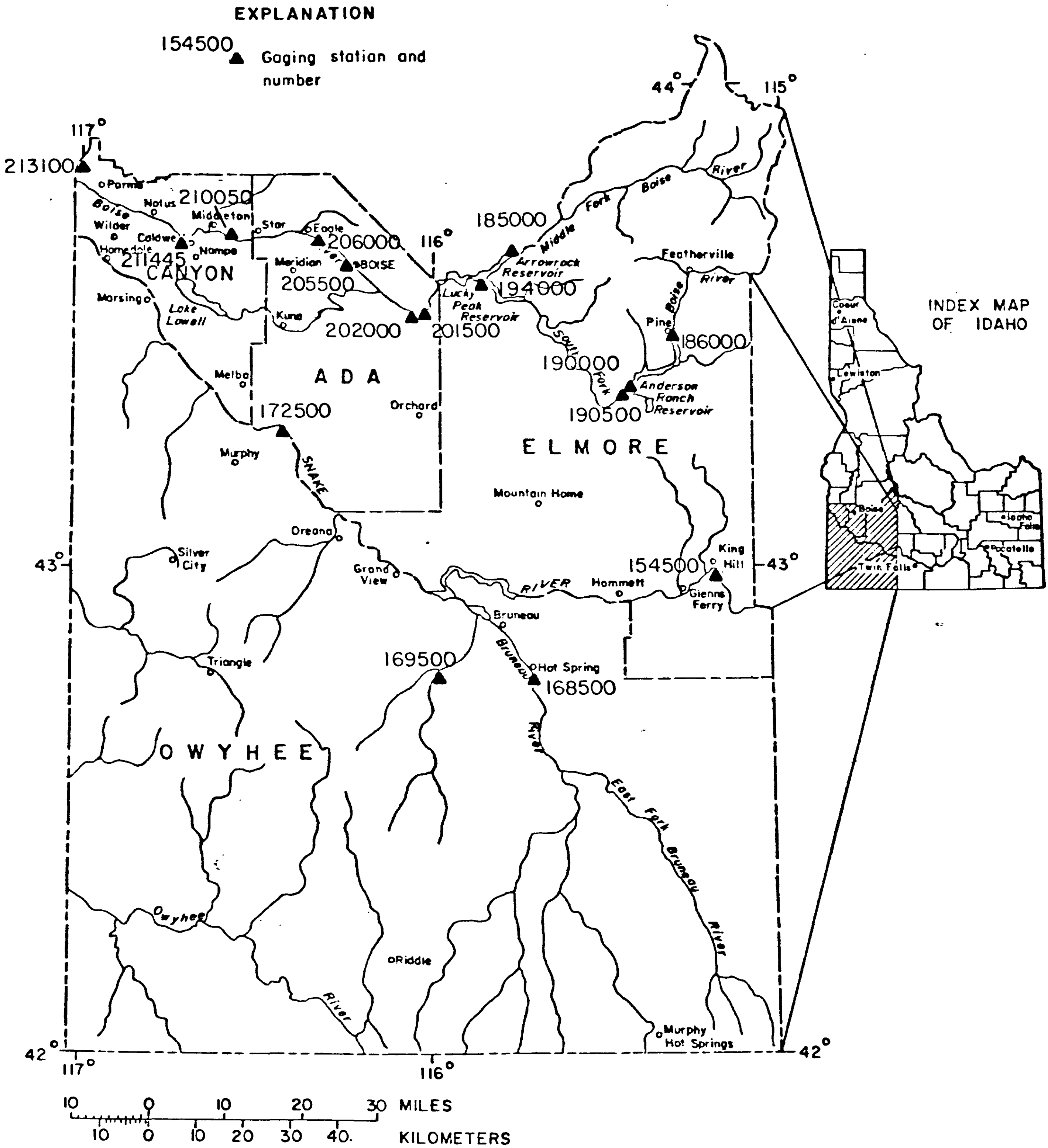

Figure 7. -- Location of surface-water stations southwest Idaho.

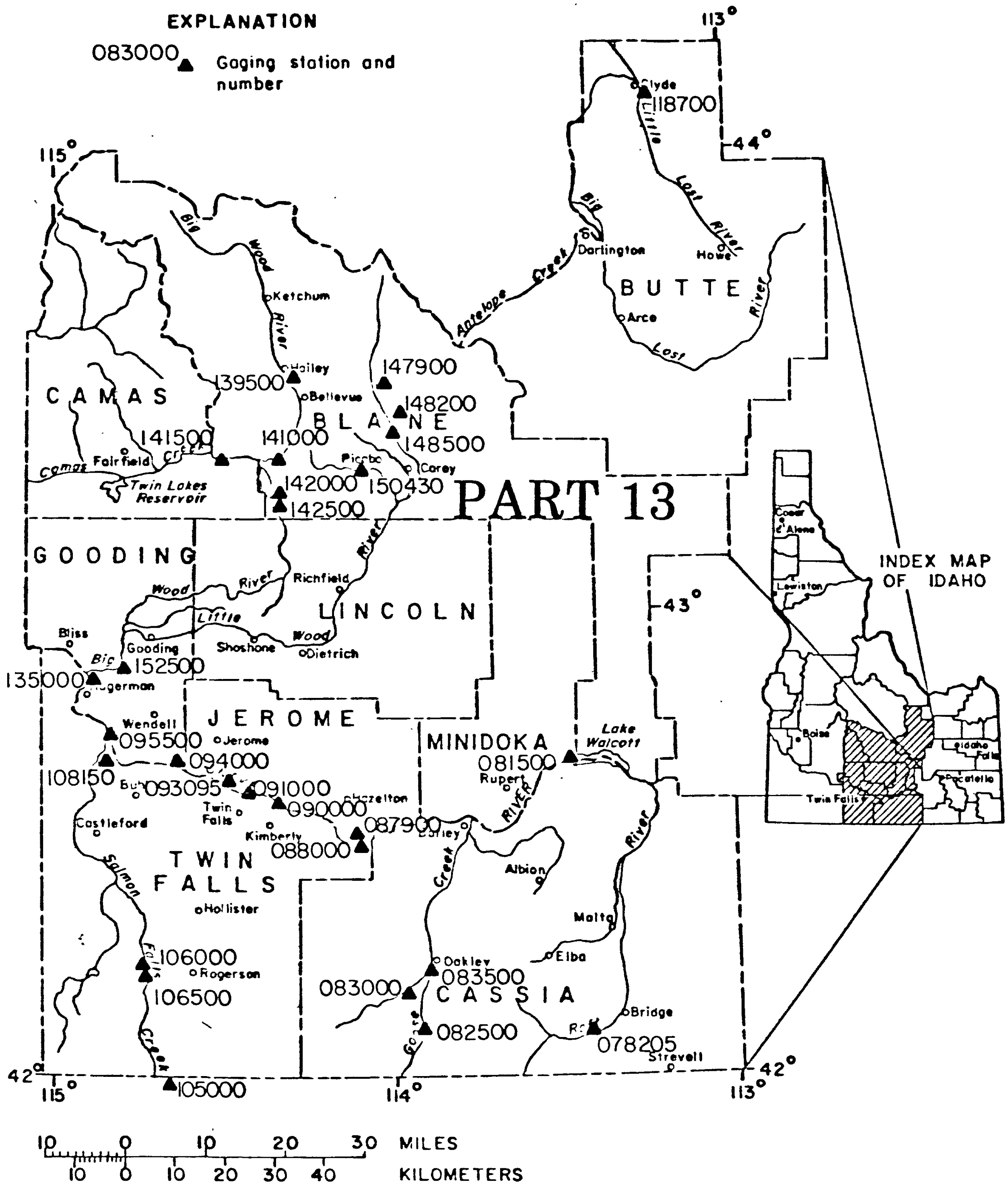

Figure 8. -- Location of surface-water stations in south-central Idaho.

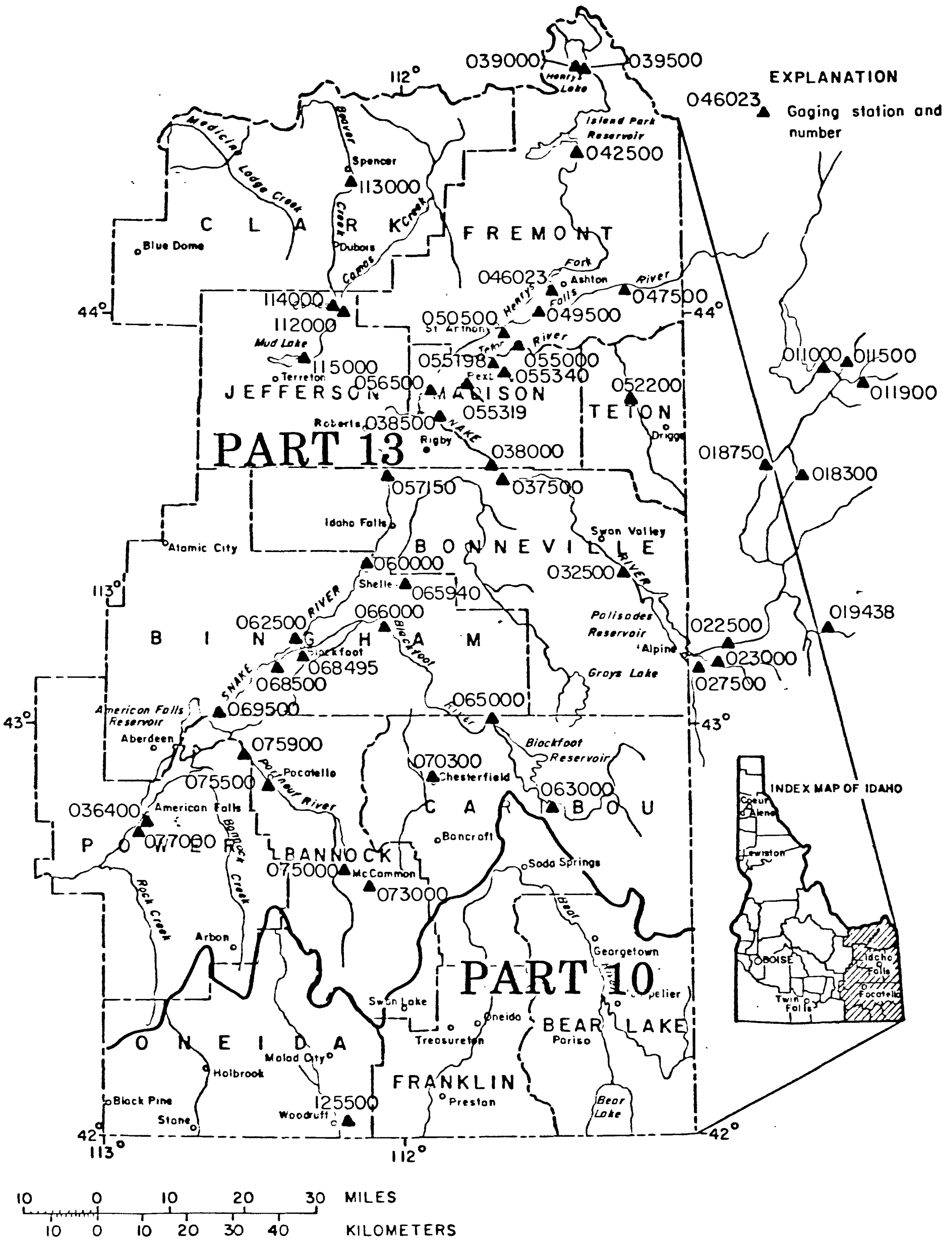

Figure 9.--Location of surface-water stations in southeast Idaho and stations in Wyoming operated by the Idaho District.

Table 1.--Selected hydrologic data for surface-water gaging stations in the Idaho network
[--, drainage area is not applicable to canals and mean annual flow is not applicable to lakes and reservoirs]

Station No.	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
10125500	Malad River at Woodruff, ID	472	1938-82	63.7
12305000	Kootenai River at Leonia, ID	11,740	1928-	13,960
12306500	Moyie River at Eastport, ID	570	[1]1915, 1916, 1929-	706
12309500	Kootenai River at Bonners Ferry, ID	13,000	[2]1904, 1927-	--
12314000	Kootenai River at Klockmann Ranch nr Bonners Ferry, ID	13,300	[3]1928, 1929, 1930-	--
12318500	Kootenai River nr Copeland, ID	13,400	1927-	15,550
12321500	Boundary Creek nr Porthill, ID	97	[4]1928-	197
12322000	Kootenai River at Porthill, ID	13,700	[5]1904, 1927, 1928-	15,960
12392000	Clark Fork at Whitehorse Rapids nr Cabinet, ID	22,073	1928-	22,390
12392300	Pack River nr Colburn, ID	124	1958-82	320
12392500	Pend Oreille Lake at Hope, ID	22,900	[6]1914-	--
12392895	Blanchard Creek ab Reservoir, nr Blanchard, ID	31.46	[7]1979-	--
12393000	Priest Lake at outlet nr Coolin, ID	572	[8]1911-13, 1928-	--
12394000	Priest River nr Coolin, ID	611	1948-	1,296
12395000	Priest River nr Priest River, ID	902	1903-05, 1910-11, 1923, 1929-	1,660
12395500	Pend Oreille River at Newport, WA	24,200	1903-41, 1952-	25,970
12411000	Coeur d'Alene River ab Shoshone Creek nr Prichard, ID	335	1950-	719

[1] Operated as a partial year station January 1915 to December 1916.
[2] Elevations only prior to March 1928 and October 1960 to current year.
[3] Operated as a partial year station prior to April 1930. Elevations only.
[4] No winter records 1929-30.
[5] Elevations only prior to April 1928. 1924 to 1927 (gage heights only) in reports of Water Survey of Canada.
[6] Gage heights only.
[7] Miscellaneous measurements made at different sites and different datums since 1958. Non-recording gage.
[8] Fragmentary gage-height records at Coolin, published as a part of records for "Priest River at outlet of Priest Lake," at Coolin, June 1911 to September 1913. Gage-height record only April 1928 to July 1950.

Table 1.--Selected hydrologic data for surface-water gaging stations in the Idaho network--Continued

Station No.	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
12413000	Coeur d'Alene River at Enaville, ID	895	[1]1911-13, 1939-	1,926
12413140	Placer Creek at Wallace, ID	14.9	1967-	37.8
12413150	South Fork Coeur d'Alene River at Silverton, ID	108	[2]1967-	252
12413250	South Fork Coeur d'Alene River at Kellogg, ID	194	1974-82	350
12414500	St. Joe River at Calder, ID	1,030	1911-12, 1920-	2,365
12414900	St. Maries River nr Santa, ID	275	1965-	350
12415500	Coeur d'Alene Lake at Coeur d'Alene, ID	3,700	1903-	--
12416000	Hayden Creek bl North Fork nr Hayden Lake, ID	22	[3]1948-53, 1958-59, 1961-	28.6
12417000	Hayden Lake at Hayden Lake, ID	62.3	1920-	--
12418000	Rathdrum Prairie Canal nr Huetter, ID	--	1945-	--
12419000	Spokane River nr Post Falls, ID	3,840	[4]1912-	6,264
13011000	Snake River nr Moran, WY	807	[5]1903-	1,433
13011500	Pacific Creek nr Noran, WY	169	[6]1906, [7]1917-18, 1944-75, 1978-	264
13011900	Buffalo Fork ab Lava Creek nr Moran, WY	323	1906, 1917-18, [8]1944-60, 1965-	556
13018300	Cache Creek nr Jackson, WY	10.6	1962-	13.4
13018750	Snake River bl Flat Creek nr Jackson, WY	2,627	1975-	3,279
13019438	Little Granite Creek nr Bondurant, WY	([9])	1982-	--

[1] Fragmentary, published as "North Fork of Coeur d'Alene River at Enaville."
[2] Nonrecording gage.
[3] Annual maximum only September 1961 to September 1965.
[4] Monthly discharge only prior to January 1913.
[5] Monthly discharge only for some periods, published in WSP 1317.
[6] Gage heights only.
[7] No winter record.
[8] At sites about 4 miles downstream.
[9] Drainage area not determined.

Table 1.--Selected hydrologic data for surface-water gaging stations in the Idaho network--Continued

Station No.	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
13022500	Snake River ab Reservoir nr Alpine, WY	3,465	1937-39, 1953-	4,531
13023000	Greys River ab Reservoir nr Alpine, WY	448	1917, [1]1918, 1937-39, 1953-	647
13027500	Salt River ab Reservoir nr Etna, WY	829	1953-	766
13032500	Snake River nr Irwin, ID	5,225	1935, [1]1936, 1949-	6,558
13037500	Snake River nr Heise, ID	5,752	1910-	6,925
13038000	Dry Bed nr Ririe, ID	(2)	1923-27, [3]1970-72, [4]1976-	--
13038500	Snake River at Lorenzo, ID	5,810	1978-	--
13039000	Henrys Lake nr Lake, ID	99	1923-	--
13039500	Henrys Fork nr Lake, ID	99.3	[5]1920-	52.5
13042500	Henrys Fork nr Island Park, ID	481	1933-	598
13046023	Henrys Fork nr Ashton, ID	1,040	[6]1890-91, 1902-09, 1920-	1,459
13047500	Falls River nr Squirrel, ID	326	[7]1902-09, 1918-	774
13049500	Falls River nr Chester, ID	520	[8]1920-	754
13050500	Henrys Fork at St. Anthony, ID	1,770	[8]1919-	1,904
13052200	Teton River ab South Leigh Creek nr Driggs, ID	335	1961-	398
13055000	Teton River nr St. Anthony, ID	890	[9]1890-93, 1903-09, 1920-76, 1977-	807
13055198	North Fork Teton River at Teton, ID	(2)	1977-	290
13055319	Moody Creek nr Rexburg, ID	(2)	[10]1979-	--

[1]Partial year record.
[2]Drainage agea not determined.
[3]Miscellaneous measurements only. Formerly published as "Great Feeder Canal."
[4]Irrigation seasons only prior to 1977.
[5]Irrigation seasons only prior to October 1929.
[6]Seasonal records only 1920-26.
[7]Gage heights only prior to 1904.
[8]Irrigation seasons only prior to 1962.
[9]Irrigation seasons only 1920-21, 1923-33. Destroyed by flood of June 5, 1976 (Teton Dam failure).
[10]Nonrecording gage.

Table 1.--Selected hydrologic data for surface-water gaging stations in the Idaho network--Continued

Station No.	Station name	Drainage area (mi²)	Period of record	Mean annual flow (ft³/s)
13055340	South Fork Teton River at Rexburg, ID	(1)	1982-	--
13056500	Henrys Fork nr Rexburg, ID	2,920	1909-	2,034
13057150	Snake River at Lewisville, ID	9,100	1978-	--
13060000	Snake River nr Shelley, ID	9,790	[2]1915-	5,637
13062500	Snake River at Blackfoot, ID	9,950	1978-	--
13063000	Blackfoot River ab Reservoir nr Henry, ID	350	[3]1914-25, 1967-82	164
13065000	Blackfoot Reservoir nr Henry, ID	581	[4]1912-25, 1929-	--
13065940	Wolverine Creek nr Goshen, ID	(1)	[5]1973, 1975-78, 1979-	--
13066000	Blackfoot River nr Shelley, ID	909	[6]1909-50, 1975-	348
13068495	Blackfoot River Bypass nr Blackfoot, ID	(1)	1964-	--
13068500	Blackfoot River nr Blackfoot, ID	1,295	[7]1913-	191
13069500	Snake River nr Blackfoot, ID	11,310	1910-	4,762
13070300	Portneuf Reservoir at Chesterfield, ID	100	[8]1979-	--
13073000	Portneuf River at Topaz, ID	570	1913-15, 1919-	197
13075000	Marsh Creek nr McCammon, ID	353	1954-	83.8
13075500	Portneuf River at Pocatello, ID	1,250	1897, 1898-99, 1911-	268
13075900	Fort Hall Michaud Canal nr Pocatello, ID	--	[9]1964-82	40.5
13076400	Michaud Canal at American Falls, ID	--	[9]1957-82	31

[1] Drainage area not determined.
[2] Irrigation season only prior to 1931.
[3] No winter records except water year 1915.
[4] No winter records 1949-59.
[5] Nonrecording gage.
[6] Irrigation season only May 1926 to September 1950.
[7] Summer months only prior to 1931.
[8] Nonrecording gage, miscellaneous measurements.
[9] Discharge from sparling meters at pumping station.

Table 1.--Selected hydrologic data for surface-water gaging stations in the Idaho network--Continued

Station No.	Station name	Drainage area (mi²)	Period of record	Mean annual flow (ft³/s)
13077000	Snake River at Neeley, ID	13,600	1906-	7,159
13078205	Raft River bl One Mile Creek nr Malta, ID	433	1946-53, 1955-71, 1975-	17.9
13081500	Snake River nr Minidoka, ID	15,700	1895-	6,185
13082500	Goose Creek ab Trapper Creek nr Oakley, ID	633	1911-16, 1919-	46.6
13083000	Trapper Creek nr Oakley, ID	53.7	1911-16, 1919-	15
13083500	Oakley Reservoir nr Oakley, ID	729	[1]1912-	--
13087900	Lake Milner at Milner Dam, ID	17,180	1974-	--
13088000	Snake River at Milner, ID	17,180	1909-	2,465
13090000	Snake River nr Kimberly, ID	(2)	1923-	2,869
13091000	Blue Lakes Spring nr Twin Falls, ID	(2)	1950-	212
13093095	Rock Creek at mouth nr Twin Falls, ID	300	1975-	200
13094000	Snake River nr Buhl, ID	(2)	1946-	5,011
13095500	Box Canyon Spring nr Wendell, ID	(2)	1950-82	403
13105000	Salmon Falls Creek nr San Jacinto, NV	1,450	[3]1909-16, 1918-	140
13106000	Salmon River Canal Co. Canal nr Rogerson, ID	--	1937-	107
13106500	Salmon River Canal Co. Reservoir nr Rogerson, ID	1,610	1922-	--
13108150	Salmon Falls Creek nr Hagerman, ID	2,120	1970-	161
13112000	Camas Creek at Camas, ID	400	1925-70, 1971-82	33.9
13113000	Beaver Creek at Spencer, ID	120	1938-52, 1968-82	43
13114000	Beaver Creek at Camas, ID	510	[4]1921-82	6

[1] Nonrecording gage.
[2] Drainage area undetermined.
[3] Gage heights only September 1909 to June 1910.
[4] Flood season only 1971-81.

Table 1.--Selected hydrologic data for surface-water gaging stations in the Idaho network--Continued

Station No.	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
13115000	Mud Lake nr Terreton, ID	1,130	1921-	--
13118700	Little Lost River bl Wet Creek nr Howe, ID	440	1958-	67.5
13120000	North Fork Big Lost River at Wild Horse nr Chilly, ID	114	1944-	105
13120500	Big Lost River at Howell Ranch nr Chilly, ID	450	[1]1904-14, 1920-	322
13126000	Mackay Reservoir nr Mackay, ID	788	1919-	--
13127000	Big Lost River bl Mackay Reservoir nr Mackay, ID	313	1903-06, 1912-15, 1919-	303
13128900	Lower Cedar Creek nr Mackay, ID	8.26	[2]1963, 1964-73, 1979-	19.4
13135000	Snake River bl Lower Salmon Falls nr Hagerman, ID	([3])	1937-	8,987
13139500	Big Wood River at Hailey, ID	640	1889, 1915-	447
13141000	Big Wood River nr Bellvue, ID	824	[4]1911-	300
13141500	Camas Creek nr Blaine, ID	648	1912-21, [5]1923-25, [6]1926-	177
13142000	Magic Reservoir nr Richfield, ID	1,600	1909-	--
13142500	Big Wood River bl Magic Reservoir nr Richfield, ID	1,600	[7]1911-	458
13147900	Little Wood River ab High Five Creek nr Carey	248	1958-74, 1979-	160
13148200	Little Wood Reservoir nr Carey, ID	279	1955-	--
13148500	Little Wood River nr Carey, ID	312	[8]1904-05, 1926-42, 1943-	150
13150430	Silver Creek at Sportsman Access nr Picabo, ID	70	1974-	167

[1] No winter records 1904, 1906-14, 1920-48.
[2] Annual maximums only prior to August 1966.
[3] Drainage area not determined.
[4] No winter records prior to 1943 except water years 1916, 1921-22, 1940-41.
[5] Fragmentary.
[6] No winter records March 1926 to September 1944.
[7] No winter records 1912.
[8] Gage heights and discharge measurements only.

Table 1.--Selected hydrologic data for surface-water gaging stations in the Idaho network--Continued

Station No.	Station name	Drainage area (mi²)	Period of record	Mean annual flow (ft³/s)
13152500	Big Wood River nr Gooding, ID	2,990	[1]1916-	267
13154500	Snake River at King Hill, ID	35,800	1909-	10,720
13168500	Bruneau River nr Hot Spring, ID	2,630	1909-15, 1943-	390
13169500	Big Jacks Creek nr Bruneau, ID	253	1938-49, 1965-	3.39
13172500	Snake River nr Murphy, ID	41,900	1912, 1913-	10,980
13185000	Boise River nr Twin Springs, ID	830	1911-	1,197
13186000	South Fork Boise River nr Featherville, ID	635	1945-	783
13190000	Anderson Ranch Reservoir at Anderson Ranch Dam, ID	980	1945-	--
13190500	South Fork Boise River at Anderson Ranch Dam, ID	982	1943-	992
13194000	Arrowrock Reservoir at Arrowrock Dam, ID	2,210	1917-	--
13200000	Mores Creek ab Robie Creek nr Arrowrock Dam, ID	399	1950-	291
13201500	Lucky Peak Lake nr Boise, ID	2,680	1954-	--
13202000	Boise River nr Boise, ID	2,680	[2]1895-1916, 1950-54, 1954-	2,926
13205500	Boise River at Boise, ID	2,760	[3]1938-39, 1940-82	1,279
13206000	Boise River at Glenwood Ave. Bridge nr Boise, ID	([4])	1982-	--
13210050	Boise River nr Middleton, ID	3,050	[5]1974-	--
13211445	Indian Creek at mouth at Caldwell, ID	([4])	1981-	--
13213000	Boise River nr Parma, ID	3,970	[3]1938-39, 1971-	1,600

[1] Fragmentary October 1923 to September 1926; no winter records for water years 1923, 1936-37, 1942; irrigation seasons only for water years 1927-35.
[2] No winter records 1904-05, 1907; discharge measurements only November 1950 to September 1954.
[3] Gage heights only.
[4] Drainage area not determined.
[5] Low flows only.

Table 1.--Selected hydrologic data for surface-water gaging stations in the Idaho network--Continued

Station No.	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
13213100	Snake River at Nyssa, OR	58,700	1974-	12,430
13235000	South Fork Payette River at Lowman, ID	456	1941-	875
13236000	Deadwood Reservoir nr Lowman, ID	112	[1]1935-	--
13236500	Deadwood River bl Deadwood Reservoir nr Lowman, ID	112	1926-	233
13238500	Payette Lake at McCall, ID	144	[1,2]1921-	--
13239000	North Fork Payette River at McCall, ID	144	1908-17, 1919-	365
13240000	Lake Fork Payette River above Jumbo Creek nr McCall, ID	48.9	1945-	147
13244500	Cascade Reservoir at Cascade, ID	620	1948, 1949-	--
13245000	North Fork Payette River at Cascade, ID	626	1941-	1,036
13246000	North Fork Payette River nr Banks, ID	933	1947-	1,355
13247500	Payette River nr Horseshoe Bend, ID	2,230	1906-16, 1919-	3,245
13249500	Payette River nr Emmett, ID	2,680	1925-	2,993
13250000	Payette River nr Letha, ID	2,760	1978-	--
13250600	Big Willow Creek nr Emmett, ID	47.4	1961-82	23.8
13251000	Payette River nr Payette, ID	3,240	1935-	3,077
13254000	Lost Valley Reservoir nr Tamarack, ID	29.4	1924, 1926-66, [3]1980-	--
13254500	Lost Creek bl Lost Valley Reservoir nr Tamarack, ID	29.4	1910-14, 1920-21, 1924-29, 1930-69, [3]1980-82	39.1
13255050	West Fork Weiser River nr Fruitvale, ID	87.7	1910-13, 1919-25, 1937-49, 1981-82	--
13255060	Weiser River nr Fruitvale, ID	390	1981-82	--
13257000	Middle Fork Weiser River nr Mesa, ID	86.5	1910-13, [3]1919-21, 1937-49, 1981-82	--

[1]Gage heights only.
[2]Fragmentary prior to November 1943.
[3]Fragmentary record.

Table 1.--Selected hydrologic data for surface-water gaging stations in the Idaho network--Continued

Station No.	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
13258500	Weiser River nr Cambridge, ID	605	1939-	650
13260500	Little Weiser River bl Mill Creek nr Indian Valley, ID	81.9	1920-21,1923,1924-27,1938-71, 1973,1976-78,1981-82	--
13261150	C Ben Ross Reservoir nr Indian Valley, ID	(1)	[2]1981-82	--
13264000	Crane Creek Reservoir nr Midvale, ID	242	1923-69, [2]1979-82	--
13265500	Crane Creek at mouth nr Weiser, ID	288	1920, 1921-73, 1981-82	84
13266000	Weiser River nr Weiser, ID	1,460	1890-91,1894-96,1897,1898-99,1900-04,1910-14,1952-	1,125
13269000	Snake River at Weiser, ID	69,200	1910-	18,010
13289700	Brownlee Reservoir at Brownlee Dam, ID	72,590	1958-	--
13289960	Wildhorse River at Brownlee Dam, ID	177	1978-	--
13290190	Pine Creek nr Oxbow, OR	230	1966-	369
13290450	Snake River at Hells Canyon Dam, ID-OR line	73,300	1965-	20,390
13296500	Salmon River bl Yankee Fork nr Clayton, ID	802	[3]1921-	996
13297330	Thompson Creek nr Clayton, ID	29.1	1972-	17.3
13297350	Bruno Creek nr Clayton, ID	6.29	1971-	1.62
13297355	Squaw Creek bl Bruno Creek nr Clayton, ID	79	1972-	33.9
13297450	Little Boulder Creek nr Clayton, ID	18.4	1970-82	21.7
13297597	Herd Creek bl Trail Gulch nr Clayton, ID	110	1979-	--
13302500	Salmon River at Salmon, ID	3,760	1912-16, 1919-	1,962
13305000	Lemhi River nr Lemhi, ID	895	1938-39, 1955-63, [4]1964-	280
13307000	Salmon River nr Shoup, ID	6,270	1944-81	3,037

[1] Drainage area not determined.
[2] Nonrecording gage.
[3] Operated as high flow only station 1972-76.
[4] Annual maximum 1964-67.

Table 1.--Selected hydrologic data for surface-water gaging stations in the Idaho network--Continued

Station No.	Station name	Drainage area (mi^2)	Period of record	Mean annual flow (ft^3/s)
13310700	South Fork Salmon River nr Krassel Ranger Station, ID	330	1966-82	556
13313000	Johnson Creek at Yellow Pine, ID	213	1928-	349
13316500	Little Salmon River at Riggins, ID	576	1951-55, 1956-	819
13317000	Salmon River at Whitebird, ID	13,550	1910-17, 1919-	11,240
13334300	Snake River nr Anatone, WA	92,960	1958-	35,580
13336500	Selway River nr Lowell, ID	1,910	[1]1911-12, 1929-	3,805
13337000	Lochsa River nr Lowell, ID	1,180	1910-12, 1929-	2,899
13338500	South Fork Clearwater River at Stites, ID	1,150	1910-12, 1964-	1,097
13339500	Lolo Creek nr Greer, ID	243	[2]1911-12, 1928, 1929, 1961, 1964, 1979-	--
13339800	Orofino Creek ab Whiskey Creek nr Orofino, ID	([3])	1982	--
13340000	Clearwater River at Orofino, ID	5,580	1930-38, 1964-	8,950
13340600	North Fork Clearwater River nr Canyon Ranger Station, ID	1,360	1967-	3,631
13340950	Dworshak Reservoir nr Ahsahka, ID	2,440	1971-	--
13341050	Clearwater River nr Peck, ID	8,040	1964-	15,380
13341128	Long Hollow Creek nr Nez Perce, ID	17.66	[4]1979-	--
13342450	Lapwai Creek nr Lapwai, ID	235	1974-	85.7
13342500	Clearwater River at Spalding, ID	9,570	1910-13, 1924-	15,470
13345000	Palouse River nr Potlatch, ID	317	1914-19, 1966-	274
13346800	Paradise Creek at U. of I. at Moscow, ID	17.7	1978-	--
13350448	Cow Creek at Genesee, ID	34.3	[4]1979-	--

[1] Gage heights or fragmentary discharge records only.
[2] Miscellaneous measurements only 1928, 1929, 1961, 1964.
[3] Drainage area not determined.
[4] Nonrecording gage.

Regional Hydrology

Regional hydrology stations are useful in developing regionally transferable information about the relation between basin characteristics and streamflow. In this class of uses, the effects of man on streamflow are not necessarily small but are limited to those caused primarily by land-use changes.

For data to be useful in defining regional hydrology, a gage must be on a stream that is largely unaffected by manmade storage or diversion. Large amounts of manmade storage may exist in the basin, provided that the outflow is uncontrolled.

Eighty-six stations in the Idaho network compose the regional hydrology data-use category (fig. 10). Seven stations are hydrologic benchmark or index stations. Three are benchmark stations that report hydrologic conditions in watersheds relatively free of manmade alteration; four are index stations that represent current hydrologic conditions in the State for comparison with the median of monthly and yearly discharge for the period 1941-70. Most stations in this category have other uses and are also included in other categories.

Hydrologic Systems

Hydrologic systems stations can be used to determine the flux of water through a basin, including regulated systems. Diversion and return-flow data collected from these stations are used to define interaction of water systems.

Benchmark and index stations are included in the hydrologic systems data-use category because they account for current and long-term conditions of the hydrologic systems that they gage. Nine Federal Energy Regulatory Commission stations are included. Data collected at these stations are used to monitor the compliance of control structures with downstream flow requirements determined by the Federal Energy Regulatory Commission.

Six other stations also are included in this category: four provide data used in conjunction with a study on impacts of mining, one is operated in support of the Bear River Compact, and one furnishes data to a municipal water supplier.

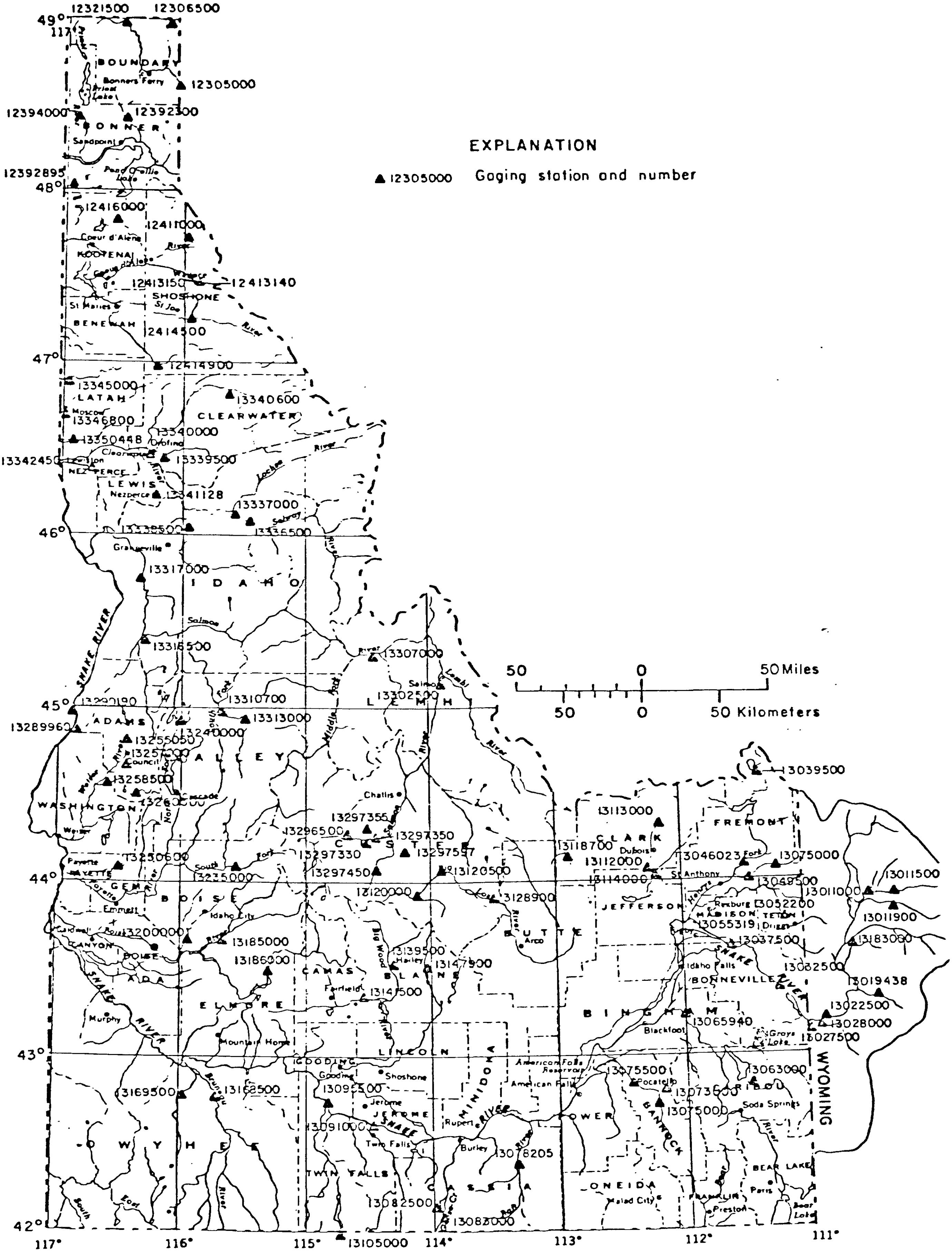

Figure 10. -- Locations of regional hydrology stream gages.

Legal Obligations

Stations in the legal obligation data-use category provide information for verification or enforcement of existing treaties, compacts, and decrees.

Three stations in the Idaho network are operated in support of the Boundary Waters Treaty of 1909 with Canada. The treaty does not specifically charge the U.S. Geological Survey with the responsibility of gaging flow in streams that cross the United States-Canadian boundary, but the International Joint Commission on Waterways has contracted with the Survey to provide streamflow data and technical advice on international matters related to water resources.

Planning and Design

Gaging stations that compose the planning and design data-use category provide information for projects involving construction of dams, levees, floodwalls, navigation systems, water-supply diversions, hydropower plants, and waste-treatment facilities. These stations are discontinued as the projects are completed. Currently, data from 43 stations in the Idaho network are used for planning and designing various hydraulic structures.

Project Operation

Project operation stations provide data to assist water managers in making decisions concerning reservoir releases, hydropower operations, and diversions. This category of data use is routinely available to water managers on a rapid-reporting basis. For projects on large streams, data may be needed only every few days.

Eighty-four stations in the Idaho network compose the project operation category. Most of these stations provide data to aid operators in managing control structures that are part of hydropower production, irrigation, and flood-control systems. Twelve stations provide data for projects concerning fish habitat, one provides data for regulating streamflow for navigation, and one provides baseline data on basin sediment and water yield.

Hydrologic Forecasts

Hydrologic forecasting stations regularly provide information for forecasting floods, determining inflow to reservoirs that are part of a hydropower generating station, or determining basin yield. These data are routinely available to forecasters on a rapid-reporting basis. On large streams, data may be needed only every few days.

In Idaho, 78 stations compose this data-use category. The data are used by the U.S. National Weather Service, the U.S. Army Corps of Engineers, and the U.S. Soil Conservation Service. Additionally, the National Weather Service uses data from some stations to predict probability of snowmelt floods.

Water-Quality Monitoring

Gaging stations on streams where water-quality or sediment-transport data are collected compose the water-quality monitoring data-use category. Three are benchmark stations and seven are NASQAN (National Stream-Quality Accounting Network) stations. Water-quality samples from benchmark stations represent characteristics of streams that are and probably will continue to be relatively unimpacted by man's activities. NASQAN stations are part of a nationwide network designed to assess water-quality trends in selected streams. Thirty-eight stations provide data for Idaho's water-quality monitoring program, one provides data for Washington's program, two provide data for Wyoming's program, and one provides data for Canada's program. Also, one station provides data for the U.S. Forest Service's assessment of environmental impact from development of petroleum resources.

Research

Research stations provide data for specific water-investigation studies. Typically, these stations are operated for only a few years.

Data from thirteen stations in the Idaho network support research activities, including federally funded interpretive studies of the Coeur d'Alene and Spokane River systems and research related to environmental impact of mining. Additionally, the Departments of Engineering and Entomology, University of Idaho, are conducting research on methodology of constructing flow-duration curves for ungaged basins and effects of regulated flow on fish habitat.

Other

In addition to the eight categories described, 14 stations provide streamflow information for recreation and fishing. Fifty-four stations provide streamflow information for adjudication of water rights or for compliance with court decrees on established water rights. Two stations provide information to private companies who resolve litigation concerning impact of their operations on water quality.

Funding

Sources of funding for Idaho's stream-gaging network are:

1. Federal.--Funds directly allocated to the U.S. Geological Survey.

2. OFA (Other Federal Agency).--Funds transferred to the U.S. Geological Survey by other Federal agencies. Funds in this category are not matched by U.S. Geological Survey cooperative funds.

3. Cooperative.--Funds contributed jointly by the U.S. Geological Survey and a non-Federal agency. Cooperating agency funds may be in the form of direct services or cash.

4. Other non-Federal.--Funds provided entirely by a non-Federal agency or a private concern under the auspices of a Federal agency. Other non-Federal funding mentioned in this report was limited to licensing and permitting requirements for hydropower development by the Federal Energy Regulatory Commission. Funds in this category are not matched by U.S. Geological Survey cooperative funds.

Frequency of Data Availability and Uses of Data

Streamflow data may be furnished to users by direct-access telemetry equipment for immediate use, by periodic release of provisional data, or by data reports published annually (U.S. Geological Survey, 1983). Data for all 185 surface-water gaging stations in the 1982 network were published in the annual report, data from 67 stations were available on a real-time basis, and data from 44 stations were released on a provisional basis. Uses of data and funding for surface-water gaging stations are presented in table 2.

Table 2.--Uses of data and funding for surface-water gaging stations

Station No.	Uses									Funding				Data availability
	Regional hydrology	Hydrologic systems	Legal obligations	Planning and design	Project operation	Hydrologic forecasts	Water-quality monitoring	Research	Other	Federal program	OFA program	Coop program	Other non-Federal	
10125500		12										1		A
12305000	21					13				*				A,T
12306500	21		15	14							2			A,P
12318500					16		18			*				A,P
12321500	21		15								2			A,P
12322000			15		16		17				2			A,P
12392000		19					20					3		A
12392300	21	23					20					1		A
12392895	21											1		A
12394000	21	26			24	25					5			A
12395000		26				22	20				7			A,T
12395500					27		28				5			A,P
12411000	21				29	30				*				A,T
12413000					29	30	20	32			5			A,T
12413140	21			31						5				A,P
12413150	21	33		31		34					5			A
12413250		35					20					1		A
12414500	21	33		36	38	37	20				7			A,T
12414900	21	33				34	20					1		A
12416000	21	39					40			*				A
12418000					42							1		A,P
12419000		33				34	20	41				1		A
13011000	21	44			43	13			45		8			A,T,P
13011500	21	44			43	13					8			A,T,P
13011900	21				43	13					8			A,T,P
13018300	21	47					40		49	*				A,P
13018750					43	13			46		8			A,T,P
13019438	21			48			50		49		9			A,P
13022500	21	44			43		51		45		8			A,T,P
13023000	21	44			43				45		8			A,T,P

See footnotes at end of table.

Table 2.--Uses of data and funding for surface-water gaging stations--Continued

Station No.	Uses: Regional hydrology	Uses: Hydrologic systems	Uses: Legal obligations	Uses: Planning and design	Uses: Project operation	Uses: Hydrologic forecasts	Uses: Water-quality monitoring	Uses: Research	Uses: Other	Funding: Federal program	Funding: OFA program	Funding: Coop program	Funding: Other non-Federal	Data availability
13027500	54	44			43		51		52		8			A,T,P
13032500	21	44		53	43	13			45		8			A,T,P
13037500	21	44		53	43	55	18		45	*				A,T,P
13038000		44			43	13			52			1		A,T,P
13038500		44		53	56	55			52		8			A,T,P
13039500	21	44			43				52			1		A,T,P
13042500		44		57	43	55			45		8			A,T,P
13046023	21	44				55			52			1		A,T,P
13047500	21	44				55			52			1		A,T,P
13049500	21	44			43				52		8	1		A,T,P
13050500		44			43	13	20		52		8	1		A,T,P
13052200	21	44			43	55			52			1		A,T,P
13055000		44			58	55	20		52			1		A,T,P
13055198		44			59				52			1		A
13055319	21	44										1		A
13055340		44			59				52			1		A
13056500		44			58	55	20		52			1		A,T,P
13057150		44							52			1		A,P
13060000		44			58	13			52			1		A,T,P
13062500		44			60	55	20		52			1		A,T,P
13063000	21	44			61		20					1		A
13065940	21	44			61							1		A
13066000		44		57	61	41			52			1		A,P
13068495		44			60							1		A,T,P
13068500		44			61		20					1		A,P
13069500		44			43	55			52			1		A,T,P
13073000	21	44			43	55						1		A,T
13075000	62	44										1		A
13075500	21	44		63	61	55	20					1		A,T,P
13077000		44		57	43	13			52		8			A,T,P

See footnotes at end of table.

Table 2.--Uses of data and funding for surface-water gaging stations--Continued

Station No.	Uses: Regional hydrology	Uses: Hydrologic systems	Uses: Legal obligations	Uses: Planning and design	Uses: Project operation	Uses: Hydrologic forecasts	Uses: Water-quality monitoring	Uses: Research	Uses: Other	Funding: Federal program	Funding: OFA program	Funding: Coop program	Funding: Other non-Federal	Data availability
13078205	21	44		64								1		A
13081500		44			65	13	20		52		8			A,T,P
13082500	21	44							52			1		A
13083000	21	44				34			52			1		A
13088000		44		57	65	13			52			1		A,T,P
13090000		66		57									4	A
13091000	67	44										1		A
13093095				57			68		69			1		A
13094000		44		57								1		A
13095500	67	44										1		A
13105000	21				70	34						1		A
13106000					70							1		A
13108150		44					20					1		A
13112000	21	44		71	72	34					6			A
13113000	21	44			72	34						1		A
13114000	21	44		71	72						6			A
13118700	21	44			73	34						1		A
13120000	54	44		74		34						1		A
13120500	21	44		74	75	34						1		A
13127000		44		74	75	34	20					1		A
13128900	21										10			A
13135000		76											4	A
13139500	21					55			52			1		A,T
13141000		44				34			52			1		A
13141500	21	44				34			52			1		A
13142500		44		77		13			52			1		A
13147900	21	44			63				52		6			A
13148500		44			65	55			52			1		A,T
13150430		44										1		A
13152500		44			78							1		A

See footnotes at end of table.

Table 2.--Uses of data and funding for surface-water gaging stations--Continued

Station No.	Uses									Funding				Data availability
	Regional hydrology	Hydrologic systems	Legal obligations	Planning and design	Project operation	Hydrologic forecasts	Water-quality monitoring	Research	Other	Federal program	OFA program	Coop program	Other non-Federal	
13154500		79					18						4	A,T
13168500	21	44				55	20		80			1		A,T
13169500	21						40			*				A
13172500		81					20		52			1	4	A,T
13185000	21	82		84	83	34	20		52			1		A,T
13186000	21	82		84	83				52		8			A,T
13190500		82			85	55			52		8			A,T
13200000	21				83	34	20				6			A,T
13202000		82		57	83	55			52		6			A,T
13205500		82			63				52		6			A
13206000		82			83	13			52		6			A,T
13210050		82							52			1		A
13211445		82										1		A
13213000		82			83		20		52			1		A,T
13213100		44										1		A
13235000	21	82			86	13						1		A,T
13236500		82		84	86	55					8			A,T
13239000		82			87							1		A,T
13240000	21	82				34			52			1		A
13245000		88		84		55							4	A,T
13246000		82		90		34			46			1		A
13247500		82			86	55					8	1		A,T
13249500		82			86	13						1		A,T
13250000		82							52			1		A
13250600	21					34				*				A
13251000		82					20					1		A,P
13254500		82		90								1		A
13255050	21	82		90								1		A
13255060		82		90								1		A
13257000	21	82		90								1		A

See footnotes at end of table.

Table 2.--Uses of data and funding for surface-water gaging stations--Continued

Station No.	Uses: Regional hydrology	Hydrologic systems	Legal obligations	Planning and design	Project operation	Hydrologic forecasts	Water-quality monitoring	Research	Other	Funding: Federal program	OFA program	Coop program	Other non-Federal	Data availability
13258500	21	82		90		13	20		69			1		A,T
13260500	21			90					69			1		A
13265500		82				34	20		69			1		A
13266000		82		90	91	55	20		69			1		A,T
13269000		44			63	55	18		52	*	7			A,T
13289960	21	92											4	A
13290190	21	93											4	A
13290450		93			94	13	18		80				4	A,T
13296500	21						20					1		A
13297330	21			95			95					1		A,P
13297350	21			95			95					1		A,P
13297355	21			95			95					1		A,P
13297450	21							96		*				A
13297597	21			97							10			A
13302500	21	98				55	20		80			1		A
13305000		98				34	20					1		A
13307000	21	98										1		A
13310700	21				99			100			9			A
13313000	54							100				1		A
13316500	21			57	101	55		100				1		A,T
13317000	21	98			91	55	18		80	*	7			A,T
13334300		44		102	91	13					6			A,T
13336500	21				103	55		100	80		6			A,T
13337000	21				103	55		100			6			A,T
13338500	21				103	55	20	100			6			A,T
13339500	21			57	104						10			A
13339800				57							11			
13340000	21				105	55	20	106			6			A,T
13340600	21				105	55		100	80		6			A,T
13341050					105	13		106			6			A,T
13341128	21											1		A
13342450	21						20					1		A
13342500		108			109	55	18	106			6			A,T
13345000	21					34	20					1		A
13346800	21	111										1		A
13350448	21			110								1		A

Table 2.--Uses of data and funding for surface-water gaging stations--Continued

Funding

1. Idaho Department of Water Resources.
2. International Joint Commission on Waterways (Department of State).
3. Federal Energy Regulatory Commission.
4. U.S. Army Corps of Engineers - Seattle.
5. U.S. Army Corps of Engineers - Walla Walla.
6. Bonneville Power Administration.
7. U.S. Bureau of Reclamation (Harold Brush, Rm 436).
8. U.S. Department of Agriculture, Forest Service.
9. U.S. Bureau of Land Management.
10. City of Orofino.

Uses

11. Operated in support of Bear River Compact and hydrologic studies of basin yield.
12. Used by the National Weather Service for flood forecasting.
13. Used by the U.S. Soil Conservation Service to delineate floodway boundaries.
14. Operated under contract with the International Joint Commission on Waterways, which was established by condition of the Boundary Waters Treaty of 1909 by agreement with Canada and which is charged with the management of international waters.
15. Operated in conjunction with the gaging stations at Klockmann Ranch and at Porthill to determine inflow to Kootenay Lake, Canada, used for projects of the Kootenai Board of Control, and used in relation to operations at Libby Dam by U.S. Army Corps of Engineers.
16. Used by Canada in their water-quality-monitoring program.
17. National stream quality accounting network (NASQAN) station.
18. Operated to assure compliance with Washington Water Power Company's license conditions under project No. 2058 of the Federal Energy Regulatory Commission.
19. Operated in support of Idaho State's water-quality-monitoring program.
20. Background data used for assessment of regional hydrology.
21. Used by the National Weather Service for flood forecasting, by the U.S. Soil Conservation Service for forecasting basin yield, and by the U.S. Army Corps of Engineers for forecasting inflow to Albeni Falls hydropower project.
22. Operated in support of U.S. Army Corps of Engineers for flood control, used by Idaho State for Priest River basin studies, and used by Washington Water Power Company to determine inflow to Lake Pend Oreille.
23. Operated in support of U.S. Army Corps of Engineers for inflow forecasts to Albeni Falls hydropower project, and used by U.S. Soil Conservation Service for forecasting basin yield.
24. For inflow accounting to Lake Pend Oreille for recreational needs.
25. Operated in support of U.S. Army Corps of Engineers Albeni Falls project and for flood control project.
26. Operated in support of Idaho and Washington States' water-quality-monitoring program.
27. Used by U.S. Army Corps of Engineers for project operation of Coeur d'Alene Lake.
28. Used by the National Weather Service for flood forecasting, by the U.S. Soil Conservation Service for forecasting basin yield, and by the U.S. Army Corps of Engineers for forecasting inflow to Post Falls hydropower project.
29. Operated for planning, design, and quality assurance of channel embankment project of the U.S. Army Corps of Engineers at Wallace, Idaho.
30. Operated in support of U.S. Army Corps of Engineers for interpretive studies of Coeur d'Alene River system.
31. Used by U.S. Soil Conservation Service for watershed study.
32. Used by the State of Idaho for streamflow accounting in the Coeur d'Alene River system.
33. Used by U.S. Soil Conservation Service for forecasting basin yield.
34. Operated in support of Idaho State's studies related to the mining of mineral resources and streamflow accounting in the Coeur d'Alene River system.
35. Used by University of Idaho, Department of Civil Engineering, for planning and design of Federal Highway project.
36. Used by U.S. Army Corps of Engineers for forecasting inflow to Lake Coeur d'Alene and to power-producing sites downstream, by the National Weather Service for flood forecasting, and by the U.S. Soil Conservation Service for forecasting basin yield.
37. Operated in support of Bonneville Power Administration for Washington Water Power Company project operations.
38. Used by Idaho State for streamflow accounting of inflow to Hayden Lake.

Table 2.--Uses of data and funding for surface-water gaging stations--Continued

39. Hydrologic benchmark station.
40. Operated in support of Idaho State for inflow to Rathdrum Prairie irrigation project.
41. Used by U.S. Army Corps of Engineers for interpretive studies of Coeur d'Alene Lake.
42. Operated in support of U.S. Bureau of Reclamation irrigation and power-production projects downstream.
43. Used by State of Idaho for Snake River basin model.
44. Used by outfitters for recreational float trips.
45. Used by the State of Idaho in compliance with a court decree to furnish streamflow data for management of water rights downstream.
46. Used by the State of Idaho in compliance with a court decree to furnish streamflow data for management of water rights downstream and used by outfitters for recreational float trips.
47. Used by city of Jackson to determine municipal water supply.
48. Used by U.S. Forest Service for determination of culvert design.
49. Used by J. H. Getty and Texaco Oil Companies to resolve a litigation process on the impact of their operations on water quality.
50. Operated in accordance with the U.S. Forest Service's assessment of environmental impact by development of petroleum resources.
51. Operated in support of the State of Wyoming's Department of Agriculture, Department of Environmental Quality, and Division of Conservation.
52. Used by the U.S. Army Corps of Engineers to design flood control levees near Heise, Idaho.
53. A key station used to correlate streamflow data collected at nearby sites for quality control.
54. Used by the National Weather Service for flood forecasting, and by U.S. Soil Conservation Service for forecasting basin yield.
55. Operated in support of U.S. Bureau of Reclamation irrigation and power-production projects downstream, and used by Idaho Department of Fish and Game for controlling minimum flows for fish habitat.
56. Operated in support of U.S. Bureau of Reclamation irrigation and power-production projects downstream, and used by U.S. Army Corps of Engineers for flood-control project.
57. Used by Idaho Department of Fish and Game for controlling minimum flows for fish habitat.
58. Operated in support of U.S. Bureau of Reclamation irrigation and power-production projects downstream, and used by Shoshone-Bannock Indians for assessment of water rights and for flood control.
59. Used by the U.S. Soil Conservation Service in a flood-plain management study of Deep Creek and Devil Creek.
60. Used by Shoshone-Bannock Indians for assessment of water rights and for flood control.
61. Used by the U.S. Soil Conservation Service for flood-abatement study.
62. Used by the U.S. Army Corps of Engineers for flood-control project.
63. Used by State of Idaho Irrigation District No. 01 for water-resource management.
64. Used by the U.S. Soil Conservation Service in the Raft River Irrigators project design.
65. Used by the U.S. Bureau of Reclamation Hydromet project to provide real-time data to downstream water users.
66. Operated to assure compliance of Idaho Power Company to meet licensing conditions under project No. 2778 of the Federal Energy Regulatory Commission.
67. Used by the State of Idaho to monitor trends in spring flow from Snake River Plain aquifer.
68. Used by the State of Idaho and U.S. Soil Conservation Service to monitor quality of irrigation-return flows.
69. Used by the State of Idaho to determine the availability of water for adjudicated water rights.
70. Operated in support of Idaho State's agreement with Salmon River Canal Company for inflow to irrigation project.
71. Operated in support of U.S. Army Corps of Engineers Mud Lake project, and by U.S. Soil Conservation Service for planning erosion control.
72. Used by Mud Lake Irrigation Company to determine storage in Mud Lake.
73. Used by U.S. Soil Conservation Service for the Little Lost River recharge study.
74. Used by the U.S. Soil Conservation Service for design of streambank stabilization.
75. Used by Big Lost River Irrigation District for water-management purposes.
76. Operated to assure compliance of Idaho Power Company to meet licensing conditions under project No. 2061 of the Federal Energy Regulatory Commission.

Table 2.--Uses of data and funding for surface-water gaging stations--Continued

77. Used by the U.S. Soil Conservation Service in designing the Richfield Canal and associated sprinkler-irrigation system.
78. Used by Big Wood River Irrigation District for water-management purposes.
79. Used by the U.S. Army Corps of Engineers for flood-control project.
80. Operated to assure compliance of Idaho Power Company to meet licensing conditions under project No. 1975 of the Federal Energy Regulatory Commission.
81. Used by the National Weather Service for reporting streamflow to recreational users.
82. Operated to assure compliance of Idaho Power Company to meet licensing conditions under project No. 503 of the Federal Energy Regulatory Commission.
83. Used by Idaho State for streamflow accounting and water management.
84. Used by U.S. Bureau of Reclamation for Boise basin hydropower and irrigation projects and by the U.S. Army Corps of Engineers for flood-control projects.
85. Used by the U.S. Bureau of Reclamation for updating design floods for dams.
86. Operated in support of the U.S. Bureau of Reclamation Boise River hydropower projects.
87. Used by the U.S. Bureau of Reclamation for Payette River hydropower project.
88. Used by the U.S. Bureau of Reclamation for Payette River hydropower project, and used by Idaho Department of Fish and Game for controlling minimum flows for fish habitat.
89. Used to assure compliance of Idaho Power Company to meet licensing conditions under project No. 2348 of the Federal Energy Regulatory Commission.
90. Used by Idaho Power Company for planning and design of proposed hydropower project.
91. Used by the State of Idaho for planning and design of proposed hydropower project.
92. Used by Bonneville Power Administration for management of power-production projects, and by the U.S. Army Corps of Engineers for flood-control project.
93. Operated to assure compliance of Idaho Power Company to meet licensing conditions under project No. 1971 of the Federal Energy Regulatory Commission.
94. Operated to assure compliance of Idaho Power Company to meet licensing conditions under project No. 1971 of the Federal Energy Regulatory Commission, used by the U.S Army Corps of Engineers for flood-control project and for regulation of downstream navigation and power production, and used by Idaho Department of Fish and Game in conjunction with anadromous fisheries project.
95. Operated in support of Idaho State's agreement with Cypress Mines, Inc., for planning and design related to mining of mineral resources.
96. Operated in support of the U.S. Geological Survey's research of background data related to impact on the environment from development of mineral resources.
97. Operated in support of the U.S. Bureau of Land Management's study of impact on the environment from development of mineral resources.
98. Operated in support of Idaho State's basin study related to mining of mineral resources and streamflow accounting in the Salmon River system.
99. Operated in support of U.S. Forest Service projects to provide information on streamflow for recreational use and baseline monitoring of sediment yield and basin runoff.
100. Used by University of Idaho, Department of Civil Engineering, for research on the methodology of flow durations in ungaged basins.
101. Used by U.S. Forest Service for studies relating to development of anadromous fisheries.
102. A key station for planning lower Snake River hydropower and flood-control projects and systemwide power-planning studies by the U.S. Army Corps of Engineers.
103. Operated in support of U.S. Army Corps of Engineers studies related to power planning and fish propagation, and project operations at Dworshak and Lower Granite Dams.
104. Operated in support of U.S. Bureau of Reclamation study of aquatic-resource protection.
105. Data were used for planning and design of proposed power site.
106. Operated in support of the U.S. Army Corps of Engineers and Bonneville Power Administration for power planning, flood control, and river fluctuations caused by releases at Dworshak Dam, and for projects related to the development of anadromous fisheries.
107. Operated in support of the U.S. Army Corps of Engineers projects to determine inflow to Dworshak Reservoir for power production, recreation, and flood control.
108. Used by University of Idaho, Department of Entomology, for research on the effects of regulated flow on fish habitat.
109. Used by the State of Idaho for streamflow accounting from the Clearwater River basin.
110. Operated in support of the U.S. Army Corps of Engineers projects to determine inflow to Lower Granite Reservoir for power production and flood control.
111. Used by the U.S. Soil Conservation Service for planning watershed project.

Data availability

* No footnote required.
A Published annually.
P Provisional records supplied.
T Telemetered.

Conclusions Pertaining to Data Uses

In 1981, as part of a pilot study done in preparation for the nationwide evaluation, Quillian and Harenberg (1982) applied the NARI (Network Analysis for Regional Information) procedure to evaluate the stream-gaging network in Idaho. NARI is a procedure to identify contributions to error reduction for a regional regression analysis of statistical streamflow characteristics expected from future stream-gaging activities. These activities include extending data collection at existing stations, establishing new stations, or various combinations of each (Moss and others, 1982). Preliminary results indicated that significant improvements in the accuracy of transferring streamflow data to ungaged sites will not be obtained by collecting more data. Stream-discharge characteristics analyzed were mean annual discharge, standard deviation of the mean annual discharge, and four flood-frequency exceedance probabilities ranging from 50 percent to 1 percent chance of occurrence. No low-flow characteristics were analyzed because previous attempts to define regression equations for estimating low-flow characteristics in Idaho were unsatisfactory (Thomas and Harenberg, 1970).

NARI results indicate that collection of data solely for use in transferring information to ungaged sites by regional regression equations is unwarranted. Therefore, stations being operated in the regional hydrology category are superfluous if their data are to be used only in this manner. One station in table 2 has regional hydrology identified as its sole data-use category. This station, 13341100, Long Hollow Creek at Nezperce, provides information on yields and flood flows in a relatively ungaged part of the State. It is also being operated as an economy site, staff gage and observer with a crest-stage gage to record peaks. Because of its low annual cost and location in an area of sparse data, this station should be continued until an adequate flood-frequency curve can be defined.

Few stations are operated for a single purpose and many stations are funded on a cost-sharing basis by more than one cooperator. The following stations could be discontinued because they have more than 10 years of record and the data have limited use:

10125500 Malad River at Woodruff
12392300 Pack River near Colburn
12413250 South Fork Coeur d'Alene River at Kellogg
13063000 Blackfoot River above reservoir near Henry
13113000 Beaver Creek at Spencer

13114000 Beaver Creek at Camas
13205500 Boise River at Boise
13250600 Big Willow Creek near Emmett
13307000 Salmon River near Shoup
13310700 South Fork Salmon River near Krassel Ranger Station

Discretion should be used when identifying stations that could be discontinued. Although table 2 illustrates the broad spectrum of data use, it does not distinguish between relative importance of the various uses. Most stations have one primary use and more than one secondary use. A station may be listed showing only one category (the primary) of data use, but that use may be adequate justification to retain the station.

The following stations in the Weiser River basin were part of a short-term project to establish ratings and methods of operation so the cooperator could collect data from the basin. The project has been completed so the stations could be discontinued:

13254000 Lost Valley Reservoir near Tamarack
13254500 Lost Creek below Lost Valley Reservoir near Tamarack
13255050 West Fork Weiser River near Fruitvale
13255060 Weiser River near Fruitvale
13257000 Middle Fork Weiser River near Mesa
13260500 Little Weiser River below Mill Creek near Indian Valley
13261150 C Ben Ross Reservoir near Indian Valley
13264000 Crane Creek Reservoir near Midvale
13265500 Crane Creek at mouth near Weiser

Figures 4, 6, and 8 illustrate that few small streams in the uninhabited mountainous areas of Idaho are currently gaged, although over the past 60 years, numerous such streams were gaged for 1-5 years in support of short-term studies. These short-term data, although sparse and in many cases quite old, are all that are available to meet the needs of small hydropower developers. The Idaho Office has been deluged with requests for data on small streams since the Public Utilities Regulatory Policies Act of 1978 gave small hydropower developers a guaranteed market for electricity, and the enactment of more liberal tax laws created a favorable climate for investment in such projects. Small hydropower development has underscored a major weakness in the Idaho stream-gaging network--a lack of streamflow data on small (drainage area less than 30 mi^2) mountain streams.

Many gaging stations operated to collect data for hydrologic systems or project operation are not well suited for assessment of regional hydrology; those that are usually involve large drainage areas. Therefore, as money becomes available, additional stream gages should be established on small, unregulated streams throughout Idaho, especially in the southwestern and north-central parts of the State where streamflow information is particularly sparse.

A way to establish a data base for small-stream hydrology would be to develop a revolving 5-year plan. Initially, five sites would be selected from the large number of small, ungaged basins for gaging stations that would operate for 5 years. After that time, the stations would be moved to another group of sites and data collection would begin in the new basins. This process could be continued until an adequate data base was established.

ALTERNATIVE METHODS OF DEVELOPING STREAMFLOW INFORMATION

Alternative technology could provide information about daily mean streamflow in a more cost-effective manner than operating a continuous-record stream gage. No guidelines exist concerning suitable accuracies for particular uses of streamflow data; therefore, judgment is required in deciding whether the accuracy of estimated daily flows is suitable for the intended purpose. Uses of data can determine whether a station has potential for alternative methods of developing streamflow information. For example, stations for which flood hydrographs are required in a real-time sense, such as hydrologic forecasts and project operation, are not candidates for alternative methods. Likewise, legal obligations to operate a gaging station would preclude utilizing alternative methods. Primary candidates for alternative methods are multiple stations operated on a single stream. Accuracy of the estimated streamflow at these stations may be suitable because of the high redundancy of flow information between stations. Stations operated in watersheds located in the same physiographic and climatic area also may have potential for alternative methods.

All stations in the Idaho stream-gaging network were categorized as to their potential for alternative methods, and selected methods were applied at nine stations. Categorization of gaging stations and application of the methods are described in subsequent sections of this report.

Desirable attributes of a proposed alternative method follow: (1) It should be computer oriented and easy to apply; (2) it should have an available interface with the Geological Survey WATSTORE Daily Values File (Hutchinson, 1975); (3) it should be technically sound and generally acceptable to the hydrologic community; and (4) it should permit easy evaluation of the accuracy of the simulated streamflow records. According to these selection criteria, flow-routing and multiple-regression analysis methods were chosen.

Description of Flow-Routing Method

The hydrologic flow-routing method uses the law of conservation of mass and the relation between storage and outflow. The hydraulics of the stream system are not considered. The method usually requires only a few parameters and treats the reach as a whole. The input is usually a discharge hydrograph at the upstream end of the reach and the output is a discharge hydrograph at the downstream end. Several types of hydrologic routing are available: Muskingum, Modified Puls, Kinematic Wave, and unit response. The unit-response method was selected for the Idaho analysis.

Computer programs for the unit-response method can be used to route streamflow from one or more upstream locations to a downstream location. Downstream hydrographs are produced by the convolution of upstream hydrographs with their appropriate unit-response functions. This method can be applied only at a downstream station where an upstream station exists on the same stream. An advantage of this method is that it can be used for regulated stream systems. Reservoir routing techniques are included in the computer program so flows can be routed through reservoirs if the operating rules are known. Calibration and verification of the flow-routing model are achieved using observed upstream and downstream hydrographs and estimates of tributary inflows. The model treats a stream reach as a linear, one-dimensional system in which the system output (downstream hydrograph) is computed by multiplying (convoluting) the ordinates of the upstream hydrograph by the unit-response function and lagging them appropriately. The model has the capability of combining hydrographs, multiplying a hydrograph by a ratio, and changing the timing of a hydrograph. In the Idaho analysis, the model is used only to route an upstream hydrograph to a downstream point. Routing can be accomplished using hourly data, but only daily data were used in this analysis.

Three options are available in the computer program for determining the unit-response function. One option uses the storage-continuity technique (Sauer, 1973). The other two options use the diffusion-analogy technique (Keefer, 1974; and Keefer and McQuivey, 1974). The option with single linearization uses coefficients for one range of discharges. The option with multiple linearization uses coefficients for a multiple range of discharges.

Selection of the appropriate option depends primarily on the variability of wave celerity (traveltime) and dispersion (channel storage) throughout the range of discharges to be routed. Adequate routing of daily flows usually can be accomplished using a single unit-response function (linearization about a single discharge) to represent the system response. However, if the routing coefficients vary drastically with discharge, linearization about a low-range discharge results in overestimated high flows that arrive late at the downstream site, whereas linearization about a high-range discharge results in low-range flows that are underestimated and arrive too soon. A single unit-response function may not provide acceptable results in such cases. Therefore, the option of multiple linearization (Keefer and McQuivey, 1974), which uses a family of unit-response functions to represent the system response, is available.

Determination of the system's response to the input at the upstream end of the reach is not the total solution for most flow-routing problems. The convolution process makes no accounting of flow from the intervening area between the upstream and downstream locations. Such flows may be totally unknown or estimated by some combination of gaged and ungaged flows. An estimating technique that should prove satisfactory in many instances is the multiplication of known flows at an index gaging station by a factor (for example, a drainage-area ratio).

The objective in either the storage-continuity or diffusion-analogy flow-routing method is to calibrate two parameters that describe the storage-discharge relation in a given reach and the traveltime of flow passing through the reach. In the storage-continuity technique, a response function is derived by modifying a translation hydrograph technique developed by Mitchell (1962) to apply to open channels. A triangular pulse (Sauer, 1973) is routed through reservoir-type storage and then transformed by a summation curve technique to a unit response of desired duration. The two parameters that describe the routing reach are K_s, a storage coefficient that is the slope of the storage-discharge relation, and W_s, the translation hydrograph time base. These two parameters determine the shape of the resulting unit-response function.

In the diffusion-analogy technique, the two parameters requiring calibration are K_o, a wave dispersion or damping coefficient, and C_o, the floodwave celerity. K_o controls the spreading of the wave (analogous to K_s in the storage-continuity technique), and C_o controls the traveltime (analogous to W_s in the storage-continuity technique). In the single linearization option, only one K_o and C_o value is used. In the multiple linearization option, C_o and K_o are varied with discharge so a table of wave celerity (C_o) versus discharge (Q) and a table of dispersion coefficient (K_o) versus discharge (Q) are used.

In both the storage-continuity and diffusion-analogy techniques, the two parameters are calibrated by trial and error. The analyst must decide if suitable parameters have been derived by comparing the simulated discharge to the observed discharge.

Description of Regression Analysis

Simple- and multiple-regression analyses also can be used to estimate daily flow records. Regression equations can be computed that relate daily flows (or their logarithms) at a single station to daily flows at a combination of upstream, downstream, and(or) tributary stations. This statistical method is not limited, like the flow-routing method, to stations where an upstream station exists on the same stream. The explanatory variables in the regression analysis can be stations from different watersheds or downstream and tributary watersheds. The regression analysis has many of the same attributes as the flow-routing method in that it is easy to apply, provides indices of accuracy, and is generally accepted as a good tool for estimation. The theory and assumptions of regression analysis are described in several textbooks (Draper and Smith, 1966; Kleinbaum and Kupper, 1978). The application of regression analysis to hydrologic problems was described and illustrated by Thomas and Benson (1970) and Riggs (1973). Only a brief description of regression analysis is provided in this report.

A linear regression model of the following form was developed for estimating daily mean discharges in Idaho:

$$y_i = B_o + \sum_{j=1}^{p} B_j x_j + e_i$$

where

y_i = daily mean discharge at station i (dependent variable),

x_j = daily mean discharges at nearby stations (explanatory variables),

B_o and B_j = regression constant and coefficient, and

e_i = the random error term.

The above equation is calibrated (B_o and B_j are estimated) using observed values of y_i and x_j. These observed daily mean discharges can be retrieved from the WATSTORE Daily Values File. The values of x_j may be discharges observed on the same day as discharges at station i or may be for previous or future days, depending on whether station j is upstream or downstream of station i. Once the equation is calibrated and verified, future values of y_i are estimated using observed values of x_j. The regression constant and coefficient (B_o and B_j) are tested to determine if they are significantly different from zero. A given station j should be retained in the regression equation only if its regression coefficient (B_j) is significantly different from zero. The regression equation should be calibrated using one period of time and then verified or tested on a different period of time to obtain a measure of the true predictive accuracy. Both the calibration and verification period should be representative of the range of flows that could occur at station i. The equation should be tested by (1) plotting the residuals e_i (difference between simulated and observed discharges) against the dependent and all explanatory variables in the equation, and (2) plotting the simulated and observed discharges versus time. These tests are intended to determine whether (1) the linear model is appropriate or if some transformation of the variables is needed, and (2) there is any bias in the equation such as overestimating low flows. These tests might indicate, for example, that a logarithmic transformation is desirable, that a nonlinear regression equation is appropriate, or that the regression equation is biased in some way. In this report, these tests indicated that a linear model with y_i and x_j, in cubic feet per second, was appropriate. The application of linear-regression analysis to nine watersheds in Idaho is described in the following section.

Use of a regression analysis to synthesize data at a discontinued gaging station entails a reduction in the variance of the streamflow record relative to that which would be computed from an actual record of streamflow at the site. The reduction in variance expressed as a fraction is approximately equal to one minus the square of the correlation coefficient that results from the regression analysis.

CATEGORIZATION OF STREAM GAGES BY THEIR POTENTIAL FOR ALTERNATIVE METHODS

Early in the Idaho stream-gaging network evaluation, a committee comprised of operating and project personnel was formed. The committee identified 20 gaging stations where a potential existed for providing streamflow information by alternative methods. These 20 stations were submitted to persons experienced in the application of the alternative methods, who removed 11 stations from consideration, primarily because intervening ungaged drainage areas were too great. The final selection consisted of nine gaging stations:

12394000	Priest River near Coolin
13018750	Snake River below Flat Creek
13049500	Falls River near Chester
13062500	Snake River at Blackfoot
13068500	Blackfoot River near Blackfoot
13083000	Trapper Creek near Oakley
13120500	Big Lost River at Howell Ranch
13246000	North Fork Payette River near Banks
13341050	Clearwater River near Peck

Regression analyses were applied to all nine stations and are described in the section "Regression Analysis Results." The following section describes the application of flow routing to two of those nine stations.

Flow-Routing Model Results

The flow-routing model was applied to two stations which, in the final selection, had an upstream station from which to route flow: Falls River near Chester (13049500) and North Fork Payette River near Banks (13246000).

Flow-Routing Model for Falls River Near Chester

The purpose of the flow-routing model for Falls River near Chester was to investigate potential for the CONROUT unit-response model (Doyle and others, 1983) to simulate daily mean discharges at Chester. The model uses the single linearization option of the diffusion-analogy method. A schematic diagram of the Falls River stream system is presented in figure 11. A best-fit model for an entire range of discharge is the desired product. Streamflow data available for this analysis are summarized in table 3.

The Chester gage is 18.3 mi downstream from the next gage at Squirrel. In this reach, several canals divert water during May-September of each year. Total diversions from all canals were published as Falls River Diversion Canal and are available for 1966-77 from WATSTORE.

Flows diverted from the basin were subtracted from routed flows. Estimated intervening ungaged area flows then were added to routed flows by using data from the index station (13047500, Falls River near Squirrel), adjusted by a drainage-area ratio factor of 0.58 (194 mi^2 divided by 335 mi^2).

The first step in the simulation process was determination of model parameters C_o (floodwave celerity) and K_o (wave dispersion coefficient). The coefficients C_o and K_o are functions of channel width (W_o), in feet; channel slope (S_o), in feet per foot (ft/ft); slope of the stage-discharge relation (dQ_o/dY_o), in cubic feet per second per foot [(ft^3/s)/ft], representative of the Falls River reach and were determined as follows:

$$C_o = \frac{1}{W_o} \frac{dQ_o}{dY_o} \qquad (2)$$

$$K_o = \frac{Q_o}{2 S_o W_o} \qquad (3)$$

Discharge for which initial values of C_o and K_o were linearized was the mean daily discharge for the Squirrel and Chester gages as published for the 1981 water year (U.S. Geological Survey, 1982). Channel width was calculated as the average for the 18.3-mi reach between the gages and was obtained from discharge measurements made at the Squirrel gage. Channel slope was determined by using gage heights for a common discharge at both stations relative to a common datum. The difference between these values then was divided

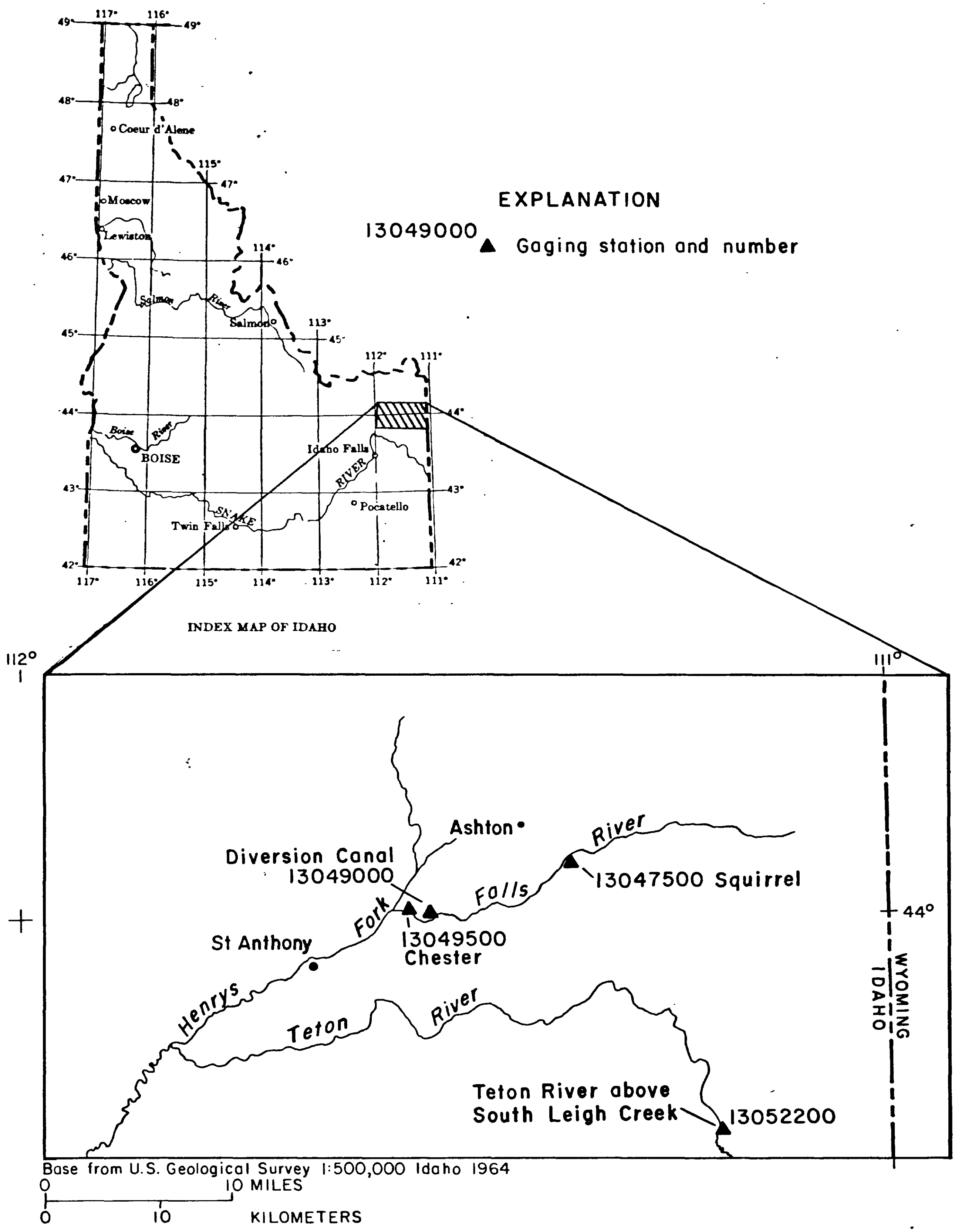

Figure 11. -- Location of gaging stations and diversions in Falls River area.

Table 3.--Gaging stations used in the Falls River near Chester flow-routing analysis

Station No.	Station name	Drainage area (square miles)	Period of record
13047500	Falls River near Squirrel	326	1918-82
13049000	Canal diversions		1966-77
13049500	Falls River near Chester	520	1920-82
13052200	Teton River above South Leigh Creek	335	1961-82

by channel length to obtain a slope. The slope of the stage-discharge relations was determined from rating curves at each gage by using a 1-ft increment that bracketed the mean discharge. The difference in discharge through the 1-ft increment then represented the slope of the relation at that point. Model parameters are listed in table 4.

Available data for 1971-74 from the four stations were used as a calibration data set. Several trials were made using data obtained during the irrigation season (May-September). Calibration data obtained during the nonirrigation season (October-April) were expanded to include data from 1973-81.

During the irrigation season, the magnitude of flows at Chester depend on inflows from Squirrel, diversions from the reach between Squirrel and Chester, contribution from the intervening area, and return flows, if any, from farms along the reach. Flows from the intervening area were difficult to account for. The Teton index station proved unsuitable for determining intervening flows, even though the ratio, 0.58, was adjusted during calibration runs. Also, none of the adjustments to C_o and K_o resulted in a better model for the calibration data set. A summary of the best simulation of mean daily discharge at Chester for the irrigation and nonirrigation seasons is given in tables 5 and 6.

The main reason for such poor results obtained using data from the irrigation season was the difference in hydrologic response of the Teton watershed from that of the ungaged intervening area between Squirrel and Chester. This difference was not as significant during the nonirrigation season. Overall results indicate that a flow-routing model would not be a suitable replacement for determining daily flow at the gage at Chester.

Flow-Routing Model for North Fork Payette River Near Banks

The purpose of the flow-routing model for North Fork Payette River near Banks was to investigate the potential for simulating flows at the gage near Banks. A schematic diagram of the North Fork Payette River area is presented in figure 12. Streamflow data for this analysis are summarized in table 7.

The distance between the gage at Cascade and the gage at Banks is 35.8 mi. The intervening ungaged area between these two stations is 307 mi^2, or 32.9 percent of the total drainage area contributing to flow past the Banks gage.

Table 4.--Calibrated model parameters for the Falls River basin

Reach	Station No.	Length (miles)	C_o	K_o
From Squirrel	13047500			
to Chester	13049500	18.3	6.4	306

Table 5.--Calibration results of flow-routing model for Falls River near Chester during the irrigation season, May 1 to September 30, 1973

Mean absolute error for 153 days = 24 percent

Mean negative error for 59 days = -8 percent

Mean positive error for 94 days = 34 percent

Total volume error = -2 percent

17 percent of the total observations had error ≤5 percent

45 percent of the total observations had error ≤10 percent

62 percent of the total observations had error ≤15 percent

67 percent of the total observations had error ≤20 percent

72 percent of the total observations had error ≤25 percent

28 percent of the total observations had error >25 percent

Table 6.--Calibration results of flow-routing model for Falls River near Chester during the nonirrigation season, October 1979 to April 1980

Mean absolute error for 213 days	= 13 percent
Mean negative error for 143 days	= -4 percent
Mean positive error for 70 days	= 31 percent
Total volume error	= 2 percent

62 percent of the total observations had error ≤5 percent

83 percent of the total observations had error ≤10 percent

86 percent of the total observations had error ≤15 percent

89 percent of the total observations had error ≤20 percent

89 percent of the total observations had error ≤25 percent

11 percent of the total observations had error >25 percent

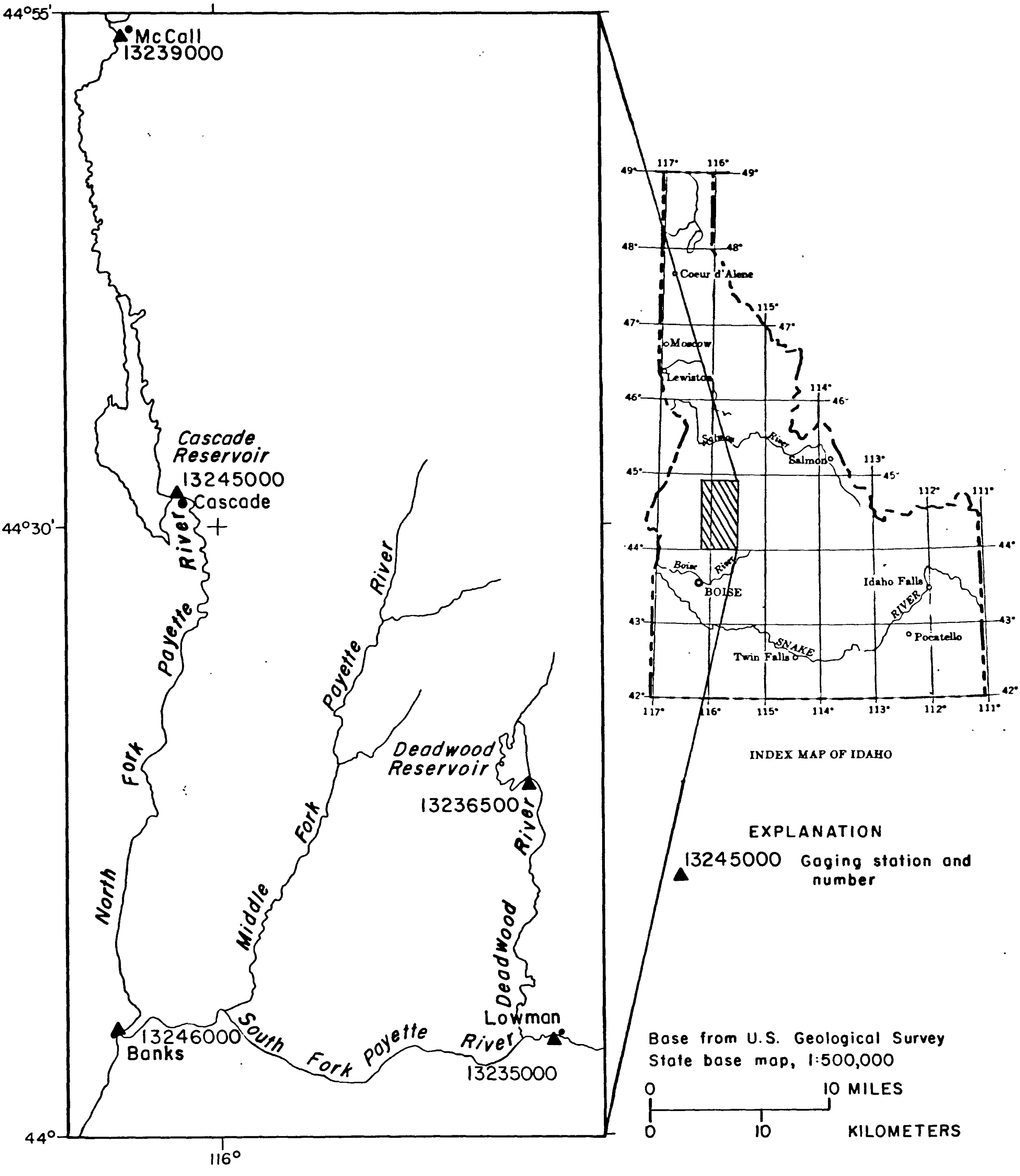

Figure 12. -- Location of surface-water stations, North Fork Payette River area.

Table 7.--Gaging stations used in the North Fork Payette River near Banks flow-routing analysis

Station No.	Station Name	Drainage area (square miles)	Period of record
13235000	South Fork Payette River at Lowman	456	1941-82
13236500	Deadwood River below Deadwood Reservoir near Lowman	112	1926-82
13239000	North Fork Payette River at McCall	144	1908-17, 1919-82
13245000	North Fork Payette River at Cascade	626	1941-82
13246000	North Fork Payette River near Banks	933	1947-82

Flow was routed along the North Fork Payette River from Cascade to Banks. During calibration runs, ungaged flow was computed as a factor times the flow at McCall, Deadwood, or Lowman.

Model parameters C_o and K_o, as previously defined, were computed. The procedure outlined in the Falls River discussion was used to determine average model parameter values. Parameter values used in the model are identified in table 8.

To simulate flow from the intervening ungaged drainage area of 307 mi^2, three index stations were used on separate calibration runs. The McCall gage is 72.8 mi above the Banks gage and represents 144 mi^2 of the 933-mi^2 drainage area gaged at Banks. An initial estimate of intervening flows was made by multiplying flows at McCall by 2.13 and adding them to routed flows at Banks. The calibration runs consisted of adjusting this ratio from 2.13 to 0.4, and resulted in no improvement. During the 1980 calibration period, storms in the intervening area of the modeling reach did not affect the watershed above McCall; thus, use of the McCall gage as an index proved ineffective. The Deadwood River index station (13236500) produced even poorer results. The Lowman index station (13235000) produced better results (table 9), but these were still unsatisfactory. Calibration periods were 1978, 1979, and 1980 water years. It is doubtful whether other combinations of stations or use of other time periods would have improved the simulation.

Regression Analysis Results

The streamflow record for each of the nine stations considered for simulation (the dependent variable) was regressed against streamflow records at other stations (explanatory variables) during a given period of record (calibration period). "Best fit" linear regression equations were developed and used to provide a daily streamflow record, which was compared to the observed streamflow record. The percent difference between the simulated and actual records for each day was calculated. Results of the regression analysis for each site are summarized in table 10.

Streamflow records during the calibration period were not reproduced with an acceptable degree of accuracy at any of the nine stations. Best results were obtained from the station Snake River below Flat Creek (13018750),

Table 8.--Calibrated model parameters for the North Fork Payette River reach

Reach	Station No.	Length (miles)	C_o	K_o
From Cascade	13245000			
to Banks	13246000	35.8	3.8	1,500

Table 9.--Results of flow-routing model for North Fork Payette River near Banks (13246000) for the 1979 water year

Mean absolute error for 365 days	=	14 percent
Mean negative error for 132 days	=	-14 percent
Mean positive error for 233 days	=	15 percent
Total volume error	=	3 percent

40 percent of the total observations had error $\leq$5 percent
60 percent of the total observations had error $\leq$10 percent
67 percent of the total observations had error $\leq$15 percent
75 percent of the total observations had error $\leq$20 percent
83 percent of the total observations had error $\leq$25 percent
17 percent of the total observations had error >25 percent

Table 10.--Summary of calibration for regression analyses of mean daily streamflow at selected gaging stations in Idaho

[Q_{xxx}, indicates daily discharge at station. Calibration period is 1976-79 water year.]

Station No.	Model	Percent of simulated flows within 5 percent of observed flows	Percent of simulated flows within 10 percent of observed flows	Mean error in percent	Median error in percent
12394000	$(Q_{3940})^{*} = 81.906 + 0.788(Q_{3950}) + 0.342(Q_{3950})^{*}$	30	54	13.6	9.0
13018750	$(Q_{01875}) = 238.855 + 0.487(Q_{0225}) + 0.569(Q_{0110}) + 1.082(Q_{0119})$	54	81	5.8	4.6
13049500	$(Q_{0495}) = 34.397 + 1.186(Q_{0475}) - 0.541(Q_{0522})$	9	23	47.4	17.1
13062500	$(Q_{0625})^{**} = -210.722 + 1.412(Q_{0695})$	45	70	11.6	5.9
13068500	$(Q_{0685}) = 104.90 + 0.555(Q_{68495}) - 0.029(Q_{0660})$	13	25	272	21.5
13083000	$(Q_{0830}) = 11.668 + 0.109(Q_{0825})$	20	43	15.4	12.3
13120500	$(Q_{1205}) = -0.178 + 2.875(Q_{1200}) + 0.058(Q_{1395})$	13	48	12.3	10.5
13246000	$(Q_{2460}) = 279.503 + 0.538(Q_{2450}) + 0.408(Q_{2450})^{***}$	8	25	51.8	20.7
13341050	$(Q_{34105}) = 5338.68 + 1.267(Q_{3400}) - 0.761(Q_{3406})$	10	18	38.9	28.6

* Flows lagged 1 day
** Flows lagged 2 days
*** Flows lagged 3 days

where the percent difference between the simulated and observed streamflow exceeded 5 percent for 46 percent of the observations and exceeded 10 percent for 19 percent of the observations.

Conclusions Pertaining to Alternative Methods of Data Generation

Simulated data from the flow-routing method for both the Falls River and North Fork Payette River were not sufficiently accurate to substitute for the operation of a continuous-record streamflow gage. The same applies to the nine stations studied using regression analysis. Therefore, all nine gages should remain in the Idaho stream-gaging network and should be included in the cost-effective resource allocation analysis that follows.

COST-EFFECTIVE RESOURCE ALLOCATION

Introduction to K-CERA

In a study of the cost effectiveness of a stream-gaging network operated to determine water consumption in the Lower Colorado River Basin, a set of techniques called K-CERA (Kalman Filtering for Cost-Effective Resource Allocation) was developed (Moss and Gilroy, 1980). The network's effectiveness was shown by the minimization of the sum of estimated error variances of annual mean discharges at each site in the network. For this nationwide evaluation, the original version of K-CERA was extended to include optional measures of effectiveness. The optional measures are sums of the estimated error variances of the following streamflow variables: annual mean discharge, in cubic feet per second; annual mean discharge, in percent; average instantaneous discharge, in cubic feet per second; or average instantaneous discharge, in percent. Percentage errors do not unduly weight records from large streams to the detriment of records from small streams. In addition, instantaneous discharge is the basic variable from which all other streamflow data are derived. Therefore, the percentage errors of the instantaneous discharge at all continuous-record gaging stations was chosen as the appropriate variable. Cost effectiveness was measured by the sums of the variances of the errors using the K-CERA technique.

The original version of K-CERA did not account for error contributed by missing stage or other correlative data used to compute streamflow data. The probabilities of missing correlative data increase as the period between service visits to a stream gage increases. A procedure for dealing with missing record has been developed and was incorporated into this study.

Following are brief descriptions of the mathematical program that optimizes cost effectiveness and application of Kalman filtering (Gelb, 1974) to determine stream-gaging record accuracy. For more detail on theory or applications of K-CERA, refer to Moss and Gilroy (1980) and Gilroy and Moss (1981).

Description of Mathematical Program

The mathematical program, "The Traveling Hydrographer," allocates among stream gages a predefined budget for collecting streamflow data in a cost-effective manner. The number of times per year several routes may be used to service stream gages and make discharge measurements are options in the mathematical program. The range of options in the program is from zero usage to daily usage for each route. A route is the most economical course of travel among a set of stream gages. Average traveltime and servicing costs for each gage visited are included in the program.

The first step in the program is to define the set of practical routes. The set may contain the route to and from a gaging station so that unique needs of the gage can be accommodated.

The next step is to determine special requirements of gages, such as necessary periodic maintenance, repair of recording equipment, or required periodic sampling of water for chemical analyses. Such special requirements are necessary constraints in terms of the minimum number of visits to each gage.

The final step is to use all the above to determine the number of times, N_i, that the i^{th} route for i = 1, 2, ..., NR (number of practical routes) is used during a year so that (1) the budget for the network is not exceeded, (2) the minimum number of visits to each station is made, and (3) the total uncertainty in the network is minimized. Figure 13 represents this step in the form of a mathematical program. Figure 14 presents a tabular layout of the computer program. Each of the NR routes is represented by a row of the table and each of the stations is represented by a column. The zero-one matrix, (ω_{ij}), defines the routes in

$$\underset{\underline{N}}{\text{Minimize}}\ V = \sum_{j=1}^{MG} \phi_j\,(M_j)$$

$V \equiv$ total uncertainty in the network

$\underline{N} \equiv$ vector of annual number times each route was used

$MG \equiv$ number of gages in the network

$M_j \equiv$ annual number of visits to station j

$\phi_j \equiv$ function relating number of visits to uncertainty at station j

Such that

Budget $\geq T_c \equiv$ total cost of operating the network

$$T_c = F_c + \sum_{j=1}^{MG} \alpha_j M_j + \sum_{i=1}^{NR} \beta_i N_i$$

$F_c \equiv$ fixed cost

$\alpha_j \equiv$ unit cost of visit to station j

$NR \equiv$ number of practical routes chosen

$\beta_i \equiv$ travel cost for route i

$N_i \equiv$ annual number times route i is used (an element of $\underline{N}$)

and such that

$$M_j \geq \lambda_j$$

$\lambda_j \equiv$ minimum number of annual visits to station j

Figure 13. -- Mathematical programming form of the optimization of the routing of hydrographers.

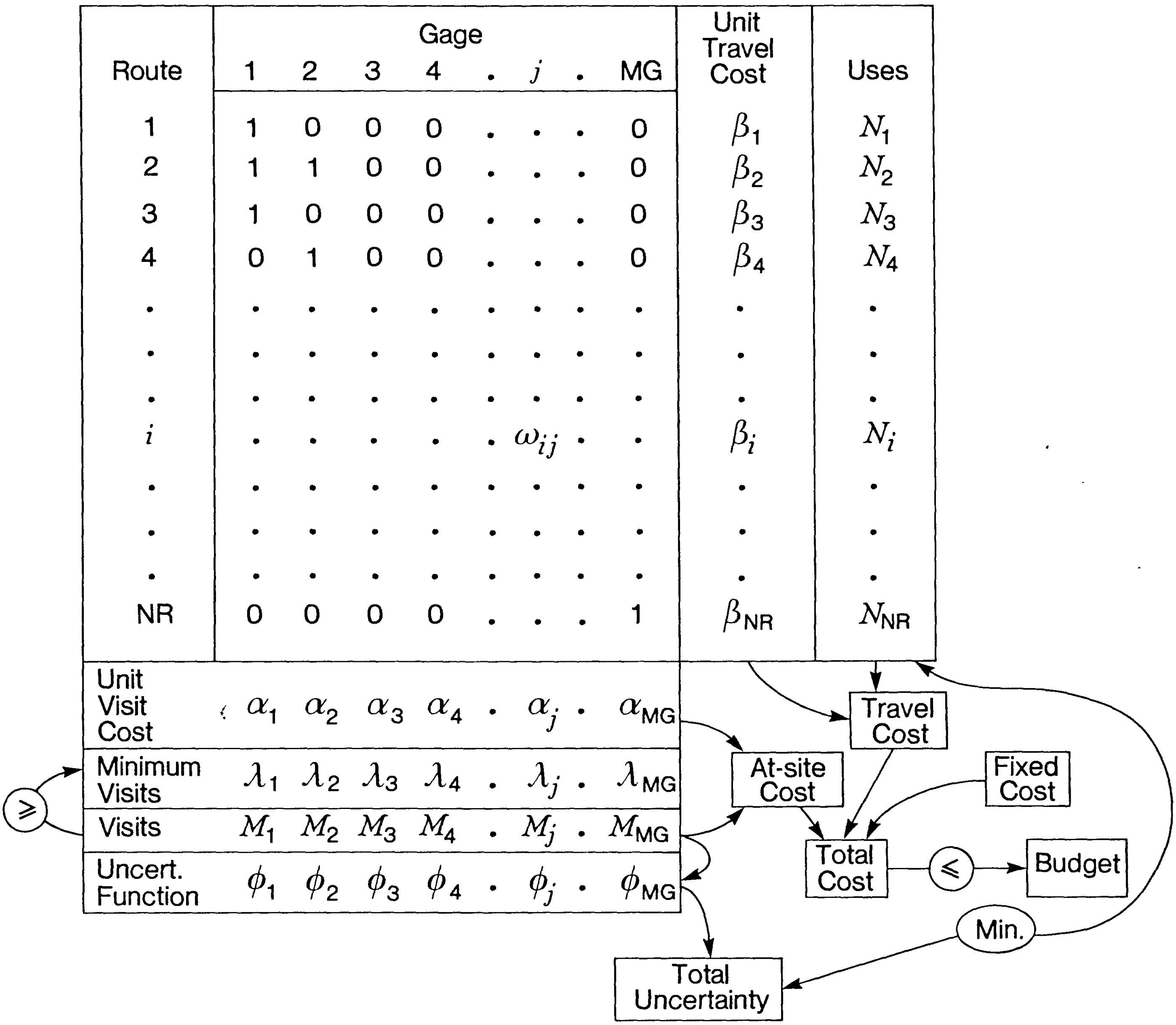

Figure 14. -- Tabular form of the optimization of the routing of hydrographers.

terms of the stations that compose it. A value of 1 in row i and column j indicates that gaging station j will be visited on route i; a value of zero indicates that it will not. The unit travel costs, β_i, are the per-trip costs of the hydrographer's traveltime and any related per diem, and operation, maintenance, and rental costs of vehicles. The sum of the products of β_i and N_i for i = 1, 2, ..., NR is the total travel cost associated with the set of decisions $\underline{N}$ = (N1, N2, ..., N_{NR}).

The unit visit cost, α_j, is comprised of the average service and maintenance costs incurred on a visit to the station plus the average cost of making a discharge measurement. The set of minimum visit constraints is denoted by the row λ_j, j = 1, 2, ..., MG (the number of stream gages). The row of integers M_j, j = 1, 2, ..., MG specifies the number of visits to each station. M_j is the sum of the products of ω_{ij} and N_i for all i and must equal or exceed λ_j for all j if $\underline{N}$ is to be a feasible solution to the problem.

Total cost expended at the stations is equal to the sum of the products of α_j and M_j for all j. The cost of record computation, documentation, and publication is assumed to be influenced negligibly by the number of visits to the station and is included with overhead in the fixed cost of operating the network. Total cost of operating the network equals the sum of travel costs, at-site costs, and fixed costs, and must be less than or equal to the available budget.

Total uncertainty in the discharge estimates at the MG stations is determined by summing the uncertainty functions, ϕ_j, evaluated at the value of M_j from the row above it, for j = 1, 2, ..., MG.

As Moss and Gilroy (1980) indicated, the steepest descent search used to solve this mathematical program does not guarantee a true optimum solution. However, the locally optimum set of values for $\underline{N}$ obtained with this program specifies an efficient strategy for operating the network, which may be the true optimum strategy. The true optimum cannot be guaranteed without testing all undominated, feasible strategies.

Description of Uncertainty Functions

As noted earlier, uncertainty in streamflow records is measured in this study as the average relative variance of estimation of instantaneous discharges. The accuracy of a streamflow estimate depends on how that estimate was obtained. Three situations are considered in this study: (1) Streamflow is estimated from measured discharge and correlative data using a stage-discharge relation (rating curve), (2) the streamflow record is reconstructed using secondary data at nearby stations because primary correlative data are missing, and (3) primary and secondary data are unavailable for estimating streamflow. The variances of the errors of the estimates of flow that would be employed in each situation were weighted by the fraction of time each situation is expected to occur. Thus, the average relative variance would be

$$\bar{V} = \varepsilon_f V_f + \varepsilon_r V_r + \varepsilon_e V_e \tag{4}$$

with

$$1 = \varepsilon_f + \varepsilon_r + \varepsilon_e$$

where

$\bar{V}$ is the average relative variance of the errors of streamflow estimates,

ε_f is the fraction of time that the primary recorders are functioning,

V_f is the relative variance of the errors of flow estimates from primary recorders,

ε_r is the fraction of time that secondary data are available to reconstruct streamflow records given that the primary data are missing,

V_r is the relative variance of the errors of estimation of flows reconstructed from secondary data,

ε_e is the fraction of time that primary and secondary data are not available to compute streamflow records, and

V_e is the relative error variance of the third situation.

The fractions of time that each source of error is relevant are functions of the frequencies at which the recording equipment is serviced.

The time τ since the last service visit until failure of the recorder or recorders at the primary site is assumed to have a negative-exponential probability distribution truncated at the next service time; the distribution's probability density function is:

$$f_{(\tau)} = ke^{-k\tau}/(1-e^{-ks}) \tag{5}$$

where

k is the failure rate in units of $(\text{day})^{-1}$,

e is the base of natural logarithms, and

s is the interval between visits to the site in days.

It is assumed that, if a recorder fails, it continues to malfunction until the next service visit. As a result,

$$\varepsilon_f = (1-e^{-ks})/(ks) \tag{6}$$

(Fontaine and others, 1983, eq. 21).

The fraction of time ε_e that no records exist at either the primary or secondary sites can also be derived assuming that the time between failures at both sites are independent and have negative exponential distributions with the same rate constant. It then follows that

$$\varepsilon_e = 1 - [2(1-e^{-ks}) + 0.5(1-e^{-2ks})]/(ks)$$

(Fontaine and others, 1983, eqs. 23 and 25).

Finally, the fraction of time ε_r that records are reconstructed based on data from a secondary site is determined by the equation

$$\varepsilon_r = 1 - \varepsilon_f - \varepsilon_e.$$
$$= [(1-e^{-ks}) + 0.5(1-e^{-2ks})]/(ks) \tag{7}$$

The relative variance, V_f, of the error derived from primary record computation is determined by analyzing a time series of residuals that are the differences between the logarithms of measured discharge and the rating curve discharge. The rating curve discharge is determined from a relation between discharge and some correlative data, such as water-surface elevation at the gaging station. The measured discharge is the discharge determined by field observations of depths, widths, and velocities. Let $q_T(t)$ be the true instantaneous discharge at time t and let $q_R(t)$ be the value that would be estimated using the rating curve. Then

$$x(t) = \ln q_T(t) - \ln q_R(t) = \ln [q_T(t)/q_R(t)] \tag{8}$$

is the instantaneous difference between the logarithms of the true discharge and the rating curve discharge.

In computing estimates of streamflow, the rating curve may be continually adjusted on the basis of periodic measurements of discharge. This adjustment process results in an estimate, $q_c(t)$, that is a better estimate of the stream's discharge at time t. The difference between variable $\hat{x}(t)$, which is defined

$$\hat{x}(t) = \ln q_c(t) - \ln q_R(t) \tag{9}$$

and x(t) is the error in the streamflow record at time t. The variance of this difference over time is the desired estimate of V_f.

Unfortunately, the true instantaneous discharge, $q_T(t)$, cannot be determined and thus x(t) and the difference, $x(t) - \hat{x}(t)$, cannot be determined as well. However, the statistical properties of $x(t) - \hat{x}(t)$, particularly its variance, can be inferred from the available discharge measurements. Let the observed residuals of measured discharge from the rating curve be z(t) so that

$$z(t) = x(t) + v(t) = \ln q_m(t) - \ln q_R(t) \tag{10}$$

where

v(t) is the measurement error, and

$\ln q_m(t)$ is the logarithm of the measured discharge equal to $\ln q_T(t)$ plus v(t).

In the Kalman-filter analysis, the z(t) time series was analyzed to determine three site-specific parameters. The Kalman filter used in this study assumes that the time residuals x(t) arise from a continuous first-order Markovian process that has a Gaussian (normal) probability distribution with zero mean and variance (subsequently referred to as process variance) equal to p. A second important parameter is β, the reciprocal of the correlation time of the Markovian process giving rise to x(t); the correlation between $x(t_1)$ and $x(t_2)$ is $\exp[-\beta|t_1-t_2|]$. Fontaine and others (1983) also define q, the constant value of the spectral density function of the white noise which drives the Gauss-Markov x-process. The parameters, p, q, and β, are related by

$$\mathrm{Var}[x(t)] = p = q/(2\beta) \tag{11}$$

The variance of the observed residuals z(t) is

$$\mathrm{Var}[z(t)] = p + r \tag{12}$$

where r is the variance of the measurement error v(t). The three parameters, p, β, and r, are computed by analyzing the statistical properties of the z(t) time series. These three site-specific parameters are needed to define this component of the uncertainty relation. The Kalman filter utilizes these three parameters to determine the average relative variance of the errors of estimation of discharges as a function of the number of discharge measurements per year (Moss and Gilroy, 1980).

If the recorder at the primary site fails and there are no concurrent data at other sites that can be used to reconstruct the missing record at the primary site, there are at least two ways of estimating discharges at the primary site. A recession curve could be applied from the time of recorder stoppage until the gage was once again functioning, or the expected value of discharge for the period of missing data could be used as an estimate. The expected-value approach is used in this study to estimate V_e, the relative error variance during periods of no concurrent data at nearby stations. If the expected value is used to estimate discharge, the value that is used should be the expected value of discharge at the time of year of the missing record because of the seasonality of the streamflow processes. The variance of streamflow, which also is a seasonally varying parameter, is an estimate of the error variance that results from using the expected value as an estimate. Thus, the coefficient of variation squared $(C_v)^2$ is an estimate of the required relative error variance V_e. Because C_v varies seasonally and the times of failures cannot be anticipated, a seasonally averaged value of C_v is used:

$$\bar{C}_v = \left(\frac{1}{365} \sum_{i=1}^{365} \frac{\sigma i^2}{\mu i}\right)^{1/2} \tag{13}$$

where

σ_i is the standard deviation of daily discharges for the i^{th} day of the year,

μ_i is the expected value of discharge on the i^{th} day of the year, and

$(\bar{C}_v)^2$ is used as an estimate of V_e.

The variance V_r of the relative error during periods of reconstructed streamflow records is estimated on the basis of correlation between records at the primary site and records from other gaged nearby sites. The correlation coefficient ρ_c between the streamflows with seasonal trends removed at the site of interest and detrended streamflows at the other sites is a measure of the goodness of their linear relation. The fraction of the variance of streamflow at the primary site that is explained by data from the other sites is equal to ρ_c^2. Thus, the relative error variance of flow estimates at the primary site obtained from secondary information will be

$$V_r = (1-\rho_c^2)\ \overline{C}_c^2 \qquad (14)$$

Because errors in streamflow estimates arise from three different sources with widely varying precisions, the resultant distribution of those errors may differ significantly from a normal or log-normal distribution. This lack of normality causes difficulty in interpretation of the resulting average estimation variance. When primary and secondary data are unavailable, the relative error variance V_e may be very large. This could yield correspondingly large values of $\overline{V}$ in equation (4) even if the probability that primary and secondary information are not available, ε_e, is quite small.

A new parameter, the equivalent Gaussian spread (EGS), is introduced here to assist in interpreting the results of the analyses. If it is assumed that the various errors arising from the three situations represented in equation (4) are log-normally distributed, the value of EGS was determined by the probability statement that

$$\text{Probability } [e^{-EGS} \leq (q_c(t)/q_T(t)) \leq e^{+EGS}] = 0.683 \qquad (15)$$

Thus, if the residuals $\ln q_c(t) - \ln q_T(t)$ were normally distributed, $(EGS)^2$ would be their variance. Here EGS is reported in units of percent because EGS is defined so that nearly two-thirds of the errors in instantaneous streamflow data will be within plus or minus EGS percent of the reported values.

The Application of K-CERA in Idaho

The first two parts of this analysis, identification of principal data uses and possible alternatives to operating gaging stations, resulted in the conclusion that all 156 continuous-record gaging stations currently operated be included for analysis by K-CERA techniques.

Definition of Missing Record Probabilities

As described earlier, the statistical characteristics of missing stage or other correlative data for computation of streamflow records can be defined by a single parameter, the value of k in the negative exponential probability distribution of times to failure of the equipment. The value of k is a function of the number of days of missing record and the length of time between inspections of the equipment. It will vary from site to site and from year to year, depending on the type of equipment and its exposure to natural elements and vandalism. The value of k also can be changed by advances in technology of data collection and recording. To estimate k in Idaho, the past 10 years of actual data collection were studied (R. W. Harper, U.S. Geological Survey, unpubl. data, 1983). During this period, technology changed little and stream gages were visited on a fairly consistent pattern of 4- to 6-week intervals. This study indicated that an average gage could be expected to malfunction about 6 percent of the time. Some gages seem to consistently lose more record than others, owing to vandalism, severity of winter conditions, and frequency of damage by flash flooding. The amount of lost record ranged from about 1 percent at a few nearly ideal gaging stations to more than 20 percent at some poor stations. The percentage of lost record and the average frequency of visits for each gage were used to determine the respective value of k and the dependent variables ε_f, ε_n, and ε_c for each of the 156 continuous-record stream gages.

Definition of Cross-Correlation Coefficient and Coefficient of Variation

To compute the values of V_n and V_c of the needed uncertainty functions, a computer program, CVCROSS, processes daily streamflow records for the last 30 years for which daily streamflow values are stored in WATSTORE (Hutchinson, 1975). For each of the 145 stream gages that had three or more complete water years of data, the value of C_v was computed and various options, based on combinations of other stream gages, were explored to determine the maximum ρ_c. For the 11 stations that had less than three water years of data, values of C_v and ρ_c were estimated somewhat subjectively on the basis of experience with similar nearby stations. The set of parameters for each station and the stations that resulted in the highest cross-correlation coefficient are listed in table 11.

Table 11.--Statistics of record reconstruction

[Cv, coefficient of variation; Pc (ρ_c), regression coefficient; MT, Montana; WA, Washington; OR, Oregon]

Station No.	Cv	Pc	Station(s) Used to Reconstruct Records		
10125500	64.8	0.635	13078205		
12305000	65.8	0.984	12303000 MT		
12306500	72.2	0.923	12304500 MT		
12318500	63.5	0.999	12322000		
12321500	74.0	0.871	12306500		
12322000	62.5	0.999	12318500		
12392000	36.4	0.819	12389000 MT		
12392300	76.9	0.769	12354000 MT		
12392895	54.5	0.473	12408500 WA		
12394000	59.9	0.955	12395000		
12395000	53.4	0.955	12394000		
12395500	34.6	0.958	12396500 WA		
12411000	85.6	0.974	12413000		
12413000	82.2	0.974	12411000		
12413140	87.7	0.875	12413150		
12413150	70.8	0.892	12414500		
12413250	69.6	0.861	12413150		
12414500	73.0	0.909	12354000 MT		
12414900	79.6	0.823	12414500		
12416000	88.8	0.766	12411000		
12418000	27.4	0.169	14023500 OR		
12419000	64.6	0.972	12422500 WA	12431000 WA	
13011000	105.0	0.771	13022500		
13011500	43.2	0.698	13011900		
13011900	35.2	0.706	06218500 MT		
13018300	30.2	0.641	06218500 MT		
13018750	32.9	0.833	13022500		
13019438*	30	0.64			
13022500	37.9	0.869	13011000	13011500	13011900
13023000	33.1	0.778	13027500		
13027500	32.5	0.778	13023000		
13032500	48.8	0.985	13037500		
13037500	44.2	0.985	13032500		
13038000	49.2	0.398	13106000		
13038500	63.2	0.743	13037500	13038000	
13039500	83.9	0.416	13042500		
13042500	65.6	0.880	13046000		
13046023**	26.8	0.880	13042500		
13047500	27.2	0.892	13049500		
13049500	46.0	0.892	13047500		
13050500	31.7	0.917	13046000	13049500	
13052200	33.1	0.724	13027500		

* Less than 3 water years of data are available. Estimates of Cv and Pc are subjective.

** Less than 3 water years of data are available. Estimates of Cv and Pc are based on station 13046000 (old station 1 mile upstream).

Table 11.--Statistics of record reconstruction--Continued

Station No.	Cv	Pc	Station(s) Used to Reconstruct Records		
13055000	33.1	0.714	13052200		
13055198	40.2	0.621	13055000		
13055319	57.4	0.467	13063000		
13055340*	40	0.70			
13056500	39.8	0.924	13050500	13055000	
13057150	42.6	0.833	13038000	13038500	13056500
13060000	46.2	0.969	13069500		
13062500	79.3	0.715	13069500		
13063000	44.1	0.818	13027500		
13065940	39.6	0.341	13055319		
13066000	53.2	0.506	13068495	13068500	
13068495	133.	0.795	13066000	13068500	
13068500	74.5	0.771	13066000	13068495	
13069500	63.5	0.969	13060000		
13073000	41.9	0.794	13075500		
13075000	46.3	0.810	13075500		
13075500	56.8	0.888	13073000	13075000	
13077000	65.7	0.943	13081500		
13078205	63.6	0.673	13082500		
13081500	63.9	0.943	13077000		
13082500	81.2	0.811	13105000		
13083000	33.8	0.736	13082500		
13088000	122.	0.990	13090000		
13090000	93.6	0.990	13088000		
13091000	7.03	0.682	13095500		
13093095	27.0	0.509	13105000		
13094000	60.6	0.974	13090000		
13095500	4.95	0.682	13091000		
13105000	62.9	0.815	13161500		
13106000	41.5	0.326	13127000		
13108150	33.1	0.443	13093095		
13112000	135.	0.623	13113000		
13113000	62.1	0.762	13114000		
13114000	82.1	0.762	13113000		
13118720	37.7	0.483	13063000		
13120000	42.4	0.891	13120500		
13120500	43.4	0.891	13120000		
13127000	49.7	0.446	13120000		
13128900	43.1	0.606	13120000		
13135000	36.4	0.968	13154500		
13139500	43.1	0.872	13147900		
13141000	68.0	0.852	13139500		
13141500	134.	0.668	13139500		
13142500	227.	0.500	13148500		

* Less than 3 water years of data are available. Estimates of Cv and Pc are subjective.

Table 11.--Statistics of record reconstruction--Continued

Station No.	Cv	Pc	Station(s) Used to Reconstruct Records		
13147900	55.8	0.872	13139500		
13148500	94.8	0.463	13127000		
13150430	26.9	0.534	13141000		
13152500	121.	0.549	13168500		
13154500	32.7	0.975	13135000	13152500	
13168500	69.8	0.891	13161500		
13169500	101.	0.380	10328475		
13172500	33.3	0.934	13154500		
13185000	51.2	0.942	13235000		
13186000	44.2	0.927	13185000		
13190500	73.9	0.344	13202000		
13200000	69.8	0.884	13185000		
13202000	102.	0.746	13205500		
13205500	92.4	0.746	13202000		
13206000*	92	0.75			
13210050	108.	0.658	13213000		
13211445*	150.	0.60			
13213000	66.7	0.768	13213100		
13213100	36.0	0.911	13172500	13213000	
13235000	39.8	0.942	13185000		
13236500	181.	0.103	13142500		
13239000	80.7	0.400	13249500		
13240000	82.0	0.854	13313000		
13245000	80.5	0.941	13246000		
13246000	60.6	0.941	13245000		
13247500	42.6	0.931	13249500		
13249500	49.1	0.961	13251000		
13250000	51.3	0.810	13251000		
13250600	96.4	0.553	13261000		
13251000	49.4	0.961	13249500		
13254500*	50.	0.90			
13255050*	86.	0.90			
13255060*	86.	0.90			
13257000*	86.	0.90			
13258500	85.8	0.907	13266000		
13260500*	86.	0.90			
13265500	175.	0.470	13266000		
13266000	87.4	0.907	13258500		
13269000	36.9	0.940	13213100	13251000	13266000
13289960	55.1	0.732	13290190		
13290190	70.8	0.834	13258500		
13290450	40.0	0.852	13334300		
13296500	34.4	0.900	13309220		
13297330	57.1	0.858	13297355		

* Less than 3 water years of data are available. Estimates of Cv and Pc are subjective.

Table 11.--Statistics of record reconstruction--Continued

Station No.	Cv	Pc	Station(s) Used to Reconstruct Records		
13297350	76.6	0.567	13297355		
13297355	50.6	0.958	13297330		
13297450	42.4	0.730	13120000		
13297597	24.2	0.560	13297450		
13302500	33.3	0.908	13307000		
13305000	35.0	0.642	13302500		
13307000	33.8	0.936	13302500		
13310700	56.6	0.897	13313000		
13313000	49.7	0.897	13310700		
13316500	60.3	0.836	13258500		
13317000	37.9	0.954	13307000	13310700	13316500
13334300	36.8	0.956	13290450	13317000	13333000
13336500	65.5	0.977	13337000		
13337000	66.2	0.977	13336500		
13338500	67.9	0.896	13340000		
13339500	47.9	0.565	12414900		
13339800*	60.	0.50			
13340000	64.1	0.973	13336500	13337000	13338500
13340600	59.8	0.928	13337000		
13341050	55.3	0.958	13342500		
13341128	98.0	0.377	13339500		
13342450	86.2	0.691	13345000		
13342500	60.6	0.958	13341050		
13345000	106.	0.837	12414900		
13346800	91.6	0.443	13345000		
13350448	107.	0.363	13342450		

* Less than 3 water years of data are available. Estimates of Cv and Pc are subjective.

Kalman-Filter Definition of Variance

Determination of the variance V_f for each of the 156 continuous-record stream gages required three steps: (1) Long-term rating analysis and computation of residuals of measured discharges from the long-term rating; (2) time-series analysis of the residuals to determine the input parameters of the Kalman-filter streamflow records; and (3) computation of the error variance, V_f, as a function of the time-series parameters, the discharge-measurement-error variance, and the frequency of discharge measurement.

For Idaho, a computerized rating function was used for all stream gages included in the analysis. The rating function determined was of the form:

$$LQM = B1 + B3 * LOG(GHT - B2) \qquad (16)$$

in which

LQM is the logarithm of the measured discharge,
GHT is the recorded gage height corresponding to the measured discharge,
B1 is the logarithm of discharge for a flow depth of 1 ft,
B2 is the gage height of zero flow, and
B3 is the slope of the rating curve.

For stations at which discharge measurements were only occasionally affected by backwater conditions such as ice, moss, or debris that collected on the control structure (natural or manmade), the rating curve was defined without those measurements, but the residuals of those measurements were included in the time series used to estimate the uncertainty of the station.

Fontaine (1982) previously documented the fact that during open-water periods (no ice), existing rating curves in most cases defined the long-term rating function required in the analysis. Winter flows at some stations in Idaho are unimportant relative to flow during the rest of the year. For four of these stations, the rating curve was defined only for the open-water period, and discharge measurements made during the winter period were not included in the time series used to estimate the uncertainty of the station.

In the Idaho network analysis, 7 of the 156 continuous-record stream gages included for analysis have different characteristics at low and high stages. As a result of this difference, a single rating function is not feasible to define the stage-discharge relation at all stages. In each case, a pair of functions was used to define each half of a segmented rating curve. The form of the function was similar to equation (16) with the coefficients applying respectively to the segment of the curve they are used to define. A point (x_o) of greatest inflection of the curve is a common point where the two segments join together. When the recorded gage height is greater than or equal to x_o, the measurement is used to define the upper end of the curve; and when the recorded gage height is less than x_o, the measurement is used to define the lower end of the curve.

Once a rating curve has been defined for a particular gaging station, the next step is to compute a time series of residuals about this curve. The residual is the difference between measured and rated discharge. This time series of residuals is input to the autocovariance analysis program that computes sample estimates of q and β, two of the three parameters required to compute V_f, by determining a best-fit autocovariance function to the time series of residuals. Measurement variance, the third parameter, is determined from an assumed constant percentage standard error. For the Idaho network, all measurements were assumed to have an error of 5 percent.

As discussed earlier, q and β can be expressed as the process variance of the shifts from the rating curve and the 1-day autocorrelation coefficient of these shifts. Table 12 presents a summary of the autocovariance analysis expressed in terms of process variance and 1-day autocorrelation. Measurement error is not presented in table 12 because all stations were assumed to have a 5 percent measurement error which translates into a constant of 0.00047094 measurement variance in $\log_{10}^2$ units. Typical fits of the covariance functions in autocovariance analyses for selected stations in Idaho are given in figures 15, 16, and 17.

Data from the autocovariance analysis and data from the definition of missing record probabilities, summarized in table 11, serve as input to the program that computes the uncertainty function. Uncertainty function, or the relation of total error variance to the number of visits and discharge measurements, is computed by this program. Stations for which fits of the autocovariance functions were previously given are used to present typical examples of uncertainty functions given in figures 18, 19, and 20. These functions are based on the assumption that a measurement was made during each visit to the station.

Table 12.--Summary results from autocovariance analyses

[Rho, ρ; process variance, $(\log_{10})^2$]

Station number	Station name	Rho	Process variance
10125500	Malad River at Woodruff	0.538	0.0016
12305000	Kootenai River at Leonia	.971	.0000
12306500	Moyie River at Eastport	.966	.0715
12318500	Kootenai River near Copeland	.960	.0310
12321500	Boundary Creek near Porthill	.965	.0447
12322000	Kootenai River at Porthill	.956	.0260
12392000	Clark Fork near Cabinet	.703	.0005
12392300	Pack River near Colburn	.252	.0000
12392895	Blanchard Creek near Blanchard	.932	.0442
12394000	Priest River near Coolin	.965	.0109
12395000	Priest River near Priest River	.937	.0018
12395500	Pend Oreille River at Newport, WA	.864	.0015
12411000	Coeur d'Alene River near Prichard	.994	.0078
12413000	Coeur d'Alene River at Enaville	.900	.0200
12413140	Placer Creek at Wallace	.980	.0700
12413150	S. Fk. Coeur d'Alene River at Silverton	.998	.0723
12413250	S. Fk. Coeur d'Alene River at Kellogg	.900	.0200
12414500	St. Joe River at Calder	.930	.0826
12414900	St. Maries River near Santa	.956	.0240
12416000	Hayden Creek near Hayden Lake	.332	.0136
12418000	Rathdrum Prairie Canal at Huetter	.986	.0224
12419000	Spokane River near Post Falls	.825	.0000
13011000	Snake River near Moran, WY	.467	.0000
13011500	Pacific Creek at Moran, WY	.996	.1229
13011900	Buffalo Fk. near Moran, WY	.992	.1057
13018300	Cache Creek near Jackson, WY	.972	.0260
13018750	Snake River near Jackson, WY	.587	.0020
13019438	L. Granite Creek near Bondurant, WY	.970	.0260
13022500	Snake River near Alpine, WY	.667	.0023
13023000	Greys River near Alpine, WY	.940	.0263
13027500	Salt River near Etna, WY	.990	.0005
13032500	Snake River near Irwin	.976	.0000
13037500	Snake River near Heise	.425	.0014
13038000	Dry Bed near Ririe	.984	.0008
13038500	Snake River at Lorenzo	.959	.0035
13039500	Henrys Fork near Lake	.987	.0652
13042500	Henrys Fork near Island Park	.993	.0595
13046023	Henrys Fork near Ashton	.957	.0000
13047500	Falls River near Squirrel	.966	.0018

Table 12.--Summary results from autocovariance analyses--Continued

Station number	Station name	Rho	Process variance
13049500	Falls River near Chester	0.955	0.0379
13050500	Henrys Fork at St. Anthony	.872	.0096
13052200	Teton River near Driggs	.634	.0037
13055000	Teton River near St. Anthony	.991	.0019
13055198	N. Fk. Teton River at Teton	.000	.0211
13055319	Moody Creek near Rexburg	.983	.0554
13055340	S. Fk. Teton River at Rexburg	.991	.0019
13056500	Henrys Fork near Rexburg	.972	.0035
13057150	Snake River near Lewisville	.962	.0202
13060000	Snake River near Shelley	.939	.0009
13062500	Snake River at Blackfoot	.970	.0018
13063000	Blackfoot River near Henry	.985	.0524
13065940	Wolverine Creek near Goshen	.997	.0414
13066000	Blackfoot River near Shelley	.944	.0273
13068495	Blackfoot Bypass near Blackfoot	.395	.0032
13068500	Blackfoot River near Blackfoot	.827	.0240
13069500	Snake River near Blackfoot	.993	.0010
13073000	Portneuf River at Topaz	.995	.0027
13075000	Marsh Creek near McCammon	.993	.0185
13075500	Portneuf River at Pocatello	.980	.0116
13077000	Snake River at Neeley	.952	.0005
13078205	Raft River near Malta	.998	.0683
13081500	Snake River near Minidoka	.336	.0009
13082500	Goose Creek near Oakley	.581	.0125
13083000	Trapper Creek near Oakley	.991	.0029
13088000	Snake River at Milner	.370	.0038
13090000	Snake River near Kimberly	.971	.0000
13091000	Blue Lakes Spring near Twin Falls	.983	.0007
13093095	Rock Creek near Twin Falls	.418	.0001
13094000	Snake River near Buhl	.875	.0000
13095500	Box Canyon Springs near Wendell	.545	.0000
13105000	Salmon Falls Creek near San Jacinto, NV	.432	.0110
13106000	Salmon River Canal Co. near Rogerson	.555	.0000
13108150	Salmon Falls Creek near Hagerman	.982	.0032
13112000	Camas Creek at Camas	.970	.0128
13113000	Beaver Creek at Spencer	.414	.0241
13114000	Beaver Creek at Camas	.892	.0017
13118700	Little Lost River near Howe	.958	.0256
13120000	N. Fk. Big Lost River near Chilly	.947	.0003
13120500	Big Lost River at Howell Ranch	.970	.0012
13127000	Big Lost River below Mackay Reservoir	.413	.0009

Table 12.--Summary results from autocovariance analyses--Continued

Station number	Station name	Rho	Process variance
13128900	Lower Cedar Creek near Mackay	0.997	0.0607
13135000	Snake River near Hagerman	.952	.0000
13139500	Big Wood River at Hailey	.988	.0059
13141000	Big Wood River near Bellevue	.999	.1393
13141500	Camas Creek near Blaine	.978	.0008
13142500	Big Wood River below Magic Reservoir	.936	.0072
13147900	Little Wood River above High Five Creek	.991	.0023
13148500	Little Wood River near Carey	.971	.0426
13150430	Silver Creek near Picabo	.991	.0130
13152500	Big Wood River near Gooding	.854	.0123
13154500	Snake River at King Hill	.477	.0000
13168500	Bruneau River near Hot Springs	.977	.0000
13169500	Big Jacks Creek near Bruneau	.000	.0123
13172500	Snake River near Murphy	.970	.0000
13185000	Boise River near Twin Springs	.991	.0012
13186000	S. Fk. Boise River near Featherville	.979	.0000
13190500	S. Fk. Boise River at Anderson Ranch Dam	.987	.0001
13200000	Mores Creek near Arrowrock Dam	.483	.0280
13202000	Boise River near Boise	.900	.0300
13205500	Boise River at Boise	.998	.0163
13206000	Boise River at Glenwood Bridge	.977	.0065
13210050	Boise River near Middleton	.989	.0043
13211445	Indian Creek at Caldwell	.992	.0116
13213000	Boise River near Parma	.972	.0000
13213100	Snake River at Nyssa, OR	.928	.0000
13235000	S. Fk. Payette River at Lowman	.935	.0037
13236500	Deadwood River near Lowman	.471	.0170
13239000	N. Fk. Payette River at McCall	.912	.0012
13240000	Lake Fork Payette River near McCall	.593	.0015
13245000	N. Fk. Payette River at Cascade	.948	.0012
13246000	N. Fk. Payette River near Banks	.978	.0000
13247500	Payette River near Horseshoe Bend	.528	.0000
13249500	Payette River near Emmett	.975	.0000
13250000	Payette River near Letha	.992	.0006
13250600	Big Willow Creek near Emmett	.900	.0300
13251000	Payette River near Payette	.979	.0000
13254500	Lost Creek near Tamarack	.924	.0006
13255050	W. Fk. Weiser River near Fruitvale	.500	.0300
13255060	Weiser River near Fruitvale	.000	.0300
13257000	Middle Fork Weiser River near Mesa	.500	.0300
13258500	Weiser River near Cambridge	.411	.0038
13260500	Little Weiser River near Indian Valley	.500	.0300
13265500	Crane Creek near Weiser	.656	.0114
13266000	Weiser River near Weiser	.939	.0014
13269000	Snake River at Weiser	.982	.0000

Table 12.--Summary results from autocovariance analyses--Continued

Station number	Station name	Rho	Process variance
13289960	Wildhorse River at Brownlee Dam	0.996	0.0241
13290190	Pine Creek near Oxbow, OR	.962	.0001
13290450	Snake River at Hells Canyon Dam, ID-OR	.927	.0000
13296500	Salmon River below Yankee Fork	.537	.0000
13297330	Thompson Creek near Clayton	.547	.0204
13297350	Bruno Creek near Clayton	.990	.0727
13297355	Squaw Creek near Clayton	.977	.0385
13297450	Little Boulder Creek near Clayton	.532	.0077
13297597	Herd Creek near Clayton	.953	.1693
13302500	Salmon River at Salmon	.964	.0004
13305000	Lemhi River near Lemhi	.977	.0172
13307000	Salmon River near Shoup	.984	.0002
13310700	S. Fk. Salmon River Krassel Ranger Sta.	.963	.0076
13313000	Johnson Creek at Yellow Pine	.805	.0089
13316500	Little Salmon River at Riggins	.010	.0006
13317000	Salmon River at White Bird	.557	.0000
13334300	Snake River near Anatone, WA	.951	.0000
13336500	Selway River near Lowell	.976	.0101
13337000	Lochsa River near Lowell	.938	.0214
13338500	S. Fk. Clearwater at Stites	.900	.0211
13339500	Lolo Creek near Greer	.916	.0008
13339800	Orofino Creek near Orofino	.928	.0161
13340000	Clearwater River at Orofino	.885	.0018
13340600	N. Fk. Clearwater near Canyon Ranger Sta.	.977	.0037
13341050	Clearwater River near Peck	.971	.0000
13341128	Long Hollow Creek at Nezperce	.900	.0200
13342450	Lapwai Creek near Lapwai	.994	.0459
13342500	Clearwater River at Spalding	.853	.0000
13345000	Palouse River near Potlatch	.969	.0273
13346800	Paradise Creek at University of Idaho	.980	.0204
13350448	Cow Creek at Genesee	.986	.1715

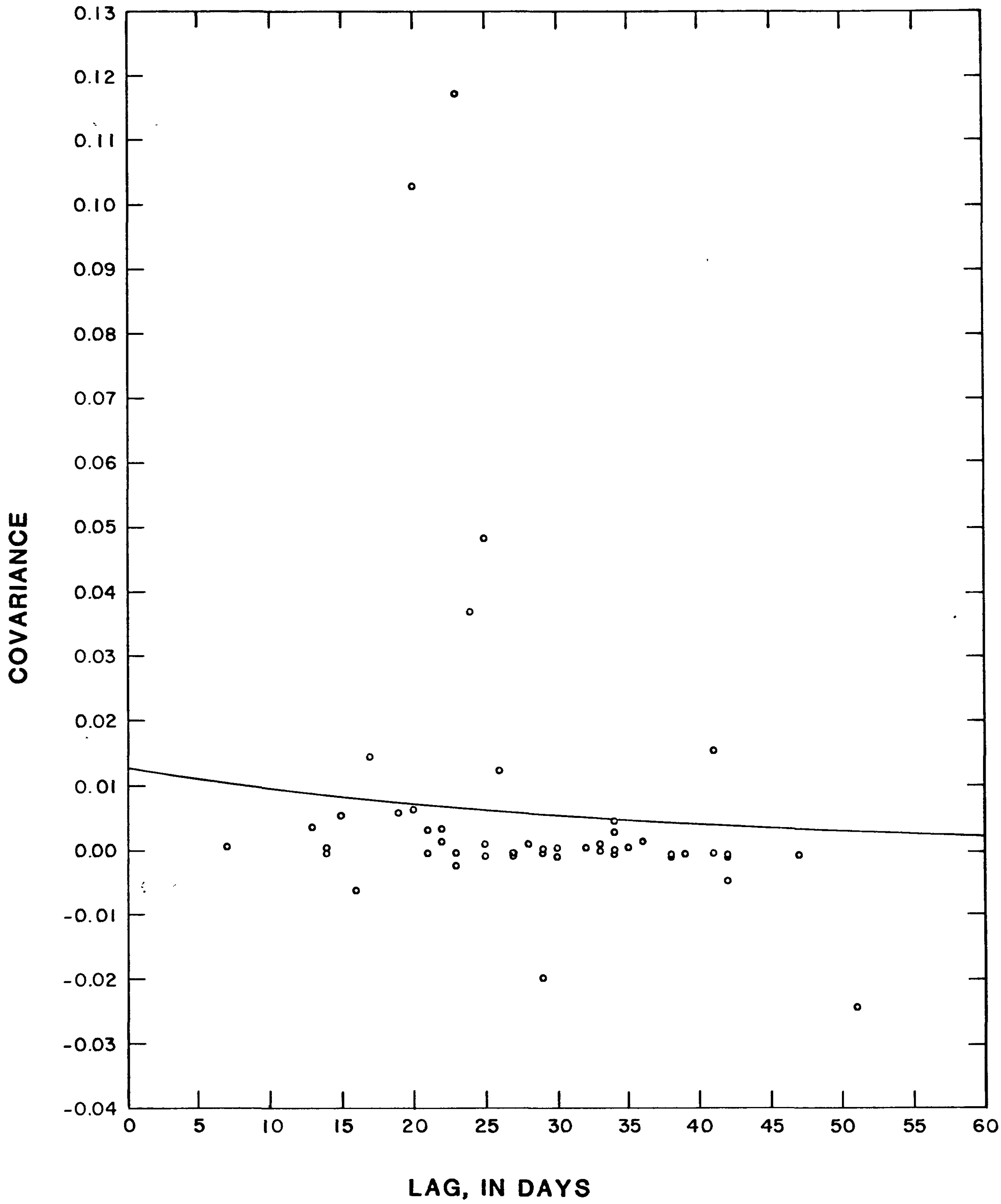

Figure 15.--Time-series data for station 13112000, Camas Creek at Camas.

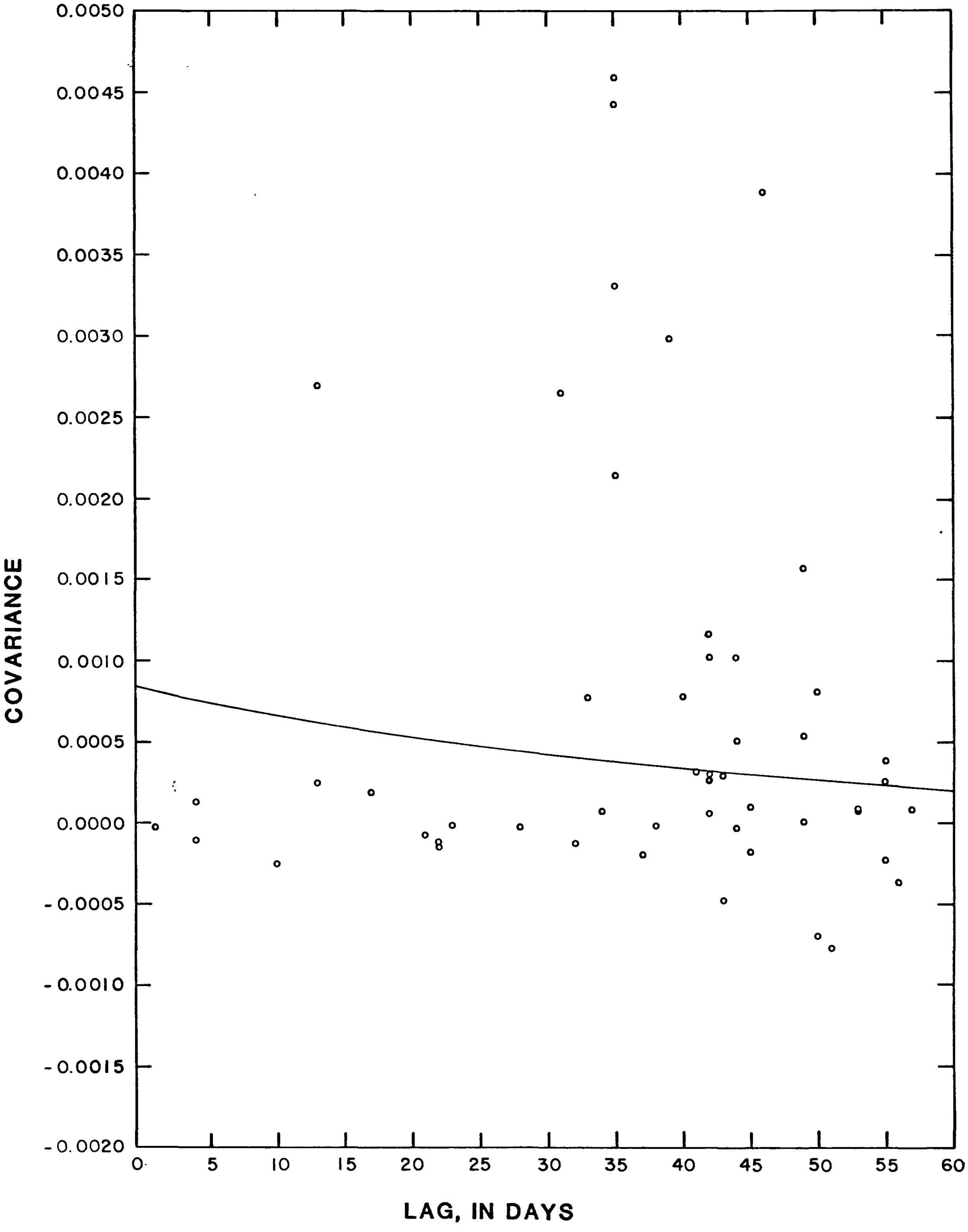

Figure 16.--Time-series data for station 13141500, Camas Creek near Blaine.

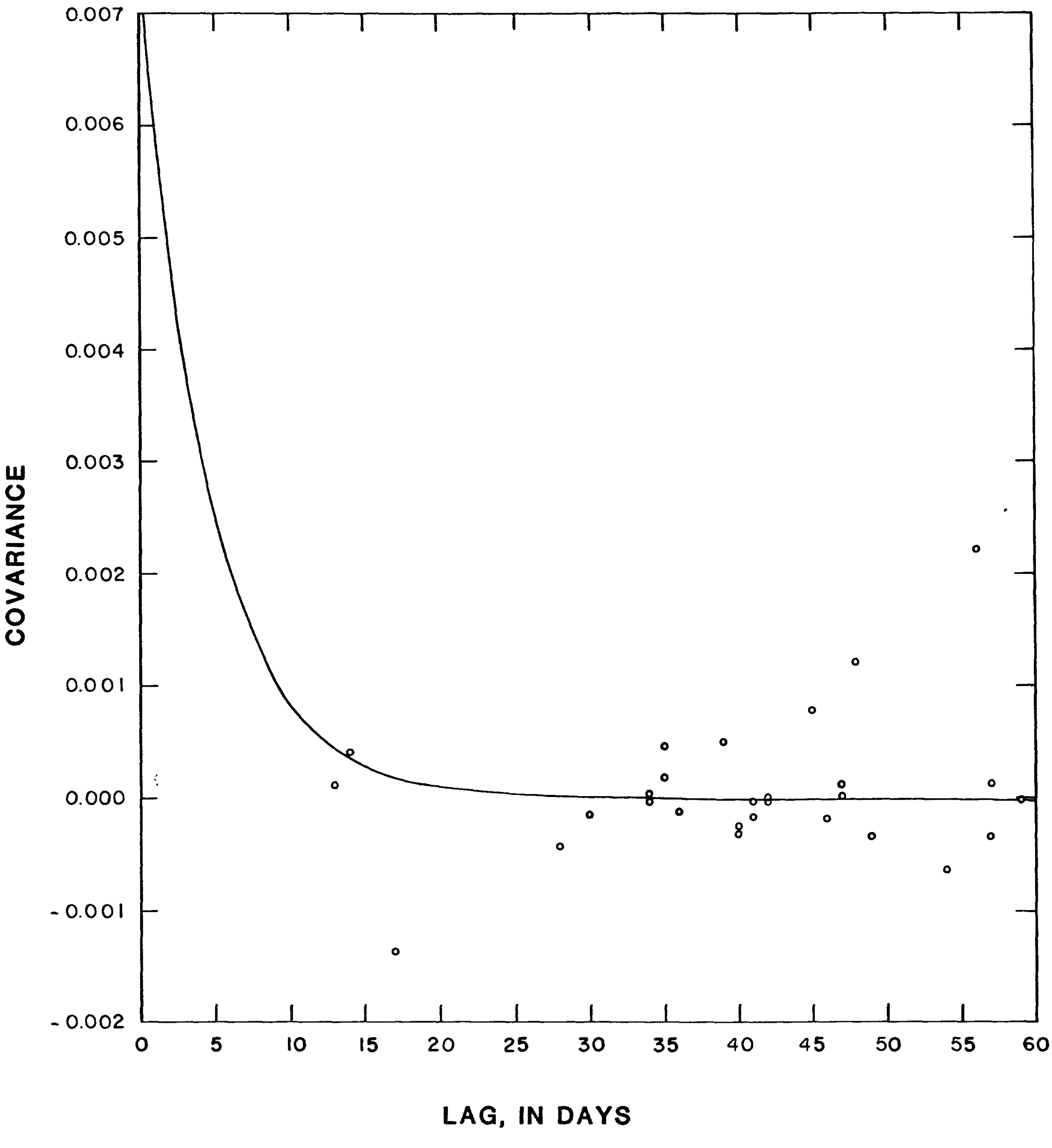

Figure 17.--Time-series data for station 13313000, Johnson Creek at Yellow Pine.

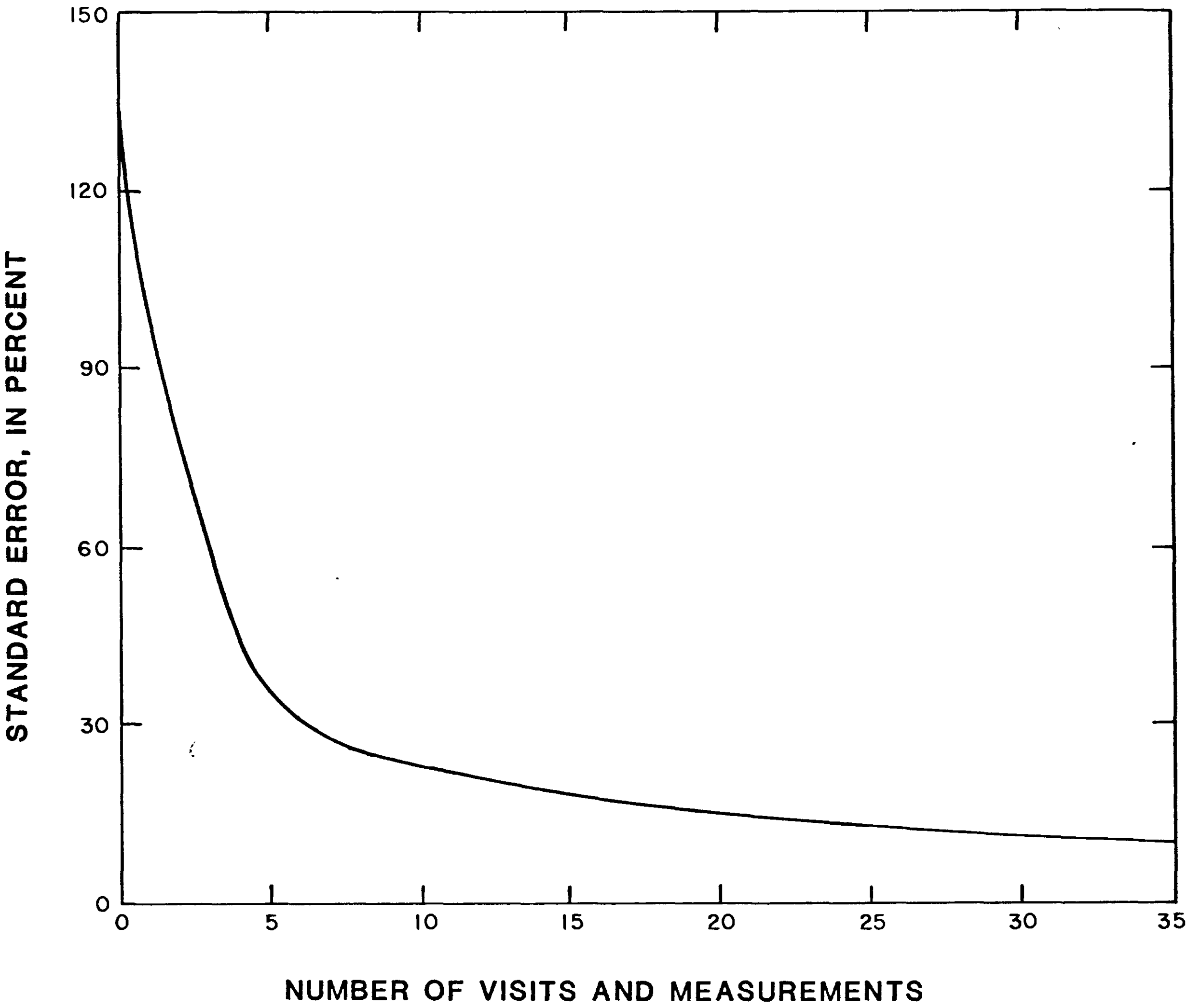

Figure 18.--Uncertainty function for instantaneous discharge at station 13112000, Camas Creek at Camas.

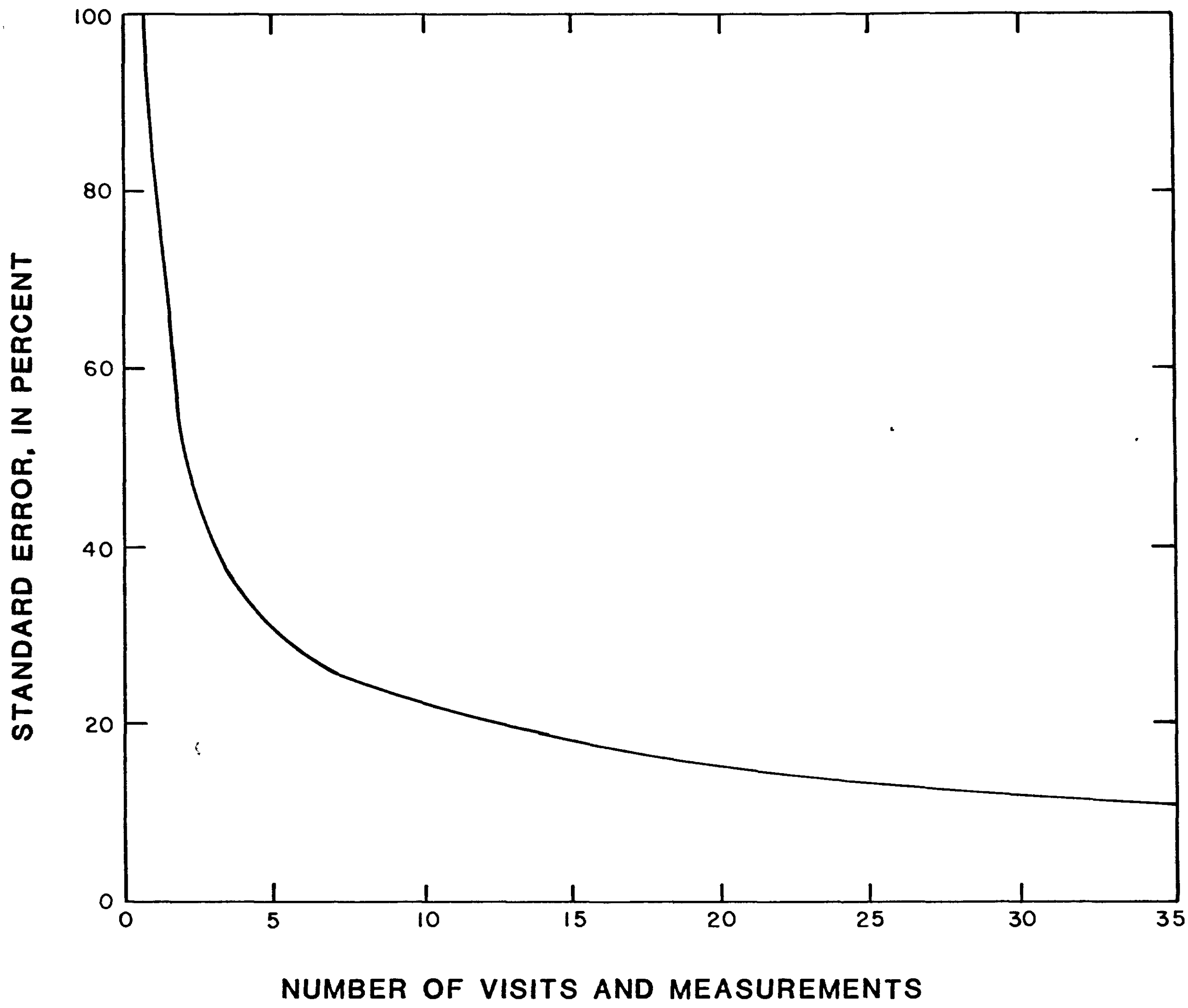

Figure 19.--Uncertainty function for instantaneous discharge at station 13141500, Camas Creek near Blaine.

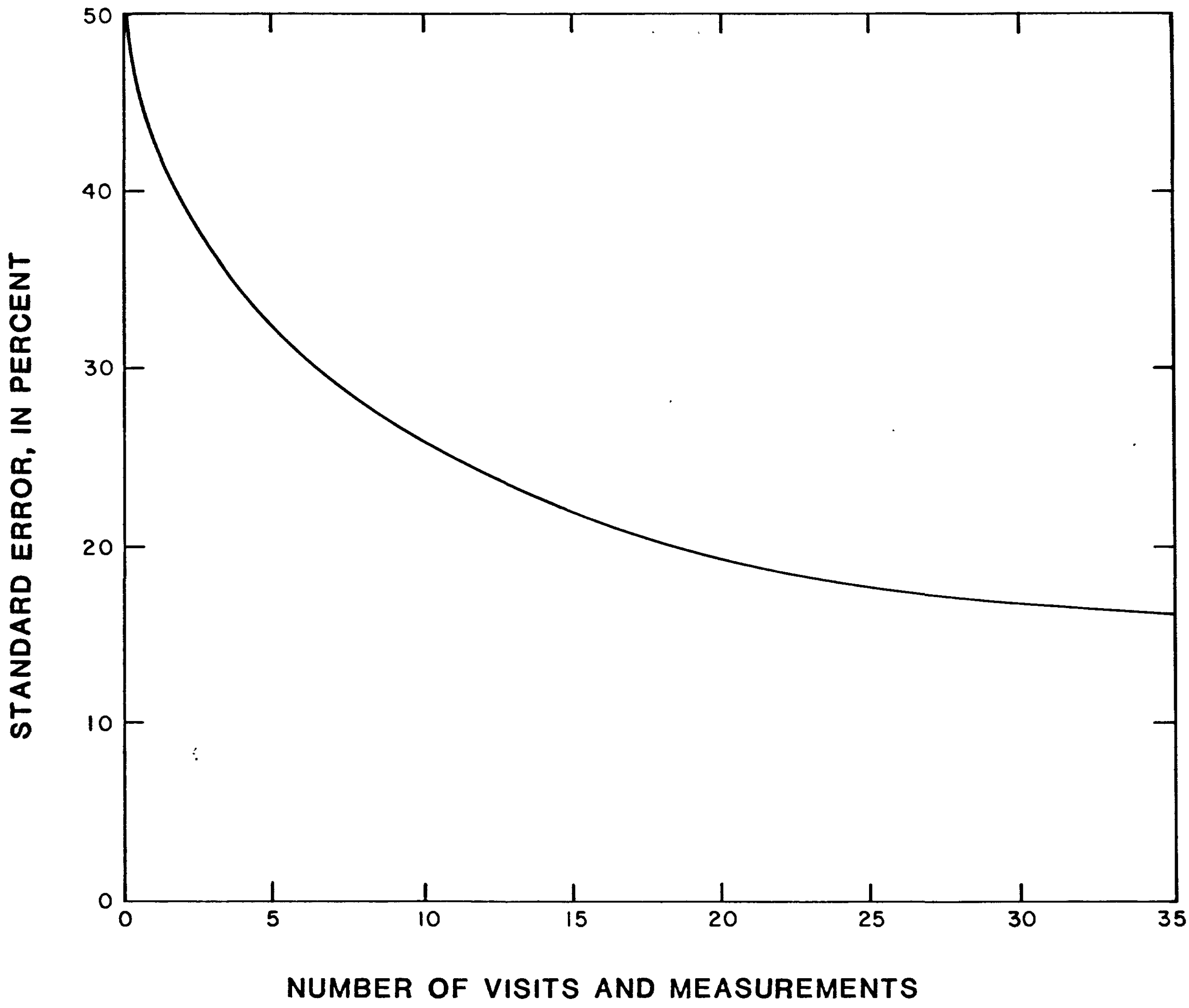

Figure 20.--Uncertainty function for instantaneous discharge at station 13313000, Johnson Creek at Yellow Pine.

All feasible routes to service the 185 surface-water gages were determined after review of the uncertainty functions. In summary, 179 routes were selected to service all stream gages operated by the Idaho Office. These routes included all possible combinations that described current operating practice, alternatives under consideration as future possibilities, routes that visited key stations, and combinations that grouped proximate gages where levels of uncertainty indicated that more frequent visits might be useful. These routes and stations visited are summarized in table 13.

Costs associated with the selected routes are the aggregate sum of the fixed costs, visit costs, and route costs. Fixed costs to operate a gage typically include equipment rental, batteries, electricity, maintenance and miscellaneous supplies, data processing and storage, computer charges, and analysis and supervisory charges. Costs of analysis and supervision (quality control) form a large percentage of the cost at each gaging station. Costs can vary widely from year to year among stations owing to differences in equipment configuration and relative difficulty of data interpretation. For Idaho, fixed costs were determined largely on a station-by-station basis relying heavily on past experience.

Visit costs are those associated with paying the hydrographer for time actually spent at a station servicing the equipment and making a discharge measurement. These costs also vary from station to station and are a function of the difficulty and time required to make the measurement or to merely service the stage-recording equipment. Average visit times were calculated for each station based on analysis of actual field office activity logs, discharge measurements, and visit data available. This time was multiplied by the average hourly salary of hydrographers in the Idaho Office to determine total visit costs.

Route costs include the vehicle cost associated with driving the number of miles to cover the route, rental cost of special transportation such as river boats and snowmobiles, cost of the hydrographer's time while in transit, and any per diem associated with the trip.

K-CERA Results

The Traveling Hydrographer Program utilizes the uncertainty functions along with the appropriate cost data and route definitions to compute the most cost-effective way of operating the stream-gaging network. In this application,

Table 13.--Summary of the routes that may be used to visit stations in Idaho

Route Number	Station(s) Serviced on the Route					
1	12305000	12392300	12309500			
2	12305000	12306500	12309500			
3	12306500	12321500				
4	12314000	12318500	12322000			
5	12322000	12314000				
6	12392000	12392500				
7	12392000					
8	12393000	12394000	12395000			
9	12392895	12395500				
10	12395500					
11	12411000	12413000	12413140	12413150	12413250	12414500
	12414900					
12	12411000					
13	12414500	12414900				
14	12415500	12417000				
15	12416000					
16	12418000	12419000				
17	12416000	12417000	12415500	12418000	12419000	
18	12419000					
19	13290460	13336500	13337000	13338500	13339500	13339800
	13340000	13340600	13341050			
20	13290460					
21	13290460	13334300	13341128	13342450	13342500	13345000
	13346800	13350448	13340950			
22	13340600					
23	13338500	13340000	13341050	13340950		
24	13339500	13340000				
25	13334300					
26	12305000					
27	12305000	12392300				
28	12305000	12306500				
29	12322000					
30	12394000	12395000				
31	12416000	12418000	12419000			
32	13336500	13337000	13338500	13339500	13339800	13340000
	13340600	13341050				
33	13334300	13341128	13342450	13342500	13345000	13346800
	13350448					
34	13052200	13018300	13018750	13011900	13011500	13011000
	13019438	13022500	13023000	13025000	13027500	13032500
35	13018300	13019438	13027500	13025000		
36	13019438					
37	13037500					
38	13037500	13038000				
39	13038000					

Table 13.--Summary of the routes that may be used to visit stations in Idaho--Continued

Route Number	Station(s) Serviced on the Route					
40	13039000	13039500	13042500	13046023	13047500	13049500
	13050500	13056500	13055000	13055340	13055319	13055198
	13038500	13057150				
41	13039000	13039500	13042500			
42	13046023	13047500	13049500			
43	13050500	13055000				
44	13056500	13055319				
45	13055340	13055198				
46	13038500	13057150				
47	13056500					
48	13060000	13066000	13065940	13062500	13069500	13076500
	13077000	13068500	13068495	13075983		
49	13062500	13068495	13069500			
50	13060000	13066000	13065940			
51	13062500	13069500				
52	13077000					
53	13112000	13113000	13114000	13115000		
54	13112000	13113000	13114000			
55	13075000	13073000	13063000	13065000	10125500	13075500
	13070300					
56	13073000	13075000	13075500			
57	13075000					
58	13075500					
59	13305000	13302500	13307000	13297330	13297350	13297355
	13297450	13297597	13126000	13118700	13120000	13120500
	13127000	13128900				
60	13115000	13118700	13126000	13120000	13120500	13127000
61	13128900	13302500				
62	13120000	13120500	13127000	13128900	13118700	
63	13120500	13126000				
64	13077000	13076500				
65	13118700					
66	13078205	13081500	13088000	13087900	13082500	13083000
	13083500					
67	13078205					
68	13081500	13088000				
69	13082500					
70	13081500					
71	13088000					
72	13106500	13090000	13091000	13093095	13094000	13095500
	13105000	13106000	13108150	13135000	13152500	
73	13105000					
74	13090000					
75	13093095					
76	13108150	13152500				

Table 13.--Summary of the routes that may be used to visit stations in Idaho--Continued

Route Number	Station(s) Serviced on the Route					
77	13152500					
78	13154500	13152500				
79	13154500					
80	13142000	13148200	13139500	13141000	13141500	13142500
	13147900	13148500	13150430			
81	13139500					
82	13141000					
83	13141000	13141500				
84	13147900	13148500	13148200			
85	13150430					
86	13141500					
87	13142500	13142000				
88	13118700	13139500	13141000	13141500	13142000	13142500
	13147900	13148200	13148500	13150430		
89	13168500	13169500	13186000	13190500	13190000	
90	13168500					
91	13186000					
92	13190500	13190000				
93	13169500					
94	13154500	13169500				
95	13269000	13289700	13289960	13290190	13290450	13316500
	13317000					
96	13135000	13108150	13094000	13095500	13152500	
97	13152500					
98	13269000					
99	13290450					
100	13289960					
101	13290190					
102	13316500					
103	13317000					
104	13120000	13120500	13127000	13126000	13128900	13296500
	13297330	13297350	13297355	13297450	13297597	13302500
	13305000	13307000				
105	13302500					
106	13305000					
107	13296500	13297330	13297350	13297355	13297450	13297597
108	13297450	13297597				
109	13297355					
110	13297330					
111	13118700	13120000	13120500	13127000	13128900	13126000
112	13120000	13120500				
113	13120500					
114	13200000	13235000				
115	13235000	13247500	13249500	13250000	13250600	13251000
116	13251000					

Table 13.--Summary of the routes that may be used to visit stations in Idaho--Continued

Route Number	Station(s) Serviced on the Route					
117	13249500	13250600				
118	13247500					
119	13246000					
120	13246000	13247500				
121	13236000	13238500	13244500	13236500	13239000	13240000
	13245000	13246000	13310700	13313000		
122	13236500	13236000				
123	13310700	13313000				
124	13240000					
125	13245000					
126	13239000					
127	13254500	13254000	13264000	13255050	13255060	13257000
	13258500	13260500	13265500	13266000		
128	13255050	13255060	13257000	13260500	13261150	13265500
	13254000					
129	13258500	13266000				
130	13258500					
131	13266000					
132	13266000	13269000				
133	13266000	13258500	13289960	13289700	13290190	
134	13265500					
135	13254000	13260500	13265500			
136	13260500					
137	13172500	13185000	13194000	13200000	13202000	13201500
	13205500	13206000	13210050	13211445	13213000	13213100
138	13206000	13213000				
139	13211445					
140	13213000					
141	13206000					
142	13200000					
143	13235000					
144	13172500					
145	13185000					
146	13213100					
147	13185000	13186000				
148	13185000	13200000	13194000			
149	13210050	13211445	13213000			
150	13250000					
151	13249500					
152	13168500					
153	13011500	13011900				
154	13018300	13018750				
155	13018300					
156	13018750					
157	13022500					
158	13027500					

Table 13.--Summary of the routes that may be used to visit stations in Idaho--Continued

Route Number	Station(s) Serviced on the Route					
159	13023000					
160	13032500					
161	13039500	13042500	13046023	13047500	13049500	13050500
	13056500	13055000	13055340	13055319	13055198	13038500
	13057150					
162	13057150					
163	13060000	13066000	13065940	13062500	13069500	13077000
	13068500	13068495				
164	13075000	13073000	13063000	10125500	13075500	
165	10125500					
166	13305000	13302500	13307000	13297330	13297350	13297355
	13297450	13297597	13118700	13120000	13120500	13127000
	13128900					
167	13118700	13120000	13120500	13127000	13128900	
168	13078205	13081500	13088000	13082500	13083000	
169	13090000	13091000	13093095	13094000	13095500	13105000
	13106000	13108150	13135000	13152500		
170	13139500	13141000	13141500	13142500	13147900	13148500
	13150430					
171	13118700	13139500	13141000	13141500	13142500	13147900
	13148500	13150430				
172	13147900	13148500				
173	13190500					
174	13269000	13289960	13290190	13290450	13316500	13317000
175	13135000	13108150	13094000	13095500	13152500	
176	13120000	13120500	13127000	13128900	13296500	13297330
	13297350	13297355	13297450	13297597	13302500	13305000
	13307000					
177	13236500	13239000	13240000	13245000	13246000	13310700
	13313000					
178	13254500	13255050	13255060	13257000	13258500	13260500
	13265500	13266000				
179	13255050	13255060	13257000	13260500	13265500	

the first step was to simulate the current practice and determine the total uncertainty associated with it. To accomplish this, the number of visits being made to each stream gage and the specific routes being used to make these visits were fixed. The resulting average error of estimation for the current practice in Idaho was plotted as a point in figure 21 and is 22.7 percent.

The solid line on figure 21 represents the minimum level of average uncertainty that can be obtained for a given budget with the existing instrumentation and technology. The line was defined by several runs of the Traveling Hydrographer Program with different budgets. Constraints on the operations other than budget were defined as follows.

To determine the minimum number of times each station must be visited, consideration was given only to the physical limitations of the method used to record data. The effect of visitation frequency on the accuracy of the data and amount of lost record is taken into account in the uncertainty analysis. In Idaho, a minimum requirement of four visits per year was calculated and applied to most stations. Several stations require 12 visits per year and one station, 13019438, requires a minimum of 21 visits per year because of specialized equipment used at the station.

The results in figure 21 and table 14 summarize the K-CERA analysis and are predicated on a discharge measurement being made each time that a station is visited. Ideally, the ratio of measurements to visits would be optimized individually for each station. This step will be accomplished in a future evaluation of the Idaho network.

Figure 21 and table 14 are based on various assumptions concerning both the time series of shifts to the stage-discharge relation and the methods of record reconstruction. Where a choice of assumptions was available, the assumption that would not underestimate the magnitude of the error variances was chosen.

Current policy requires a budget of $781,000 to operate the 185-station network and results in an average standard error of 22.7 percent. The range in standard errors is from a low of 1.0 percent for station 13095500, Box Canyon Spring near Wendell, to a high of 65.4 percent for station 13350448, Cow Creek at Genesee. This same average standard error could be obtained with a reduced budget of about $760,000 if the policy of the stream-gaging network were changed. This policy and budget change would result in a decrease in standard error from 1.0 to 0.9 percent for station 13095500, whereas the standard error for station 13350448 would remain at 65.4 percent.

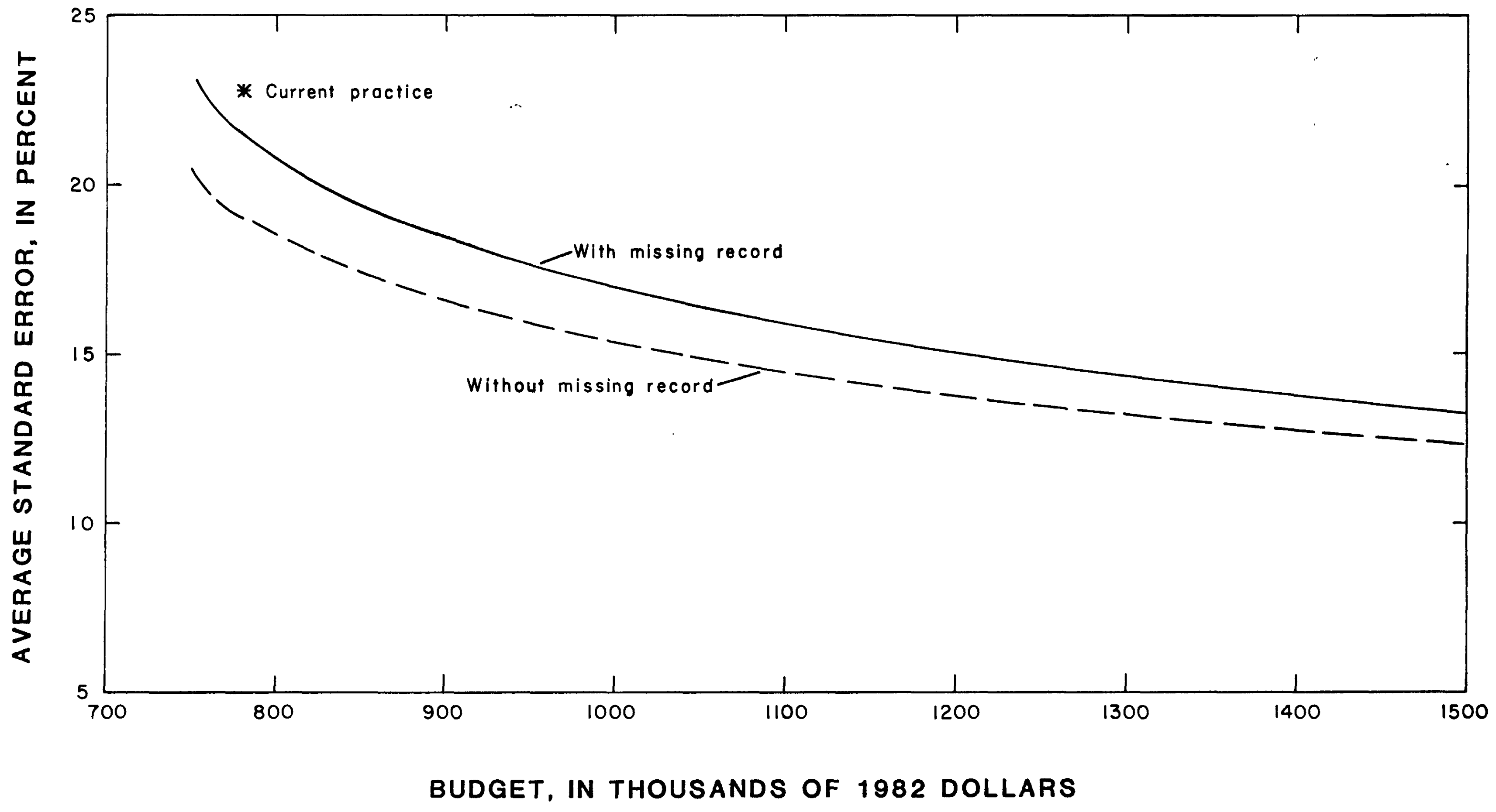

Figure 21.--Temporal average standard error per stream gage.

Table 14.--Standard error of instantaneous discharge for individual stations

Station Number	Standard error of instantaneous discharge, in percent [Equivalent Gaussian Spread] (Number of visits per year to site)					
	Current Operation	Budget, in thousands of 1982 dollars				
		751	760	781	1000	1500
Ave per Station*	22.7	23.0	22.4	21.4	17.0	13.4
10125500	11.7 [9.6] (6)	11.1 [9.5] (8)	11.1 [9.5] (8)	10.9 [9.4] (9)	10.0 [9.2] (17)	9.3 [8.8] (33)
12305000	3.2 [0.6] (8)	3.2 [0.6] (8)	3.2 [0.6] (8)	3.2 [0.6] (8)	2.2 [0.4] (14)	1.9 [0.4] (17)
12306500	48.4 [48.0] (6)	36.4 [36.3] (13)	31.4 [31.3] (18)	31.4 [31.3] (18)	17.3 [17.2] (59)	14.6 [14.6] (82)
12318500	37.3 [37.2] (6)	37.3 [37.2] (6)	37.3 [37.2] (6)	37.3 [37.2] (6)	21.2 [21.2] (40)	17.7 [17.7] (58)
12321500	41.1 [40.9] (6)	36.8 [36.7] (9)	31.5 [31.4] (14)	31.5 [31.4] (14)	16.6 [16.3] (55)	13.7 [13.5] (80)
12322000	24.8 [24.7] (12)	24.8 [24.7] (12)	24.8 [24.7] (12)	24.8 [24.7] (12)	14.5 [14.5] (40)	12.0 [12.0] (59)
12392000	8.0 [5.5] (6)	9.4 [5.8] (4)	9.4 [5.8] (4)	9.4 [5.8] (4)	7.3 [5.3] (8)	7.0 [5.2] (9)
12392300	9.9 [0.8] (8)	14.3 [0.8] (4)	14.3 [0.8] (4)	14.3 [0.8] (4)	8.8 [0.8] (10)	7.2 [0.7] (15)
12392895	44.5 [44.5] (6)	45.7 [45.6] (5)	43.4 [43.4] (7)	44.5 [44.5] (6)	20.5 [20.4] (54)	18.8 [18.7] (64)
12394000	18.8 [18.6] (6)	20.7 [20.7] (4)	20.7 [20.3] (4)	20.7 [20.3] (4)	11.9 [11.8] (20)	10.0 [10.0] (29)
12395000	9.2 [8.8] (6)	10.0 [9.3] (4)	10.0 [9.3] (4)	10.0 [9.3] (4)	6.5 [6.4] (20)	5.6 [5.5] (29)
12395500	8.6 [8.6] (6)	8.8 [8.7] (5)	8.5 [8.5] (7)	8.6 [8.6] (6)	5.4 [5.4] (54)	5.1 [5.1] (64)

Table 14.--Standard error of instantaneous discharge for individual stations--Continued

Station Number	Current Operation	Budget, in thousands of 1982 dollars: 751	760	781	1000	1500
	Standard error of instantaneous discharge, in percent [Equivalent Gaussian Spread] (Number of visits per year to site)					
12411000	10.7 [8.9] (6)	11.8 [9.7] (5)	10.7 [8.9] (6)	9.8 [8.2] (7)	4.4 [3.8] (34)	3.5 [3.1] (52)
12413000	30.5 [30.1] (6)	31.0 [30.5] (5)	30.5 [30.1] (6)	30.0 [29.7] (7)	20.3 [20.3] (34)	16.9 [16.9] (52)
12413140	40.5 [40.3] (6)	43.4 [43.2] (5)	40.5 [40.3] (6)	38.0 [37.8] (7)	17.6 [17.3] (34)	14.3 [14.0] (52)
12413150	32.5 [32.5] (6)	35.3 [35.3] (5)	32.5 [32.5] (6)	30.2 [30.2] (7)	13.6 [13.5] (34)	11.0 [10.9] (52)
12413250	29.2 [29.1] (6)	30.1 [29.9] (5)	29.2 [29.1] (6)	28.4 [28.3] (7)	16.6 [16.4] (34)	13.6 [13.4] (52)
12414500	18.1 [17.0] (6)	19.2 [17.8] (5)	18.1 [17.0] (6)	17.2 [16.2] (7)	8.7 [8.2] (35)	7.3 [6.8] (52)
12414900	30.8 [30.2] (6)	32.1 [31.5] (5)	30.8 [30.2] (6)	29.6 [29.0] (7)	15.5 [15.0] (35)	12.7 [12.3] (52)
12416000	20.4 [15.7] (6)	22.2 [17.1] (5)	17.8 [13.6] (8)	17.8 [13.6] (8)	9.8 [7.3] (27)	8.1 [6.1] (40)
12418000	23.2 [23.0] (6)	26.3 [26.1] (4)	21.8 [21.8] (7)	21.8 [21.8] (7)	12.0 [12.0] (26)	9.9 [9.9] (38)
12419000	4.5 [0.7] (6)	6.0 [0.8] (4)	4.0 [0.7] (7)	4.0 [0.7] (7)	1.8 [0.6] (26)	1.5 [0.6] (38)
13011000	7.6 [0.7] (6)	8.8 [0.7] (6)	8.8 [0.7] (6)	8.8 [0.7] (6)	8.2 [0.7] (7)	6.0 [0.7] (13)
13011500	29.8 [29.6] (8)	25.7 [25.3] (11)	25.7 [24.2] (12)	22.2 [21.6] (15)	17.0 [16.2] (26)	11.9 [11.1] (55)
13011900	34.6 [34.3] (8)	29.8 [29.7] (11)	28.5 [28.5] (12)	25.6 [25.5] (15)	19.5 [19.4] (26)	13.4 [13.3] (55)

Table 14.--Standard error of instantaneous discharge for individual stations--Continued

Station Number	Standard error of instantaneous discharge, in percent [Equivalent Gaussian Spread] (Number of visits per year to site)					
	Current Operation	Budget, in thousands of 1982 dollars				
		751	760	781	1000	1500
13018300	22.8 [22.8] (12)	22.1 [22.1] (13)	22.1 [22.1] (13)	22.1 [22.1] (13)	19.2 [19.1] (18)	13.8 [13.7] (36)
13018750	10.9 [10.5] (8)	11.2 [10.6] (6)	11.2 [10.6] (6)	11.2 [10.6] (6)	11.0 [10.6] (7)	10.2 [10.1] (17)
13019438	18.2 [18.2] (21)	18.2 [18.2] (21)	18.2 [18.2] (21)	18.2 [18.2] (21)	18.2 [18.2] (21)	13.9 [13.9] (37)
13022500	11.2 [11.0] (8)	11.4 [11.1] (6)	11.4 [11.1] (6)	11.4 [11.1] (6)	11.3 [11.1] (7)	11.0 [10.8] (13)
13023000	30.5 [30.2] (8)	32.0 [31.6] (6)	32.0 [31.6] (6)	29.0 [28.8] (10)	21.9 [21.9] (23)	14.8 [14.7] (54)
13027500	2.9 [2.2] (12)	2.8 [2.1] (13)	2.8 [2.1] (13)	2.8 [2.1] (13)	2.7 [2.0] (14)	2.3 [1.8] (19)
13032500	2.2 [1.1] (8)	2.6 [1.2] (6)	2.6 [1.2] (6)	2.6 [1.2] (6)	2.4 [1.2] (7)	1.7 [1.0] (13)
13037500	8.4 [8.4] (12)	8.4 [8.4] (12)	8.4 [8.4] (12)	8.4 [8.4] (12)	8.4 [8.4] (12)	8.4 [8.4] (12)
13038000	7.8 [4.1] (8)	6.5 [3.4] (12)	7.0 [3.7] (10)	7.4 [3.9] (9)	6.5 [3.4] (12)	6.0 [3.2] (14)
13038500	12.0 [10.9] (8)	13.0 [11.7] (6)	13.0 [11.7] (6)	12.0 [10.9] (8)	8.0 [7.4] (24)	5.9 [5.4] (48)
13039500	39.1 [34.7] (6)	30.9 [26.5] (10)	29.5 [25.1] (11)	27.2 [22.9] (13)	20.2 [16.5] (24)	15.8 [12.7] (39)
13042500	25.4 [25.1] (6)	19.7 [19.3] (10)	18.8 [18.4] (11)	17.3 [16.9] (13)	12.7 [12.3] (24)	10.0 [9.7] (39)
13046023	2.4 [0.6] (6)	2.4 [0.6] (6)	2.4 [0.6] (6)	2.0 [0.6] (9)	1.2 [0.4] (24)	0.8 [0.3] (49)

Table 14.--Standard error of instantaneous discharge for individual stations--Continued

Station Number	Standard error of instantaneous discharge, in percent [Equivalent Gaussian Spread] (Number of visits per year to site)					
	Current Operation	Budget, in thousands of 1982 dollars				
		751	760	781	1000	1500
13047500	7.9 [7.6] (6)	7.9 [7.6] (6)	7.9 [7.6] (6)	7.0 [6.7] (9)	4.7 [4.5] (24)	3.3 [3.2] (49)
13049500	38.2 [37.5] (6)	38.2 [37.5] (6)	38.2 [37.5] (6)	35.3 [34.9] (9)	35.1 [25.1] (24)	18.0 [17.9] (49)
13050500	21.3 [21.1] (7)	21.3 [21.1] (7)	21.3 [21.1] (7)	21.3 [21.1] (7)	21.3 [21.1] (7)	17.2 [17.2] (30)
13052200	15.0 [14.5] (8)	15.5 [14.8] (6)	15.5 [14.8] (6)	15.5 [14.8] (6)	15.2 [14.6] (7)	14.4 [14.1] (13)
13055000	6.9 [4.8] (7)	6.9 [4.8] (7)	6.9 [4.8] (7)	6.9 [4.8] (7)	6.9 [4.8] (7)	3.5 [2.4] (30)
13055198	34.2 [34.2] (6)	34.2 [34.2] (6)	34.2 [34.2] (6)	34.2 [34.2] (5)	34.3 [34.2] (7)	34.3 [34.3] (13)
13055319	35.4 [34.6] (6)	28.4 [27.3] (10)	28.4 [27.3] (10)	24.2 [23.0] (14)	19.0 [17.7] (23)	13.3 [12.2] (47)
13055340	7.5 [5.1] (6)	7.5 [5.1] (6)	7.5 [5.1] (6)	8.2 [5.5] (5)	7.0 [4.7] (7)	5.2 [3.5] (13)
13056500	11.0 [11.3] (6)	10.0 [9.9] (10)	10.0 [9.9] (10)	8.9 [8.8] (14)	7.3 [7.2] (23)	5.3 [5.3] (47)
13057150	24.2 [24.1] (8)	25.2 [25.1] (7)	23.3 [23.2] (9)	21.1 [21.0] (12)	15.4 [15.2] (25)	10.7 [10.5] (53)
13060000	6.5 [6.3] (6)	5.9 [5.8] (10)	5.9 [5.8] (10)	5.3 [5.2] (15)	4.3 [4.2] (29)	2.9 [2.9] (70)
13062500	17.7 [7.8] (8)	16.7 [7.4] (9)	16.7 [7.4] (9)	14.5 [6.6] (12)	11.2 [5.2] (20)	7.5 [3.6] (46)
13063000	30.6 [30.6] (6)	27.0 [27.0] (8)	27.0 [27.0] (8)	25.6 [25.6] (9)	18.8 [18.8] (17)	13.5 [13.5] (33)

Table 14.--Standard error of instantaneous discharge for individual stations--Continued

Station Number	Current Operation	751	760	781	1000	1500
	Standard error of instantaneous discharge, in percent [Equivalent Gaussian Spread] (Number of visits per year to site)					
		Budget, in thousands of 1982 dollars				
13065940	16.1 [13.8] (6)	12.7 [10.5] (10)	12.7 [10.5] (10)	10.4 [8.4] (15)	7.7 [6.2] (29)	5.1 [4.1] (70)
13066000	34.4 [34.0] (6)	30.4 [30.1] (10)	30.4 [30.1] (10)	26.7 [26.3] (15)	20.3 [19.8] (29)	13.2 [12.8] (70)
13068495	24.5 [13.9] (8)	23.4 [13.8] (9)	23.4 [13.8] (9)	21.1 [13.5] (12)	18.1 [13.2] (20)	15.0 [12.6] (46)
13068500	36.4 [36.1] (6)	36.4 [36.1] (6)	37.3 [36.8] (4)	36.4 [36.1] (6)	35.7 [35.5] (8)	26.9 [26.8] (46)
13069500	4.0 [3.1] (8)	3.7 [2.9] (9)	3.7 [2.9] (9)	3.2 [2.5] (12)	2.5 [2.0] (20)	1.6 [1.4] (46)
13073000	6.5 [4.8] (6)	5.6 [4.2] (8)	5.6 [4.2] (8)	5.3 [3.9] (9)	3.9 [2.9] (17)	2.8 [2.1] (33)
13075000	14.4 [13.1] (6)	12.5 [11.2] (8)	12.5 [11.2] (8)	11.8 [10.5] (9)	8.7 [9.6] (17)	6.3 [5.5] (33)
13075500	17.0 [16.4] (6)	15.1 [14.5] (8)	15.1 [14.5] (8)	14.5 [13.8] (9)	10.7 [10.2] (17)	7.7 [7.3] (33)
13077000	5.5 [4.4] (6)	5.5 [4.4] (6)	6.3 [4.7] (4)	5.5 [4.4] (6)	5.0 [4.1] (8)	2.5 [2.2] (46)
13078205	23.6 [15.7] (10)	23.6 [15.7] (10)	23.6 [15.7] (10)	23.6 [15.7] (10)	17.9 [11.3] (17)	12.8 [7.8] (33)
13081500	7.6 [7.0] (12)	7.6 [7.0] (12)	7.6 [7.0] (12)	7.6 [7.0] (12)	7.5 [7.0] (13)	6.9 [6.7] (33)
13082500	29.1 [27.2] (8)	29.7 [27.4] (7)	29.7 [27.4] (7)	29.7 [27.4] (7)	27.4 [26.3] (13)	24.3 [23.8] (41)
13083000	7.7 [6.2] (6)	7.1 [5.7] (7)	7.1 [5.7] (7)	7.7 [6.2] (6)	5.3 [4.2] (13)	3.4 [2.7] (33)

Table 14.--Standard error of instantaneous discharge for individual stations--Continued

Station Number	Standard error of instantaneous discharge, in percent [Equivalent Gaussian Spread] (Number of visits per year to site)					
	Current Operation	Budget, in thousands of 1982 dollars				
		751	760	781	1000	1500
13088000	14.5 [14.0] (12)	14.5 [14.0] (12)	14.5 [14.0] (12)	14.5 [14.0] (12)	14.4 [14.0] (13)	13.6 [13.6] (33)
13090000	1.9 [0.9] (8)	3.0 [1.0] (4)	1.9 [0.9] (8)	3.0 [1.0] (4)	3.0 [1.0] (4)	2.1 [0.9] (7)
13091000	4.4 [4.4] (6)	4.9 [4.9] (4)	4.1 [4.1] (8)	4.9 [4.9] (4)	4.9 [4.9] (4)	4.2 [4.2] (7)
13093095	7.9 [2.9] (9)	7.9 [2.9] (9)	7.9 [2.9] (9)	7.9 [2.9] (9)	7.9 [2.9] (9)	6.2 [2.7] (16)
13094000	3.0 [0.7] (6)	3.9 [0.7] (4)	2.5 [0.7] (8)	3.9 [0.7] (4)	3.9 [0.7] (4)	2.7 [0.7] (7)
13095500	1.0 [0.8] (6)	1.1 [0.8] (4)	0.9 [0.8] (8)	1.1 [0.8] (4)	1.1 [0.8] (4)	0.9 [0.8] (7)
13105000	25.3 [24.9] (8)	26.7 [25.6] (4)	25.3 [24.9] (8)	26.7 [25.6] (4)	25.8 [25.1] (6)	24.6 [24.4] (14)
13106000	4.0 [0.7] (6)	4.9 [0.7] (4)	3.5 [0.7] (8)	4.9 [0.7] (4)	4.9 [0.7] (4)	3.8 [0.7] (7)
13108150	8.9 [7.6] (8)	8.1 [6.8] (10)	8.1 [6.8] (10)	7.4 [6.3] (12)	6.1 [5.2] (18)	4.4 [3.7] (36)
13112000	30.8 [23.0] (6)	29.2 [22.2] (7)	29.2 [22.2] (7)	26.7 [20.6] (9)	20.6 [16.3] (17)	12.2 [9.7] (52)
13113000	37.8 [37.4] (6)	37.5 [37.2] (7)	37.5 [37.2] (7)	37.2 [37.0] (9)	36.4 [36.3] (17)	34.5 [34.4] (52)
13114000	13.5 [9.5] (6)	12.9 [9.4] (7)	12.9 [9.4] (7)	12.1 [9.2] (9)	10.3 [8.6] (17)	7.5 [6.8] (52)
13118700	30.2 [30.1] (6)	28.2 [28.1] (8)	28.2 [28.1] (8)	27.3 [27.2] (9)	21.3 [21.1] (18)	15.1 [14.8] (38)

Table 14.--Standard error of instantaneous discharge for individual stations--Continued

Station Number	Standard error of instantaneous discharge, in percent [Equivalent Gaussian Spread] (Number of visits per year to site)					
	Current Operation	Budget, in thousands of 1982 dollars				
		751	760	781	1000	1500
13120000	5.3 [3.4] (6)	4.7 [3.2] (8)	4.7 [3.2] (8)	4.5 [3.1] (9)	3.5 [2.6] (16)	2.5 [1.9] (34)
13120500	18.0 [10.8] (6)	15.6 [9.9] (8)	15.6 [9.9] (8)	14.8 [9.6] (9)	1.6 [8.6] (16)	9.2 [7.8] (34)
13127000	9.3 [7.0] (6)	8.7 [6.9] (8)	8.7 [6.9] (8)	8.5 [6.9] (9)	7.8 [6.8] (16)	7.0 [6.6] (34)
13128900	18.5 [15.3] (6)	16.2 [13.0] (8)	16.2 [13.0] (8)	15.4 [12.2] (9)	11.7 [8.9] (16)	8.2 [6.1] (34)
13135000	1.3 [0.6] (6)	1.6 [0.7] (4)	1.1 [0.6] (8)	1.6 [0.7] (4)	1.6 [0.7] (4)	1.2 [0.6] (7)
13139500	12.6 [11.0] (6)	12.6 [11.0] (6)	12.6 [11.0] (6)	11.0 [9.6] (8)	7.9 [6.8] (16)	5.9 [5.0] (29)
13141000	14.5 [11.9] (8)	13.7 [11.2] (9)	13.7 [11.2] (9)	11.9 [9.7] (12)	9.8 [8.0] (18)	7.3 [6.0] (35)
13141500	29.5 [5.3] (6)	24.0 [4.5] (9)	24.0 [4.5] (9)	20.8 [4.0] (12)	16.1 [3.2] (20)	11.7 [2.3] (38)
13142500	33.2 [18.6] (6)	28.1 [17.7] (9)	28.6 [17.7] (9)	25.8 [16.8] (12)	20.4 [14.4] (22)	14.3 [10.6] (50)
13147900	10.6 [5.9] (6)	8.5 [4.8] (9)	8.1 [4.5] (10)	7.0 [4.0] (13)	5.1 [2.9] (24)	3.7 [2.1] (46)
13148500	40.2 [37.2] (6)	34.5 [31.8] (9)	33.0 [30.4] (10)	29.4 [26.9] (13)	22.0 [19.8] (24)	15.9 [14.2] (46)
13150430	13.5 [12.8] (6)	13.5 [12.8] (6)	13.5 [12.8] (6)	11.9 [11.1] (8)	8.6 [7.8] (16)	6.5 [5.9] (29)
13152500	40.6 [28.1] (8)	35.1 [26.2] (13)	35.1 [26.2] (13)	31.9 [24.9] (18)	24.2 [20.4] (45)	17.8 [15.3] (98)

Table 14.--Standard error of instantaneous discharge for individual stations--Continued

Station Number	Standard error of instantaneous discharge, in percent [Equivalent Gaussian Spread] (Number of visits per year to site)					
	Current Operation	Budget, in thousands of 1982 dollars				
		751	760	781	1000	1500
13154500	1.7 [0.7] (6)	2.3 [0.8] (4)	2.3 [0.8] (4)	2.3 [0.8] (4)	2.3 [0.8] (4)	2.3 [0.8] (4)
13168500	8.9 [0.5] (6)	11.4 [0.6] (4)	11.4 [0.6] (4)	11.4 [0.6] (4)	8.2 [0.5] (7)	5.1 [0.4] (16)
13169500	30.3 [27.1] (12)	32.1 [27.4] (8)	32.1 [27.4] (8)	32.1 [27.4] (8)	29.8 [27.0] (14)	28.2 [26.7] (26)
13172500	4.5 [0.6] (6)	5.0 [0.7] (5)	5.8 [0.7] (4)	4.5 [0.6] (6)	2.6 [0.5] (14)	1.5 [0.3] (38)
13185000	6.6 [4.2] (6)	7.3 [4.6] (5)	8.3 [5.1] (4)	6.6 [4.2] (6)	4.1 [2.8] (14)	2.5 [1.8] (38)
13186000	4.9 [0.5] (6)	6.4 [0.6] (4)	6.4 [0.6] (4)	6.4 [0.6] (4)	4.4 [0.5] (7)	2.7 [0.3] (16)
13190500	15.7 [1.7] (6)	17.2 [1.8] (5)	17.2 [1.8] (5)	15.7 [1.7] (6)	12.2 [1.3] (10)	8.7 [1.0] (20)
13200000	39.4 [39.3] (6)	39.4 [39.3] (6)	39.6 [39.4] (4)	39.3 [39.2] (7)	35.4 [35.4] (55)	24.0 [24.0] (237)
13202000	39.0 [38.5] (6)	39.8 [39.2] (5)	40.7 [40.0] (4)	39.0 [38.5] (6)	33.8 [33.4] (14)	24.2 [23.9] (38)
13205500	19.5 [7.2] (6)	21.5 [8.0] (5)	24.1 [9.2] (4)	19.5 [7.2] (6)	12.6 [4.6] (14)	7.7 [3.0] (38)
13206000	14.8 [11.6] (8)	16.8 [13.0] (6)	15.7 [12.2] (7)	13.4 [10.5] (10)	10.2 [8.0] (18)	7.0 [5.5] (39)
13210050	18.3 [10.8] (6)	14.4 [8.8] (10)	15.2 [9.2] (9)	13.3 [8.1] (12)	10.9 [6.7] (18)	7.6 [4.7] (38)
13211445	43.2 [12.8] (6)	26.6 [7.2] (16)	25.1 [6.8] (18)	22.7 [6.1] (22)	15.9 [4.3] (45)	11.8 [3.2] (82)

Table 14.--Standard error of instantaneous discharge for individual stations--Continued

Station Number	Current Operation	Budget, in thousands of 1982 dollars: 751	760	781	1000	1500
	Standard error of instantaneous discharge, in percent [Equivalent Gaussian Spread] (Number of visits per year to site)					
13213000	7.1 [0.5] (8)	6.4 [0.5] (10)	6.7 [0.5] (9)	5.8 [0.5] (12)	4.7 [0.4] (18)	3.2 [0.3] (38)
13213100	6.2 [1.5] (6)	6.9 [1.6] (5)	7.9 [1.7] (4)	6.2 [1.5] (6)	3.7 [1.2] (14)	2.2 [0.8] (38)
13235000	13.8 [12.7] (6)	15.5 [13.6] (4)	15.5 [13.6] (4)	15.5 [13.6] (4)	13.2 [12.4] (7)	9.6 [9.4] (19)
13236500	59.3 [33.5] (6)	51.7 [32.2] (9)	51.7 [32.2] (9)	48.5 [31.7] (11)	41.6 [30.5] (19)	33.4 [28.1] (48)
13239000	14.6 [7.9] (6)	13.7 [7.7] (7)	13.7 [7.7] (7)	11.8 [7.2] (10)	9.1 [6.1] (19)	6.0 [4.3] (48)
13240000	18.7 [9.9] (6)	17.4 [9.7] (7)	17.4 [9.7] (7)	15.0 [9.3] (10)	12.0 [8.8] (19)	9.0 [7.9] (48)
13245000	11.2 [7.2] (6)	10.4 [7.0] (7)	10.4 [7.0] (7)	8.8 [6.3] (10)	6.5 [5.0] (19)	4.2 [3.4] (48)
13246000	5.7 [0.5] (6)	4.8 [0.5] (8)	5.2 [0.5] (7)	4.2 [0.4] (10)	2.9 [0.3] (19)	1.7 [0.2] (48)
13247500	5.1 [0.8] (6)	6.7 [0.8] (4)	6.7 [0.8] (4)	6.7 [0.8] (4)	5.7 [0.8] (5)	4.3 [0.8] (8)
13249500	5.8 [0.6] (6)	4.3 [0.5] (9)	4.3 [0.5] (9)	2.9 [0.4] (16)	1.8 [0.3] (35)	1.2 [0.2] (79)
13250000	6.8 [2.8] (6)	8.4 [3.4] (4)	8.4 [3.4] (4)	8.4 [3.4] (4)	7.5 [3.0] (5)	5.5 [2.3] (9)
13250600	42.2 [39.6] (6)	39.2 [37.2] (9)	39.2 [37.2] (9)	34.2 [32.8] (16)	26.0 [24.9] (35)	17.8 [17.0] (79)
13251000	3.9 [0.5] (6)	5.2 [0.6] (4)	5.2 [0.6] (4)	5.2 [0.6] (4)	5.2 [0.6] (4)	3.9 [0.5] (6)

Table 14.--Standard error of instantaneous discharge for individual stations--Continued

Station Number	Standard error of instantaneous discharge, in percent [Equivalent Gaussian Spread] (Number of visits per year to site)					
	Current Operation	Budget, in thousands of 1982 dollars				
		751	760	781	1000	1500
13254500	7.8 [5.3] (6)	7.3 [5.2] (7)	7.3 [5.2] (7)	7.3 [5.2] (7)	6.6 [4.8] (9)	4.5 [3.6] (24)
13255050	40.5 [40.4] (12)	40.5 [40.4] (12)	40.5 [40.4] (12)	40.5 [40.4] (12)	40.4 [40.3] (13)	28.1 [28.1] (163)
13255060	41.5 [41.4] (12)	41.5 [41.4] (12)	41.5 [41.4] (12)	41.5 [41.4] (12)	41.5 [41.4] (13)	41.5 [41.5] (163)
13257000	40.5 [40.4] (12)	40.5 [40.4] (12)	40.5 [40.4] (12)	40.5 [40.4] (12)	40.4 [40.3] (13)	28.1 [28.1] (163)
13258500	16.5 [14.6] (8)	16.9 [14.7] (7)	16.9 [14.7] (7)	16.9 [14.7] (7)	15.5 [14.4] (12)	14.1 [13.7] (35)
13260500	40.5 [40.4] (12)	40.2 [40.1] (15)	40.2 [40.1] (15)	40.2 [40.1] (15)	39.9 [39.9] (18)	28.1 [28.1] (163)
13265500	40.6 [26.5] (12)	37.5 [25.8] (15)	37.5 [25.8] (15)	35.3 [25.2] (18)	30.1 [23.6] (31)	17.7 [15.6] (163)
13266000	18.2 [8.5] (8)	16.0 [7.9] (10)	17.0 [8.2] (9)	17.0 [8.2] (9)	13.3 [7.1] (14)	8.1 [4.8] (37)
13269000	2.2 [0.5] (10)	2.2 [0.5] (10)	2.2 [0.5] (10)	2.2 [0.5] (10)	2.2 [0.5] (10)	2.2 [0.5] (10)
13289960	17.6 [12.6] (6)	16.4 [11.6] (7)	15.3 [10.7] (8)	15.3 [10.7] (8)	13.1 [9.0] (11)	10.0 [6.7] (19)
13290190	15.7 [2.5] (6)	14.4 [2.4] (7)	13.3 [2.3] (8)	13.3 [2.3] (8)	11.2 [2.0] (11)	8.3 [1.6] (19)
13290450	2.7 [0.7] (8)	2.9 [0.7] (7)	2.7 [0.7] (8)	2.7 [0.7] (8)	2.7 [0.7] (8)	2.7 [0.7] (8)
13296500	5.1 [0.8] (6)	5.7 [0.8] (5)	6.5 [0.9] (4)	5.1 [0.8] (6)	3.4 [0.8] (12)	1.4 [0.6] (80)

Table 14.--Standard error of instantaneous discharge for individual stations--Continued

Station Number	Current Operation	Budget, in thousands of 1982 dollars: 751	760	781	1000	1500
	Standard error of instantaneous discharge, in percent [Equivalent Gaussian Spread] (Number of visits per year to site)					
13297330	33.4 [33.2] (6)	33.0 [32.9] (9)	33.1 [33.0] (8)	32.9 [32.8] (11)	32.0 [32.0] (21)	25.6 [25.6] (102)
13297350	34.7 [31.6] (6)	28.7 [25.4] (9)	33.3 [27.1] (8)	26.0 [22.8] (11)	18.9 [16.1] (21)	8.9 [7.4] (102)
13297355	30.8 [30.5] (6)	26.3 [26.2] (9)	27.6 [27.4] (8)	24.1 [24.0] (11)	17.8 [17.6] (21)	8.2 [8.0] (102)
13297450	21.6 [21.0] (6)	21.0 [20.6] (9)	21.1 [20.7] (8)	20.7 [20.4] (11)	19.8 [19.7] (21)	14.8 [14.8] (130)
13297597	56.6 [56.1] (6)	56.7 [56.3] (9)	56.7 [56.3] (8)	56.6 [56.3] (11)	55.9 [55.7] (21)	44.9 [44.9] (130)
13302500	4.8 [3.6] (6)	5.8 [4.0] (4)	5.8 [4.0] (4)	5.2 [3.8] (5)	4.1 [3.2] (9)	2.8 [2.2] (22)
13305000	22.4 [22.3] (6)	25.0 [24.9] (4)	25.0 [24.9] (4)	23.6 [23.5] (5)	19.5 [19.3] (9)	13.1 [12.8] (22)
13307000	3.8 [2.3] (6)	4.8 [2.7] (4)	4.8 [2.7] (4)	4.2 [2.5] (5)	3.1 [2.0] (9)	1.9 [1.3] (22)
13310700	17.2 [16.9] (6)	16.6 [16.3] (7)	16.6 [16.3] (7)	14.9 [14.7] (10)	11.8 [11.6] (19)	7.7 [7.5] (48)
13313000	21.4 [21.4] (6)	21.2 [21.2] (7)	21.2 [21.2] (7)	20.9 [20.9] (10)	19.8 [19.8] (19)	16.6 [16.6] (48)
13316500	17.3 [7.1] (6)	16.0 [6.9] (7)	14.9 [6.7] (8)	14.9 [6.7] (8)	14.9 [6.7] (8)	11.2 [6.2] (15)
13317000	3.0 [0.8] (6)	2.7 [0.8] (7)	2.5 [0.7] (8)	2.5 [0.7] (8)	2.5 [0.7] (8)	2.5 [0.7] (8)
13334300	2.0 [0.7] (6)	2.6 [0.7] (4)	2.0 [0.7] (6)	1.9 [0.7] (7)	0.9 [0.4] (30)	0.7 [0.4] (49)

Table 14.--Standard error of instantaneous discharge for individual stations--Continued

Standard error of instantaneous discharge, in percent
[Equivalent Gaussian Spread]
(Number of visits per year to site)

Station Number	Current Operation	Budget, in thousands of 1982 dollars: 751	760	781	1000	1500
13336500	16.0	18.1	18.1	18.1	12.1	8.6
	[15.8]	[17.8]	[17.8]	[17.8]	[12.0]	[8.5]
	(6)	(4)	(4)	(4)	(12)	(25)
13337000	29.6	31.1	31.1	31.1	25.4	19.4
	[29.5]	[30.9]	[30.9]	[30.9]	[25.3]	[19.4]
	(6)	(4)	(4)	(4)	(12)	(25)
13338500	12.9	13.8	13.8	13.8	11.8	10.9
	[11.7]	[12.0]	[12.0]	[12.0]	[11.3]	[10.6]
	(6)	(4)	(4)	(4)	(12)	(25)
13339500	7.4	8.2	8.2	8.2	6.2	4.9
	[6.1]	[6.4]	[6.4]	[6.4]	[5.5]	[4.4]
	(6)	(4)	(4)	(4)	(12)	(25)
13339800	29.2	30.5	30.5	30.5	26.4	22.0
	[28.4]	[29.4]	[29.4]	[29.4]	[25.9]	[21.6]
	(6)	(4)	(4)	(4)	(12)	(25)
13340000	9.5	10.1	10.1	10.1	8.6	7.2
	[9.2]	[9.5]	[9.5]	[9.5]	[8.5]	[7.1]
	(6)	(4)	(4)	(4)	(12)	(25)
13340600	12.2	14.6	14.6	14.6	8.8	6.2
	[10.1]	[11.7]	[11.7]	[11.7]	[7.5]	[5.3]
	(6)	(4)	(4)	(4)	(12)	(25)
13341050	7.8	10.5	10.5	10.5	4.7	2.9
	[0.6]	[0.7]	[0.7]	[0.7]	[0.5]	[0.3]
	(6)	(4)	(4)	(4)	(12)	(25)
13341128	32.9	35.0	32.9	32.1	22.0	17.9
	[31.6]	[33.0]	[31.6]	[30.9]	[21.5]	[17.4]
	(6)	(4)	(6)	(7)	(30)	(49)
13342450	20.8	25.5	20.8	19.3	9.4	7.5
	[18.9]	[23.4]	[18.9]	[17.4]	[8.3]	[6.6]
	(6)	(4)	(6)	(7)	(30)	(49)
13342500	2.8	3.6	2.9	2.6	1.3	1.0
	[0.7]	[0.7]	[0.7]	[0.7]	[0.6]	[0.6]
	(6)	(4)	(6)	(7)	(30)	(49)
13345000	36.8	40.8	36.8	35.2	20.0	15.8
	[34.4]	[37.5]	[34.4]	[33.1]	[18.8]	[14.7]
	(6)	(4)	(6)	(7)	(30)	(49)
13346800	32.4	38.5	32.4	30.2	14.9	11.7
	[24.2]	[29.1]	[24.2]	[22.4]	[10.4]	[8.1]
	(6)	(4)	(6)	(7)	(30)	(49)

Table 14.--Standard error of instantaneous discharge for individual stations--Continued

Station Number	Current Operation	Standard error of instantaneous discharge, in percent [Equivalent Gaussian Spread] (Number of visits per year to site) — Budget, in thousands of 1982 dollars: 751	760	781	1000	1500
13350448	65.4 [64.8] (6)	77.0 [76.6] (4)	65.4 [64.8] (6)	61.0 [60.4] (7)	29.3 [27.8] (30)	22.8 [21.4] (49)

It also would be possible to reduce the average standard error by a policy change while maintaining the same budget of $781,000. In this case, the average standard error would decrease from 22.7 to 21.4 percent. Extremes of standard errors for individual sites would be 1.1 and 61.0 percent for stations 13095500 and 13350448, respectively.

A minimum budget of $751,000 is required to operate the 185-station network; a budget less than this would not permit proper service and maintenance of gages and recorders. Stations would have to be eliminated from the network if the budget fell below this minimum. At the minimum budget, the average standard error is 23.0 percent. The minimum standard error of 1.1 percent would occur at station 13095500, and the maximum of 77.0 percent would occur at station 13350448.

The maximum budget analyzed was $1,500,000, which resulted in an average standard error of 13.4 percent. Thus, almost doubling the budget in conjunction with policy change would reduce the current average standard error by 40 percent. For the $1,500,000 budget, the extremes of standard error are 0.7 percent at station 13334300, Snake River near Anatone, and 44.9 percent at station 13297597, Herd Creek below Trail Gulch near Clayton. Significant improvements in streamflow record accuracy can be obtained if larger budgets become available.

The analysis also was performed under the assumption that no correlative data at a stream gage were lost to estimate the uncertainty that was added to the stream-gaging records because of imperfect instrumentation. The curve labeled "Without missing record" on figure 21 shows the average standard errors of estimate that could be obtained if perfectly reliable systems were available to measure and record correlative data. For the minimal operational budget of $751,000, impacts of imperfect equipment are greatest; average standard errors increase from 20.3 to 23.0 percent. The minimum percent is not attainable with current equipment at a budget of $820,000.

At the other budgetary extreme of $1,500,000, under which stations are visited more frequently and the reliability of equipment is less sensitive, average standard errors increased from 12.5 percent for ideal equipment to 13.4 percent for the current systems of sensing and recording hydrologic data. Thus, improved equipment can have a positive impact on streamflow uncertainties throughout the range of operational budgets that could be anticipated for the stream-gaging network in Idaho.

Conclusions from the K-CERA Analysis

As a result of the K-CERA analysis, the following conclusions are offered:

1. Policy for definition of field activities in the Idaho stream-gaging network should be altered to maintain the current average standard error of 22.7 percent with a budget of approximately $760,000. This shift would result in some increases and some decreases in accuracy of records at individual stations.

2. Amount of funding for stations with accuracies that are not acceptable for data uses should be renegotiated with data users.

3. Funding made available by implementing the first two conclusions should be used to establish new stream gages in areas of Idaho where data are particularly sparse.

4. The K-CERA analysis should be rerun with the new stations included whenever sufficient information about the characteristics of the new stations has been obtained.

5. Schemes for reducing the probabilities of missing record, for example, increased use of local gage observers and satellite relay of data, should be explored and evaluated as to cost effectiveness.

SUMMARY

In 1982, 185 surface-water gages were operated in Idaho at a cost of $781,000. Eleven sources of funding contribute to this network and nine data-use categories are identified. In spite of the size of the network, streamflow data are sparse for a large part of Idaho's east-central and southwest areas.

Analysis of data-use categories identified 19 stations that could be discontinued. The remaining stations should be maintained in the current network.

Current operation of the 185-station network requires an annual budget of $781,000. The overall level of record accuracy of 22.7 percent at these 185 stations could be maintained with a budget of $760,000 if the allocation of manpower and equipment among gages was redistributed. Such a redistribution would allow additional money for establishing gages in data-deficient areas of the State.

One cause of record error is loss of primary record (stage or other correlative data) at stream gages owing to malfunctions of sensing and recording equipment. Upgrading equipment and developing strategies to minimize lost record would improve reliability and accuracy of streamflow data.

Studies of the cost effectiveness of the stream-gaging network should be continued. These studies should include investigation of the optimum ratio of discharge measurements to total site visits for each station, as well as investigation of cost-effective ways to reduce the probabilities of lost correlative data. Future studies would be essential to identify changes in demand for streamflow information and subsequent addition and deletion of stream gages. Such changes would impact operation of other stations in the network because of data use and data-collection cost interdependence among stations.

REFERENCES CITED

Benson, M. A., and Carter, R. W., 1973, A national study of the streamflow data-collection program: U.S. Geological Survey Water-Supply Paper 2028, 44 p.

Doyle, W. H. Jr., Shearman, J. O., Stiltner, G. J., and Krug, W. R., 1983, A digital model for streamflow routing by convolution methods: U.S. Geological Survey Water-Resources Investigations Report 83-4160, 130 p.

Draper, N. R., and Smith, H., 1966, Applied regression analysis, 2d ed.: New York, John Wiley and Sons, 709 p.

Fenneman, N. M., 1931, Physiography of the Western United States: New York, McGraw-Hill, p. 225-272.

Follansbee, Robert, [dates unknown], A history of the Water Resources Branch of the U.S. Geological Survey: U.S. Geological Survey Administrative Report, 4 vols.

Fontaine, R. A., 1982, Cost-effective stream-gaging strategies for Maine: U.S. Geological Survey Open-File Report 82-507, 43 p.

Fontaine, R. A., Moss, M. E., Smath, J. A., and Thomas, W. O. Jr., 1984, Cost-effectiveness of the stream-gaging program in Maine: U.S. Geological Survey Water-Supply Paper 2244, 39 p.

Gelb, A., ed., 1974, Applied optimal estimation: Cambridge, Mass., The Massachusetts Institute of Technology Press, 374 p.

Gilroy, E. J., and Moss, M. E., 1981, Cost-effective stream-gaging strategies for the Lower Colorado River Basin: U.S. Geological Survey Open-File Report 81-1019, 42 p.

Hutchinson, N. E., 1975, WATSTORE user's guide, volume 1: U.S. Geological Survey Open-File Report 75-426.

Keefer, T. N., 1974, Desktop computer flow routing: American Society of Civil Engineers, Journal of the Hydraulics Division, Proceedings, v. 100, no. HY7, p. 1047-1058.

Keefer, T. N., and McQuivey, R. S., 1974, Multiple linearization flow routing model: American Society of Civil Engineers, Journal of the Hydraulics Division, Proceedings, v. 100, no. HY7, p. 1031-1046.