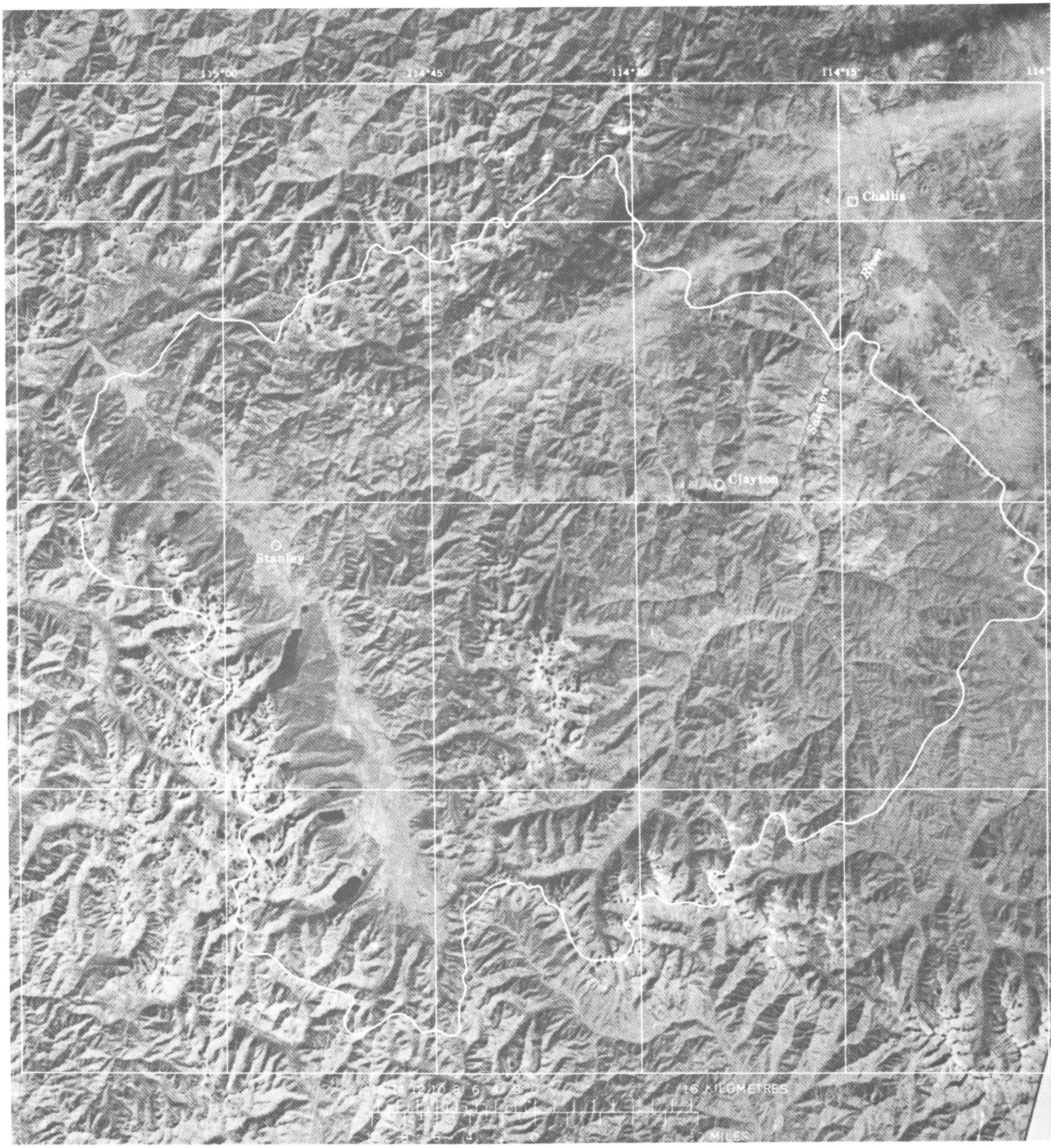
The Channels and Waters of the Upper Salmon River Area, Idaho

GEOLOGICAL SURVEY PROFESSIONAL PAPER 870-A

THE CHANNELS AND WATERS OF THE UPPER SALMON RIVER AREA, IDAHO



Imagery of study area observed at an altitude of 570 miles from the ERTS–1 earth-orbiting satellite.

The Channels and Waters of the Upper Salmon River Area, Idaho

By WILLIAM W. EMMETT

HYDROLOGIC EVALUATION
OF THE UPPER SALMON RIVER AREA, IDAHO

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ILLUSTRATIONS

TABLES

SYMBOLS

A	Flow area of stream, in square feet (=*W*×*D*)
D	Flow depth in stream, in feet
G	Suspended-sediment discharge, in tons per day
L	Stream length, in miles
Q	Water discharge of stream, in cubic feet per second
R	Unit runoff of streamflow, in cubic feet per second per square mile
S	Stream slope, in feet per foot
T	Temperature, in degrees Fahrenheit (°F) or degrees Celsius (°C)
V	Flow velocity in stream, in feet per second
W	Flow width in stream, in feet
DA	Drainage area, in square miles
DS	Dissolved solids, in milligrams per litre

RI	Recurrence interval, in years
SC	Specific conductance, in micromhos
a	Coefficient of width in hydraulic geometry
b	Coefficient of specific conductance
c	Coefficient of depth in hydraulic geometry
d	Particle diameter, in millimetres
k	Coefficient of velocity in hydraulic geometry
r	Correlation coefficient, may be either negative or positive
t	Turbidity, in Jackson Turbidity Units (JTU)
	Subscripts
A	With reference to average
B	With reference to bankfull
T	With reference to total
c	With reference to concentration
m	With reference to map values
s	With reference to field survey
	Superscripts
b	Exponent of width in hydraulic geometry
f	Exponent of depth in hydraulic geometry
j	Exponent of suspended sediment in hydraulic geometry
m	Exponent of velocity in hydraulic geometry
s	Exponent of specific conductance

CONVERSION FACTORS

[Multiply English units by factor given to obtain metric units; divide metric units by factor to obtain English units]

		Length
inches (in.)	25.4	millimetres (mm)
	.0254	metres (m)
feet (ft)	.3048	metres (m)
miles (mi)	1.609	kilometres (km)
		Area
square feet (ft²)	.0929	square metres (m²)
acres	4047	square metres (m²)
	.4047	hectares (ha)
	.4047	square hectometre (hm²)
	.004047	square kilometres (km²)
square miles (mi²)	2.590	square kilometres (km²)
		Volume
cubic feet (ft³)	28.32	cubic decimetres (dm³)
	.02832	cubic metres (m³)
		Flow
cubic feet per second (ft³/s)	28.32	litres per second (l/s)
	28.32	cubic decimetres per second (dm³/s)
	.02832	cubic metres per second (m³/s)
		Mass
pound (lb)	454	grams (g)
	.454	kilograms (kg)
ton (short)	.9072	tonne (t)

THE CHANNELS AND WATERS OF THE UPPER SALMON RIVER AREA, IDAHO

By WILLIAM W. EMMETT

ABSTRACT

The upper 1,800 square miles of the Salmon River drainage basin in south-central Idaho is an area of great scenic beauty and little-disturbed natural environment. Proper development and use of this land and its natural resources are contingent on a multifaceted and detailed environmental study. The report series emphasizes the complex interaction of hydrological, biological, geological, and chemical parameters. This particular report concentrates on the hydraulics and geometry of streamflow and the composition of stream water.

Stream runoff at bankfull stage varies with size of drainage area according to the approximate relation $R_B = 28.3\ DA^{-0.31}$, but this relation is locally variable, as precipitation is locally greater or less than the mean for the area. More exacting than size of drainage area, the size of stream channel is everywhere related to the magnitude of bankfull discharge, Q_B, by the approximate relations $W_B = 1.37\ Q_B^{0.54}$ and $D_B = 0.25\ Q_B^{0.34}$. Bankfull discharge has a recurrence interval of about 1.5 years, and flows proportional to bankfull discharge tend to have a common frequency of occurrence among streams. Mean annual discharge is approximately 25 percent of bankfull discharge, and flows equal to or greater than mean annual discharge occur about 25 percent of the time. Magnitude of high- and low-flow stream characteristics are presented in terms of the ratio of discharge to bankfull discharge, Q/Q_B, and the frequency and duration characteristics of these flows are approximately the same for all streams in the area.

Stream-water composition is primarily of the calcium bicarbonate type, and mineral concentrations generally are low. Typified by data from the main stream at the exit from the study area, major cations in the weight ratio Ca:Na:Mg:K are present in the amounts 1.0:0.22:0.12:0.04; major anions in the weight ratio HCO_3:SO_4:Cl:Fl are present in the amounts of 1.0:0.06:0.01:0.005. Dissolved solids, *DS*, vary with discharge approximately as $DS \propto (Q/Q_B)^{-0.20}$. Values of the concentration of dissolved solids at a given value of the discharge ratio are locally variable depending on solubility of upstream rock types and magnitude of runoff. At the exit from the study area, the main stream has a concentration of dissolved solids of 78 milligrams per litre at bankfull stage and 101 milligrams per litre at mean annual discharge. The concentration of individual major ions follows the trend of dissolved solids. Ions present in trace concentrations are more erratic in respect to both temporal and spatial occurrence. The frequency of occurrence of the true trace elements generally is related to their relative abundance in the average composition of the earth's crust as modified by mineral solubilities. Taking an average of the whole of 2,304 analyses for 21 different trace elements, a trace element was detected in 56 percent of the samples analyzed and occurred, at one time or another, at 96 percent of the locations sampled.

Suspended sediment varies with discharge approximately as $G \propto (Q/Q_B)^{2.5}$. Values of the concentration of suspended sediment at a given value of the discharge ratio are locally variable depending on erodibility of upstream rock types, artificially induced impacts, and the competence of the stream to transport its imposed sediment load. At the exit from the study area, the concentration of suspended sediment in the main stream is 80 milligrams per litre at bankfull discharge and 5 milligrams per litre at mean annual discharge.

On the basis of average duration of flows of various frequency, the average annual discharge of suspended and dissolved solids is about 200,000 tons. The ratio of weight of dissolved solids to weight of suspended solids is about 1.75:1.0.

Continued monitoring of all aspects of the study for detection and documentation of changes provides data to determine variations in initial or baseline relations, relations discussed here and those yet to be made such as between biological parameters and total sediment yield. The data presented in this report should help decisionmakers in the judicious use of the resources of the area so that any changes in baseline characteristics will not be degrading to the quality of the environment.

INTRODUCTION

Relatively few studies of the quality of the nation's rivers have been directed toward determining changes in specific parameters over long periods of time. As detailed by Wolman (1971), this lack of direction is due to a number of reasons. First, hydrologic records in the United States are sufficiently short that a knowledge of the background or baseline characteristics as well as temporal variations are not available. Second, techniques of observation and of analysis have changed. Third, changes in location or frequency of observations distort the record. Fourth, adequate correlation of specific water-quality parameters to hydrologic behavior has not been made. And fifth, a knowledge of the cultural or land-use background is as necessary in explaining changes in water-quality parameters as is a description of the natural resources background. This report attempts, albeit for a small area, to alleviate some of the mentioned shortcomings.

The upper drainage basin of the Salmon River in south-central Idaho consists of a river net of pristine, or nearly so, waters where the impact of man's influence is either negligible or may be described simply. Water-quality samples and associated channel-hydraulics data were systematically collected at a network of water-data stations; water-quality analyses were conducted by standardized U.S. Geological Survey techniques. The relations of hydrologic behavior to channel geometry allow extrapolation of flow characteristics to ungaged areas, and the interrelation of streamflow, water quality, geology, topography, and land use allow interpretation of data for the entire area as a river system rather than isolated observations of river quality. Although only a short-term record of water-quality data exists, the present report materially adds to a description of the hydrologic environment of the area. With the present work being undertaken before the natural environment of the area is greatly disturbed, the short length of the record may be overlooked, for future data collection will complete the record and not just add length to a partially complete record.

The author's work with overland flow on hillslopes (Emmett, 1970) has shown that considerable erosive work or modification to the landscape is done by water before it becomes confined to a tributary channel, and thus the dissolved and suspended load of the main river, and moreover its entire geomorphic character, is in large measure a function of the geologic, biologic, and meteorologic conditions within the entire watershed. The analyses of the present report specifically emphasize this complex interaction of the hydrological, geological, biological, and chemical parameters.

Few studies over the years have attempted to interrelate the many environmental factors of a given area. Other than the present study, the author knows only of the work reported by Miller, Troxell, and Leopold (1971) on the hydrology of two small watersheds in Pennsylvania before urbanization. One reason why these interrelations are seldom expressed for wide areas is that they require special types of graphs, and for this reason the author has developed some new tools. Also, this report shows the consistency of streamflow characteristics among the various channels by dimensionless curves valid for the region of study. Chemical quality of water is particularly difficult to regionalize, but the present report includes one attempt to do this. Moreover, an averaging of regional data provides a factor against which to judge individual rivers or stations.

ACKNOWLEDGMENTS

The primary effort in this study was initiated in the spring of 1971, and fieldwork was conducted through the remainder of that year and all of 1972. Prior to this primary effort, in 1970, five water-data stations were established in the Little Boulder Creek and Big Boulder Creek drainage areas by the Idaho District, U.S. Geological Survey. Throughout this study, these stations provided important data for those areas.

Many of the streamflow measurements and sample collections for water-quality analysis were made by personnel of the Idaho District under the direction of Hal K. Hall, District Chief. Especially notable was the work performed by Robert W. Luscombe. Summer field assistant for both years was Michael W. Van Liew, who also assisted in the compilation of data. The help of these and other Idaho District personnel is gratefully acknowledged.

The biological data-collection program is still underway and is being conducted in collaboration with Keith V. Slack and Larry J. Tilley, U.S. Geological Survey, Menlo Park, Calif.

Many persons provided stimulating discussions, both in the field and in the office, which materially aided the success of the study. These include Luna B. Leopold, Lawrence E. Newcomb, Paul C. Benedict, Don M. Culbertson, and Robert R. Curry. Most also assisted in review of the manuscript. For their review, comments, and suggestions regarding the manuscript, the author is indebted also to Thomas Dunne, L. Edward Perry, Vance C. Kennedy, Garnett P. Williams, Howard F. Matthai, John H. Feth, Willis L. Burnham, Alfred H. Harder, Kenneth L. Dyer, and Cecil A. Thomas.

DESCRIPTION OF THE PROBLEM

In the center of the study area are the White Cloud Peaks, renowned for their scenic vistas and primitive character. The area's 250 mountain peaks average close to 10,000 feet in height and cover an area of 80 square miles. Within a 5-mile radius of Castle Peak, the highest of the White Cloud Peaks, are more than 50 alpine lakes providing extraordinary fishing for cutthroat, rainbow, and golden trout. The Salmon River and its tributaries are important spawning grounds for salmon and steelhead. Big game in the area includes deer, elk, bighorn sheep, mountain goats, and black bear. The alpine soil supports lush meadows and their profusion of wildflowers. Even within recent years, the region has been lightly used, and man's activities have had little impact on the environment of the area. Because of its remoteness and ruggedness, the American public has, in the past, paid little attention to this area of great natural beauty.

The area is highly mineralized and contains economic deposits of numerous mineable ores. Indeed, the first settlers were miners, and many abandoned mine shafts, mill buildings, and access roads are still present. Even today, mining accounts for an appreciable amount of the area's economy. Still, these mineral exploitations have had little major impact on the natural environment. And, many believe these relics of the pick and shovel era of mining are esthetically appealing as part of the area's heritage rather than derogatory to the beauty of the landscape.

In the 1960's, the discovery of extensive deposits of molybdenum ore in the White Cloud Peaks area of the upper Salmon River country resulted in mineral claims, exploration activities, and proposals for open-pit mining of ore. One large open-pit mine was proposed at the base of Castle Peak and included an extensive tailings pond in the Little Boulder Creek drainage. The area of the proposed mine is, perhaps, the scenic highlight in an overall area of great scenic beauty; this fact, combined with the increasing concern of the American public toward conservation of the natural resources and maintenance of environmental quality, led to requests to the Federal Government, as proprietor of the land involved, to evaluate all aspects of the environment in determining the most judicious uses of the area's resources. This report series describes one aspect of the evaluation, an assessment of the hydrologic environment. The present report is confined to a description of the stream channels and an analysis of the streamflow and water-quality characteristics of the area.

Since the initiation of the present study, the Congress of the United States enacted a law in 1972 to establish the Sawtooth National Recreation Area. Included within its boundaries are the Sawtooth Mountains, White Cloud Peaks, and Boulder Mountains; these areas and the adjacent valley lands compose about half the present study area. The language of the bill establishing the recreation area is directed toward preservation of the existing environment and precludes the initiation of new mining activity within the boundaries of the recreation area. Although the prospects of large-scale mining in the White Cloud area are no longer highly probable, the data of this report assume new importance in planning and management decisions of the land and resources in their new classification status. Even more importantly, the data begin to satisfy the environmental needs detailed by Wolman (1971).

SCOPE OF THE INVESTIGATION

The study area comprises 1,800 square miles upstream from the U.S. Geological Survey gaging station on the Salmon River near Challis. About one-third of the area comprises the White Cloud Peaks drainage area, which includes the headwaters of streams draining westward to the Salmon River from its origin to the town of Stanley, northward to the Salmon River from Stanley to Clayton, and eastward to the East Fork Salmon River.

Prior to 1970, the study area contained three recording gaging stations, each with lengths of record exceeding 40 years. Three crest-stage gages were located on small tributaries, and these installations had 8 years of record. Also, five discontinued recording gaging stations had data records varying from several to 30 years. Records from all these stations were for streamflow characteristics only; few water-quality data were available prior to 1970. These data, although sparse, provided invaluable information on magnitude, frequency, and duration of streamflow in the area.

In 1970, one recording gaging station and four miscellaneous water-data stations were established in the Little Boulder Creek and Big Boulder Creek drainage basins. Water-quality data collection was initiated by quarterly samplings at these stations. Intensive data collection began in 1971 with the establishment of additional water-data stations that brought the total to 39 stations. Measurements at these stations included streamflow, chemical quality including trace metals at selected stations, and sediment quality. Channel-geometry surveys at all stations related streamflow characteristics to channel size and shape and provided a basis for extrapolation of data to ungaged areas.

Data collection in 1972 confirmed the data trends established the previous year and opened new areas of investigation. Verification measurements and sampling were conducted at all previously established stations. Determination of trace-metal concentrations was extended to several additional locations. In addition, synoptic runs which included observations of discharge, temperature, and specific conductance were made at scores of intermediate locations; these runs increase the transfer value of the chemical-quality data to unsampled areas. At several key stations, collection of sediment samples was greatly expanded. Sediment data included both suspended-sediment data and bedload-transport data. Aspects of the bedload-sampling program are being expanded, and these will be reported in more detail in a later publication. A program of biological observation in stream water of the area was also initiated in 1972; qualitative interpretation of these observations are included in this report, and quantitative results will be detailed in a later report.

In summary, data collection thus far has provided a basis for the definition of the hydrologic environment of the area. The characteristics of stream channels and their water are the most important components of the hydrology of the area; thus the geometry and flow characteristics of stream channels are discussed. A map folio (Emmett, 1972b) has summarized some of the water-quality data, and the present report details the composition of stream water.

UNITS OF MEASUREMENTS

Data used in this report and requiring units of dimension or definition are generally expressed in the customary English units of feet, pounds, and seconds. Thus, for example, water discharge is expressed as cubic feet per second and has a nominal unit weight of 62.4 pounds per cubic foot. In line with the increasing trend to present water-quality data in metric units, temperatures are expressed in degrees Celsius and concentrations of suspended and dissolved matter in water are expressed as milligrams per litre. For values of concentration used in this report, milligrams per litre are equivalent to parts per million by weight. Trace concentrations are expressed in micrograms per litre and are equivalent to parts per billion. However, values of suspended or dissolved load are expressed in the more usual units of tons per day. A list of conversion factors is provided in the "Contents" section of the report.

Symbols are defined where they first appear in the text; for symbols which are recurring throughout the text, a list is provided in the "Contents" section of the report.

DESCRIPTION OF THE STUDY AREA

The description of some of the physiographic characteristics of the study area are necessarily brief because the remoteness and ruggedness of the area generally have precluded detailed descriptions of the area. For example, within the boundaries of the study area, there are no current long-term reporting weather stations. Because of the high interest in ore deposits in the area, however, geological studies are an exception to the paucity of data, and several excellent descriptions are available for the geology. Especially notable are the geological studies by Ross (1937). The U.S. Forest Service has completed an ecological evaluation of part of the lands included in the study area which are within forest boundaries. However, this report (U.S. Forest Service, 1972) is largely a qualitative description related to resource management rather than a quantitative description of resource investigation.

GENERAL LOCATION

The region of study lies in the upper drainage basin of the Salmon River in south-central Idaho (fig. 1). It is mostly in southwestern Custer County but includes a small area in the northwestern part of Blaine County. The area comprises 1,800 square miles and extends from the headwater divide of the Salmon River downstream to the U.S. Geological Survey gaging station near Challis, Idaho. It lies in the southern part of the Northern Rocky Mountain Province (Fenneman, 1931).

The extremely rugged mountains west of Stanley Basin and defining the western divide of the area constitute the Sawtooth Range, so named because of their serrate appearance. In the area east of Stanley Basin and south of the Salmon River, a group of unnamed mountains is considered by many to form the most easterly part of the Sawtooth Mountains, which also include the Sawtooth Range. The highest part of this unnamed unit consists of the White Cloud Peaks.

East of the White Cloud Peaks, the country has the appearance of a greatly dissected plateau with flat summits. These eastern foothills differ greatly from the central mountains, for they have a much drier climate and are not forested except for a few pockets of timber on some north-facing slopes. South of the White Cloud Peaks, the altitudes increase to the peaks of the Boulder Mountains. All the mountainous areas have been shaped and modified by intense alpine glaciation. Cirques and glacier-scoured rocky ridges are common. Lands at the midaltitudes are dominated by U-shaped valleys formed by the glaciers. Lands in the lower, nonglaciated areas were shaped by folding and faulting and have been further modified by fluvial and colluvial processes resulting in long, dissected hillslopes.

The area was visited by early fur trappers, but general settlement awaited the last quarter of the 19th century. These early settlements were confined to mining camps and towns, most of which enjoyed boom days but are now relics. Today, the area is sparsely populated and has an economy based on mining, ranching, timbering, and catering to the recreational activities of visitors.

Figures 2–4 illustrate typical views of the study area. Figure 2 emphasizes the ruggedness of the country and its general pristine character. Figure 3 shows views along the main-stem Salmon River and several representative tributaries. Figure 4 shows examples of developments within the area.

TOPOGRAPHY

High mountain country exceeding 10,000 feet in altitude occupies about 3 percent of the area, uplands ranging from 8,000 to 10,000 feet in altitude occupy about 35 percent, foothills ranging from 6,000 to 8,000 feet in altitude occupy about 59 percent, and river lowlands at altitudes less than 6,000 feet occupy about 3 percent. The mean altitude of the drainage area above

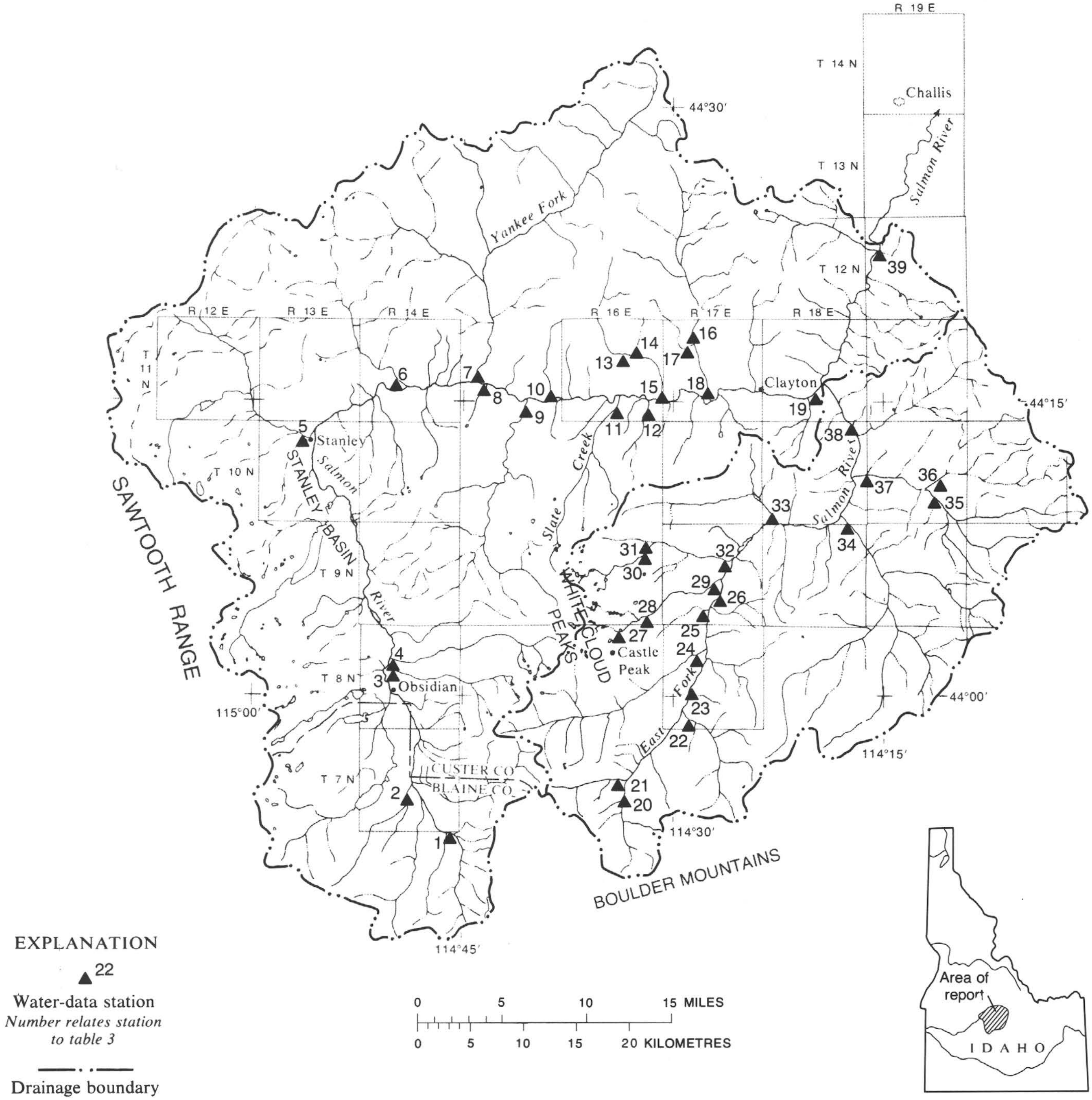

FIGURE 1.—Location of primary water-data stations.

the water-data station near Challis is about 7,820 feet.

Castle Peak, the highest of the White Cloud Peaks, has an altitude of 11,815 feet above mean sea level, and a number of other peaks in this group, as well as in the Boulder Mountains to the southeast, are well above 10,000 feet. At the exit from the study area, the gaging station Salmon River near Challis, Idaho, is at an altitude of about 5,165 feet. Figure 5 is a generalized topographic map of the upper Salmon River area.

GEOLOGY

The region is underlain by a thick sequence of Paleozoic sedimentary rocks intruded on the west by the Idaho batholith and in large part overlain to the east by

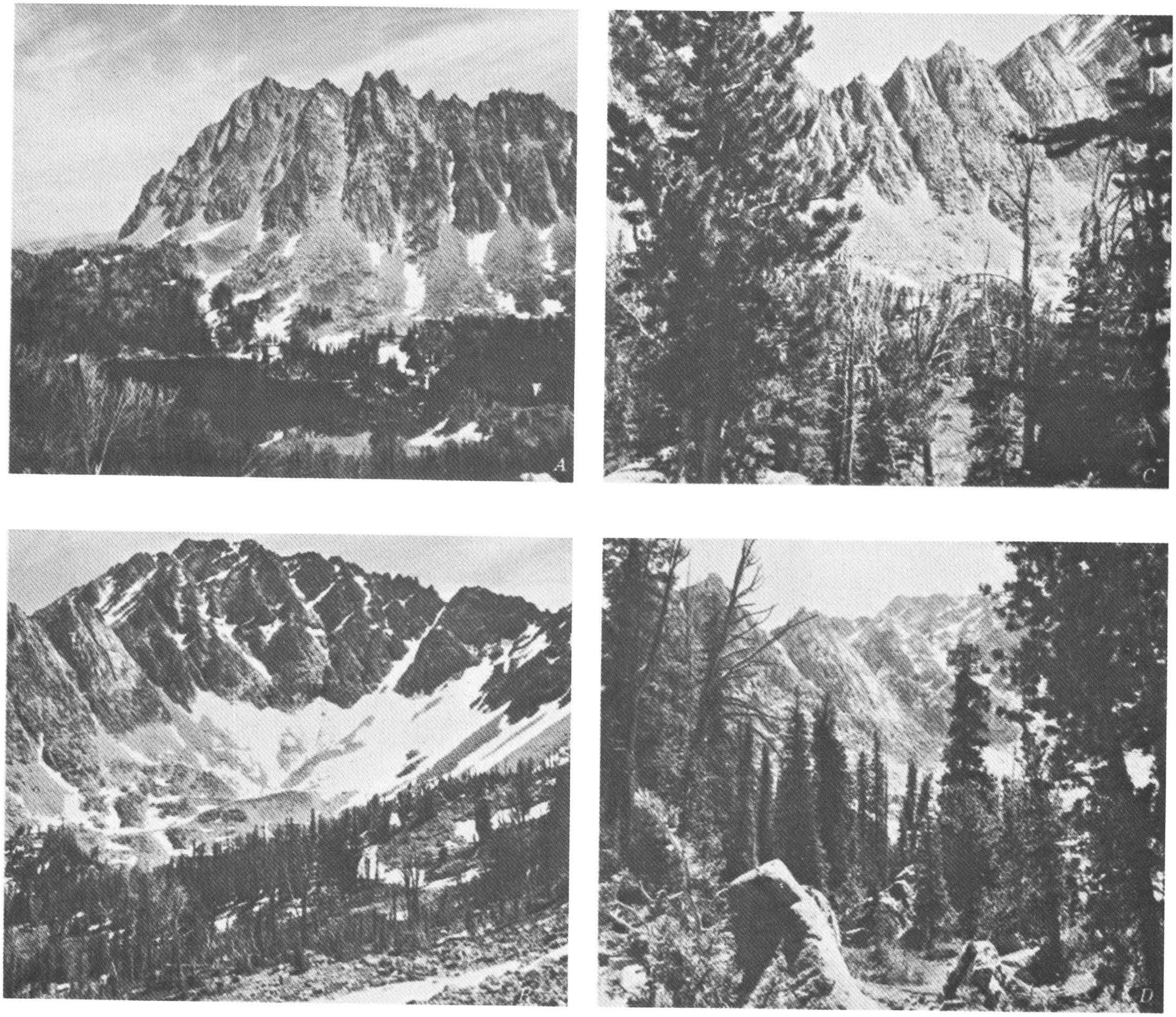

FIGURE 2.—Photographs showing pristine character and rugged topography in the White Cloud Peaks area. *A*, Quiet Lake on Little Boulder Creek. *B*, Cirque basin of Quiet Lake. *C*, Cross-valley view in Little Boulder Creek drainage. *D*, Downvalley view in Little Boulder Creek drainage.

Tertiary volcanic strata and associated sedimentary rocks. Figure 6 is a generalized geologic map of the studied area (Ross, 1937; Ross and Forrester, 1947).

The Idaho batholith underlies a major part of the study area, particularly the central and western parts. The batholith is composed of granitelike rock, primarily granodiorite, quartz diorite, and quartz monzonite. It is believed to be of Late Jurassic or Early Cretaceous age. Ross (1937) stated that this rock type is 20–40 percent quartz, 40–80 percent feldspar, and 5–15 percent biotite mica.

The volcanic rocks are designated the Challis Volcanics and crop out widely in the east half of the area, generally but not entirely at altitudes considerably below the high peaks and ridges. They are of Tertiary age, younger than the granitic rocks of the Idaho batholith, yet of sufficient age that considerable erosion and physical alteration has occurred. They are composed chiefly of volcanic flows with some interbedded flow breccias, mostly of andesitic and rhyolitic composition. A moderately consolidated tuff member of the Challis Volcanics is widespread and is shown separately in figure 6. The various members are highly variable in composition. Ross (1937) reported for the most extensive member, a latite-andesite, a composition of 63.5 percent silica, 3.1 percent lime, 4.0 percent soda, and 3.4 percent potash.

The Paleozoic rocks appear in two north-south trending bands. One band, through the center of the White Cloud Peaks area, is approximately 25 miles long and as much as 8 miles wide. A smaller band extends north and south from the town of Clayton. In both areas the sedimentary rocks run through high and low altitudes. These sedimentary exposures may be regarded as erosional remnants or islands perched on the massive intrusions of the granitic rocks and perhaps buried in places by the volcanic rocks. The band through the White Cloud Peaks area is mapped as about half Wood River Formation (impure quartzite, argillaceous and calcareous, and some limestone) and about half Milligen Formation (argillite and argillaceous quartzite with impure dolomite beds; most of the formation is characterized by much carbonaceous matter). The Clayton band consists primarily of the

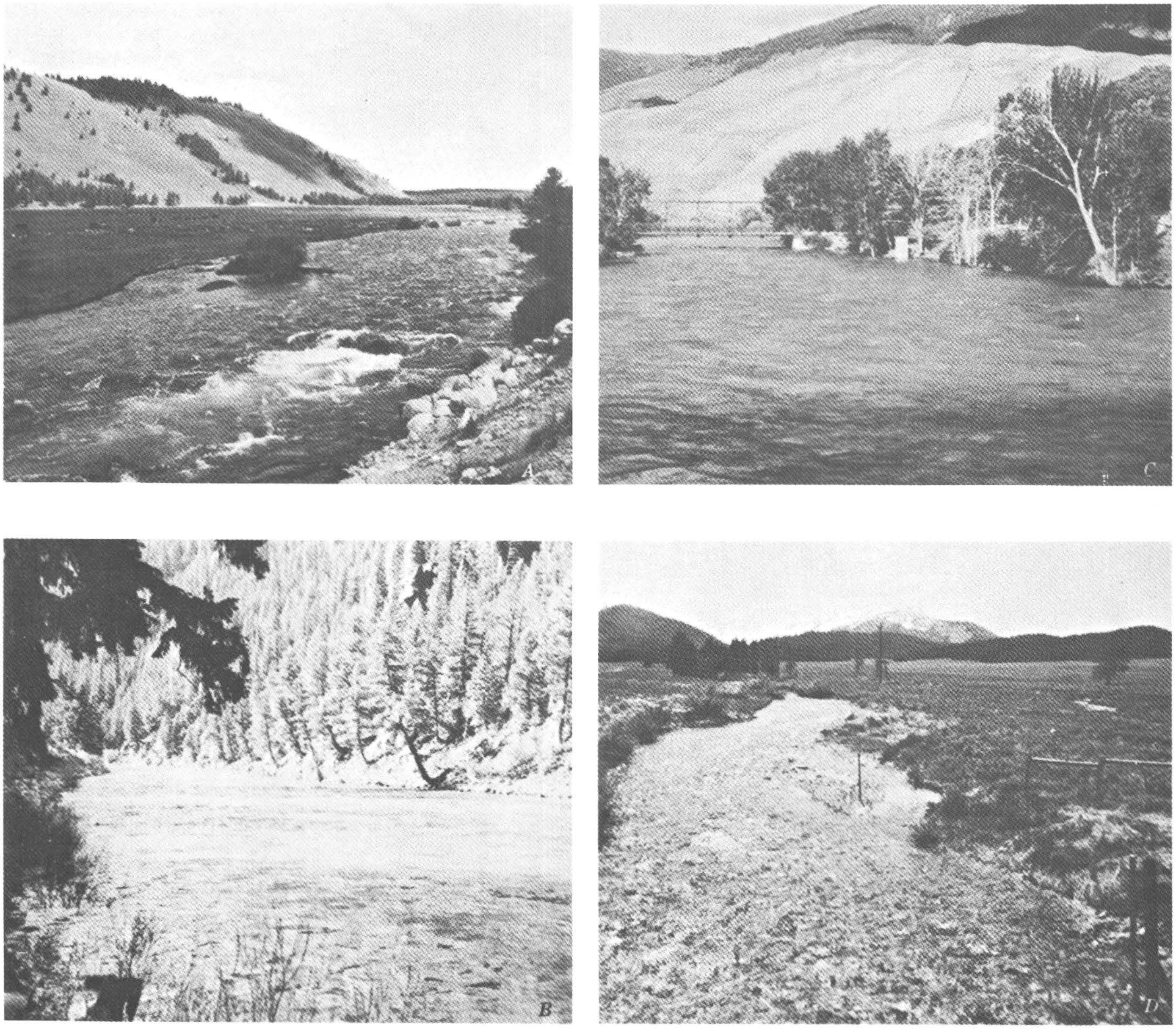

FIGURE 3.—Photographs of selected rivers in the study area. *A*, Salmon River upstream of Valley Creek and showing flood plain and low terrace levels in Stanley Basin. *B*, Salmon River downstream of Yankee Fork River at gaging-station location. *C*, Salmon River at gaging station near Challis, Idaho. *D*, Beaver Creek tributary to Salmon River at crest-stage gage location. *E*, Valley Creek at gaging station near Stanley, Idaho. *F*, Little Boulder Creek at headwater reach in White Cloud Peaks area. *G*, Little Boulder Creek below Boulder Chain Lakes; Castle Peak is in the left background. *H*, Wickiup Creek tributary to East Fork Salmon River. Figure continued on next page.

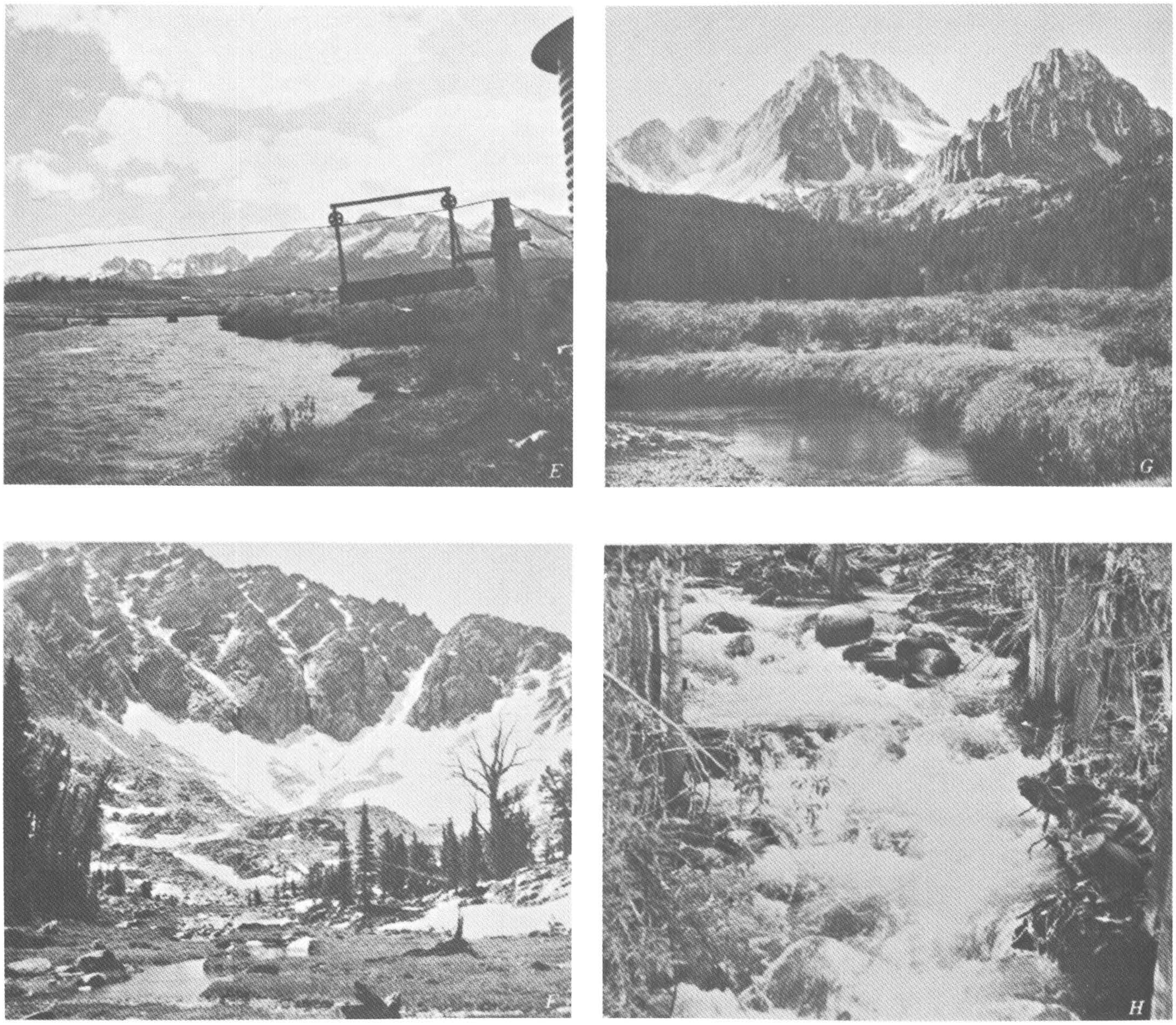

FIGURE 3.—Continued.

Kinnikinic Quartzite and Ramshorn Slate.

A few surficial deposits of Quaternary age are present in the area. Large glacial deposits occur in the Big Boulder Creek and Little Boulder Creek drainage basins. These deposits are mainly till and coarse gravel of glacial origin and are of Pleistocene age. The largest extent of alluvial deposits occurs in the Stanley Basin. These deposits range in age from the Pleistocene alluvium on the upper terraces hundreds of feet above the present stream channel through the more recent terrace alluvium on the lower terraces to the Holocene terrace and flood plain alluvium.

CLIMATE

Although some 500 miles from the Pacific Ocean, the upper Salmon River area is, nevertheless, influenced by maritime air borne eastward on the prevailing westerly winds. In the winter months, the Aleutian low dominates the weather and produces cloudiness and abundant precipitation. During the summer months, the Pacific high dominates with fair weather, except when moisture-laden air from the Gulf of Mexico and Caribbean areas is brought in from the south at high levels to produce thundershowers, especially in the eastern fringes of the area.

FIGURE 4.—Photographs showing development within study area. *A*, Scars associated with exploration for mineral deposits on Railroad Ridge in the White Cloud Peaks area. *B*, Summer home construction near Obsidian, Idaho, in Stanley Basin.

Only one weather station, at Stanley, is currently operated within the boundaries of the study area. The records of a former weather station, at Obsidian, and of a station just outside the downstream perimeter of the area, at Challis, can be combined with the Stanley records to infer some of the climatic characteristics of the area.

Tables 1 and 2 give values of mean monthly temperature and precipitation for the year 1971 at the Stanley and Challis stations (National Oceanic and Atmospheric Administration, 1971a). The records at Challis are of sufficient length to determine long-term normals, and these values are included in tables 1 and 2 (National Oceanic and Atmospheric Administration, 1971b). The mean annual precipitation ranges from less than 10 inches to more than 60 inches depending on altitude and location, but the major part of the area receives about 30 inches. The effects of altitude are seen in the low amounts of precipitation recorded at Stanley and Challis, both of which are along the main stem of the Salmon River. The effect of location is illustrated by the Challis station, which is located at the northeastern fringe of the area on the leeward side of the mountains. On the basis of available records, the station at Challis has the lowest average annual precipitation in the State, with a long-term average of 7 inches. These amounts of precipitation may be compared with an average annual runoff from the area of about 12 inches.

The mean annual temperature ranges from about −4° to 7°C[1] depending on location but averages about 2°C. Obsidian, at an altitude of 6,870 feet, is the only station within the area with sufficient length of record to compute a mean annual temperature. With a mean annual temperature of 1.7°C, it has the lowest annual average of any reporting station in the State. Very cold winters alternate with cool summer months when temperatures rarely exceed 30°C. In January the mean minimum temperature is about −20°C, and the mean maximum is about 0°C. Frost can occur in any month of the year, and the continuous days of killing frost generally extend from September through May.

VEGETATION

The area contains numerous forested areas. The principal tree species include Douglas fir, subalpine fir, lodgepole pine, whitebark pine, and Engelmann spruce. Several hundred species of plant life are present. Grass, sedge, figwort, and composite families make up the larger number of herbaceous species. Sagebrush is often found on south-facing slopes and in patchwork with forested areas.

On strongly glaciated lands, generally at altitudes above 10,000 feet, large areas are open and sparsely vegetated. On the deeper soils of the cirque basins, subalpine fir may be found. On rocky dry soils, whitebark pine predominates. In many areas, whitebark pine has been attacked by mountain pine beetle leaving statuesque snags. The lower glaciated lands have a heavy conifer cover on north-facing slopes, but sagebrush covers many ridgetops and south-facing slopes. At the higher altitudes, whitebark pine is associated with subalpine fir. Below altitudes of about

[1]Degrees Fahrenheit=($\frac{9}{5}$degrees Celsius)+32.

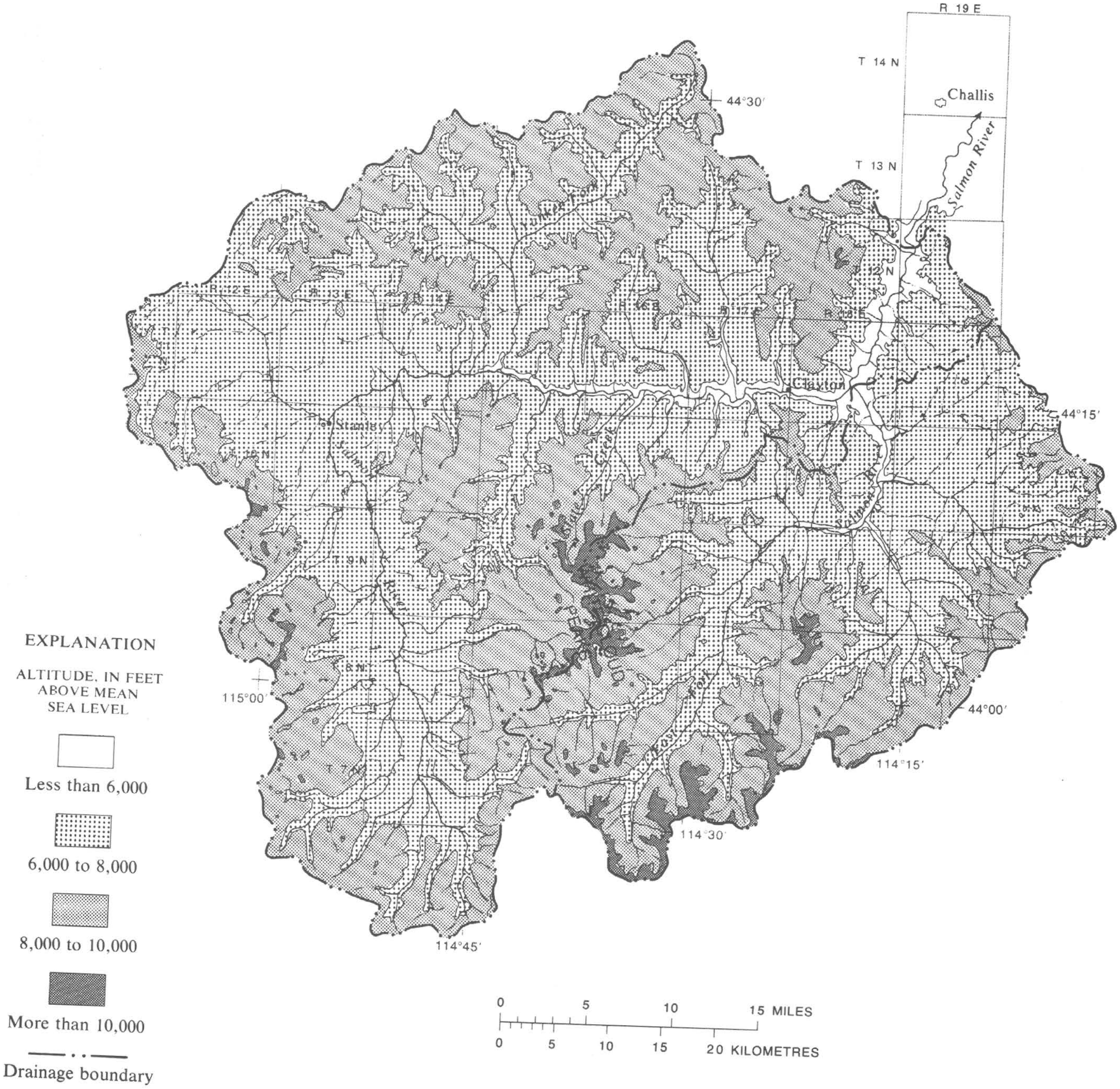

FIGURE 5.—Generalized topography.

8,200 feet, Douglas fir occurs on north-facing slopes, and below altitudes of about 7,800 feet, Douglas fir occurs in all areas. Seral stands of lodgepole pine occur and are quick to replace the firs after a fire or other agent has destroyed the original stand.

Unglaciated mountain lands provide for an open and closed stand of conifers with sagebrush-grass openings. Timber occupies about two-thirds of these lands with Douglas fir predominant. At the higher altitudes some subalpine fir occurs. Lodgepole pine is the dominant sere and is invading the areas of fir. Pockets of quaking aspen occur, especially at the lower altitudes. On the still lower hillslope lands, Douglas fir grows on the north- and east-facing slopes where available moisture and other environmental factors permit. A sagebrush-grass cover occupies the rest of hillslope lands except for scattered aspen stands along streams and at seeps.

Depositional lands, as contrasted to the erosional

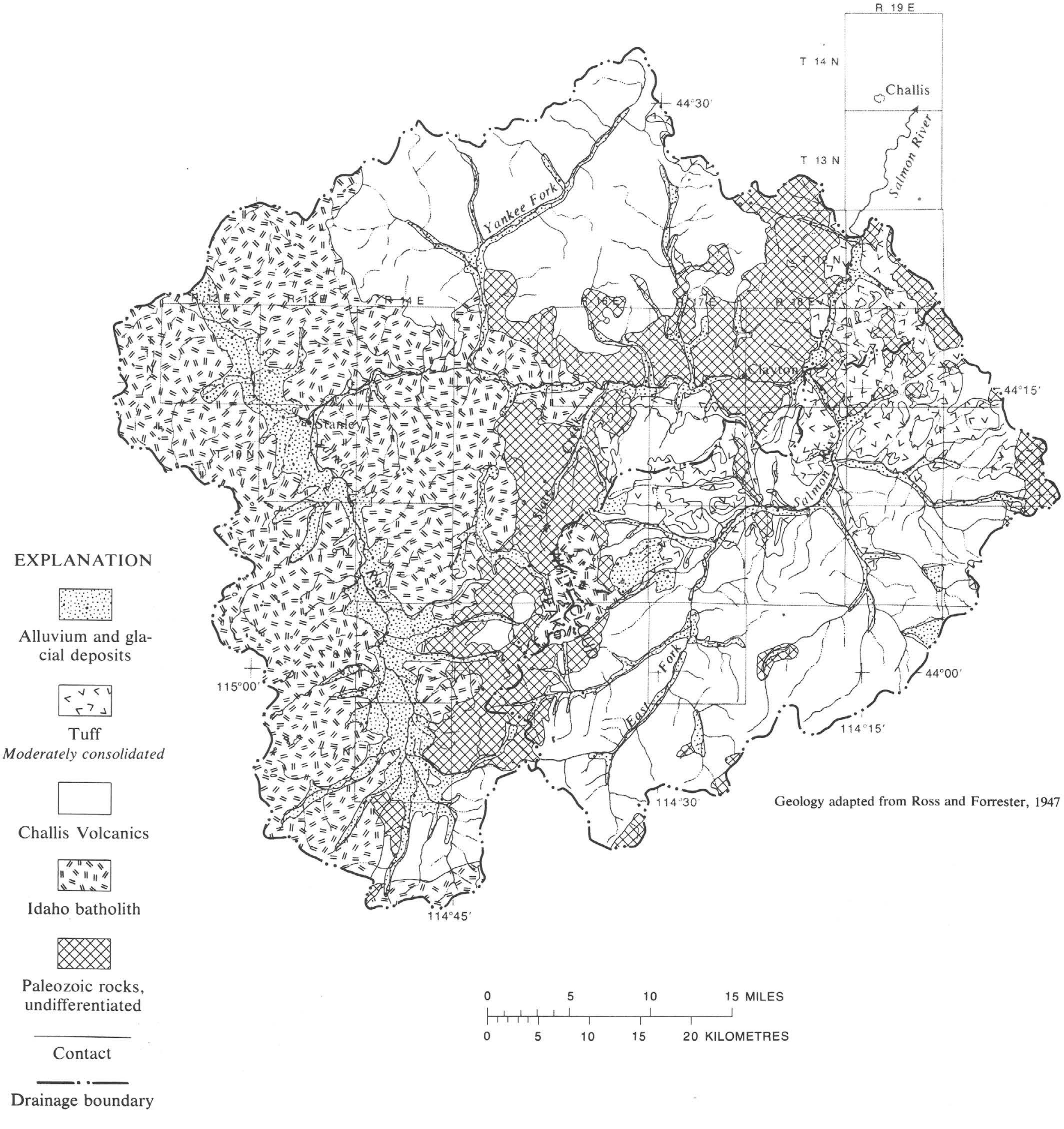

FIGURE 6.—Generalized geology.

surfaces discussed, are almost entirely covered with sagebrush-grass except for scattered groups of conifers and meadow species in moist areas.

The harshness of climate on growth and survival of trees, combined with the remoteness and ruggedness of the country, make commercial timbering of little importance. A reasonable estimate would classify less than 10 percent of the forest land as commercial. Areas of commercial timber occur most often in the lower unglaciated mountain and hillslope areas.

LAND USE

The land is sparsely populated, and the pressures of land use on the area are minimal. In 1970, the population within the area was estimated at about 600 persons (U.S. Bureau of Census, 1970), or a population

TABLE 1.—*Mean monthly temperatures, in degrees Celsius, for two weather-station locations within study area*

[M = missing]

Month	Stanley 1971	Challis	
		1971	Average[1]
January	−6.2	−3.8	−7.6
February	−7.1	−1.4	−3.9
March	−4.8	.5	1.2
April	1.2	5.7	7.1
May	6.3	11.3	11.6
June	9.6	15.0	15.4
July	13.9	20.2	20.1
August	15.2	21.8	18.8
September	6.8	12.0	14.2
October	3.3	7.3	8.4
November	M	.6	.2
December	M	−7.3	5.0
Average	----	6.8	6.7

[1]1921–71 period of record.

TABLE 2.—*Mean monthly precipitation, in inches, for two weather-station locations within study area*

Month	Stanley 1971	Challis	
		1971	Average[1]
January	2.20	0.85	0.48
February	.82	.26	.33
March	1.84	.56	.35
April	.25	.66	.53
May	.72	1.05	1.11
June	2.48	.99	1.18
July	.44	.35	.58
August	.38	.23	.53
September	.97	.28	.60
October	1.05	.52	.46
November	1.73	.45	.31
December	2.09	1.31	.47
Total	14.97	7.51	6.93

[1]1916–71 period of record.

density of about 1 person per 2,000 acres. Land ownership helps explain the low population density. The Federal Government owns about 96 percent of the land with about 75 percent administered by the Forest Service and 21 percent by the Bureau of Land Management. An additional 2 percent is owned by the State Government. The remaining 2 percent of land, which is privately owned, is mostly in the Stanley Basin and at other scattered locations along the Salmon River and East Fork Salmon River.

Ranching and farming account for the livelihood of most of the inhabitants. Although in recent years the number of persons engaged in farming has decreased, the total acreage of land utilized is nearly constant. Cattle and sheep are the primary products. In former years overgrazing created serious erosion and forage problems. However, the numbers of stock, especially sheep, have been reduced until the balance of stock and forage is about in equilibrium. It is estimated that the number of sheep in the area is now only 10 percent of that number in the peak years of 1905–10. Only in isolated areas are examples of past or present overgrazing still evident; these areas are centered around Challis and in the valley of the East Fork Salmon River. Ranching activity is expected to remain stationary for at least the next several years.

Because of the high mineralization of the area, mining and mineral exploration are causes of considerable activity and interest. Past mining provided even more activity than today, and present-day ghost towns like Custer and Bonanza on the Yankee Fork Salmon River had populations in the thousands during the late 1800's. Relics of these past exploitations are scattered mine shafts, mill structures, and a maze of roads seemingly abandoned at midslope locations. Better preserved of the relics is the large hydraulic dredge on the Yankee Fork and the miles of mounds from dredging that it left.

Today, several mines are still in operation and exploration continues, most notably in the Thompson Creek drainage basin. However, the establishment of the Sawtooth National Recreation Area in 1972 has imposed considerable restraint on future mineral exploration and mining activity within the boundaries of the recreation area.

Timber in the area has been logged in the past and will undoubtedly continue to be in the future. Because only a small percentage of the total land supports commercial timber, lumbering is not expected to present seriously degrading impacts. Good timbering practices and care in locating and constructing logging roads can minimize environmental impact due to this use. However, any use which includes road construction means additional country is opened by easy access, and increased use caused by accessibility can create other imbalances such as the ratio of hunters to game animals.

Residential use poses no serious threat to environmental stability because of the small number of residents. However, the high quality of the area for recreational uses has in the last decade resulted in the construction of many recreational and seasonal homes, especially in the Stanley Basin. If this trend continues uncontrolled, irreparable damage to the environmental quality could occur.

Recreational use of the area has dramatically increased since the early 1950's and in recent years has increased at about 10 percent annually. Primary recreational uses include fishing, hunting, and backpacking. Generally, the area has borne well the impact of recreational use, but some controls clearly will have to be placed on some mechanized traffic, especially off-road vehicles. Management of a large part of the area as a National Recreation Area will by law place some restraints on indiscriminate use of the area.

STREAM CHANNEL NETWORK

The 1,800 square miles of the study area are drained by the main stem of the Salmon River and a principal tributary, the East Fork Salmon River, which has a drainage area of about 540 square miles. The entire drainage area of the Salmon River, about 14,000 square miles, is tributary to the Snake River, thence to the Columbia River, and into the Pacific Ocean.

GENERAL DESCRIPTION

The main Salmon River flows first north, then east, then north again diagonally across the region. Above its junction with Valley Creek near the town of Stanley, it flows in the wide alluvium-floored depression of Stanley Basin. At Stanley it turns eastward and flows in a steep-sided valley that widens somewhat downstream. Near its junction with the East Fork Salmon River, the river swings northward, and its valley widens further.

West of Stanley Basin several of the numerous short tributaries of the Salmon River have lakes in their lower reaches. Elsewhere in the study area, lakes are more commonly found in alpine locations. Valley Creek is the largest tributary from the west or northwest. Below Stanley, the Yankee Fork is by far the largest tributary from the north. On the opposite side of the Salmon River is one of the larger tributaries, Warm Springs Creek, which enters at Robinson Bar, formerly a placer-mining camp and now a year-round resort. The East Fork Salmon River joins the Salmon River from the south 22 miles below Robinson Bar. Through much of its length, the East Fork Salmon River flows through country of only moderate relief. In the northeast quadrant of the drainage area of the East Fork Salmon River, streamflow runoff decreases noticeably because of the more arid environment. All streams entering the Salmon River from the east below the East Fork Salmon River and within the study area are ephemeral and flow only in response to snowmelt and thunderstorm activity.

WATER-DATA STATIONS

Thirty-nine locations were chosen as principal points of data collection. These stations along with other station descriptions are given in table 3 and are shown on the area map (fig. 1). Primary station identification is the eight-digit U.S. Geological Survey station number. The first two digits of this number refer to the major drainage basin involved. In this study, all stations have the prefix 13 in reference to the Snake River basin. The last six digits refer to individual station location with increasing numbers referring to locations progressively farther downstream. The last two digits are offset with a decimal to facilitate reading.

TABLE 3.—*Station number and name of primary data sites*

Figure plotting No. (fig. 1)	U.S. Geological Survey station No.	Station name
1	13–2922.00	Salmon River near Galena Summit.
2	2924.00	Beaver Creek near mouth.
3	2932.00	Champion Creek near mouth.
4	2934.00	Fourth of July Creek near mouth.
5	2950.00	Valley Creek near mouth.
6	2956.50	Basin Creek near mouth.
7	2960.00	Yankee Fork near mouth.
8	2965.00	Salmon River below Yankee Fork.
9	2970.00	Warm Springs Creek near mouth.
10	2971.00	Peach Creek near mouth.
11	2972.50	Slate Creek near mouth.
12	2973.00	Holman Creek near mouth.
13	2973.10	Thompson Creek above Pat Hughes Creek.
14	2973.20	Pat Hughes Creek near mouth.
15	2973.30	Thompson Creek near mouth.
16	2973.40	Squaw Creek above Bruno Creek.
17	2973.50	Bruno Creek near mouth.
18	2973.60	Squaw Creek near mouth.
19	2973.80	Salmon River above East Fork Salmon River.
20	2973.84	South Fork East Fork Salmon River near mouth.
21	2973.88	West Fork East Fork Salmon River near mouth.
22	2973.96	West Pass Creek near mouth.
23	2974.00	East Fork Salmon River below West Pass Creek.
24	2974.04	Germania Creek near mouth.
25	2974.18	Wickiup Creek near mouth.
26	2974.25	East Fork Salmon River below Wickiup Creek.
27	2974.40	Little Boulder Creek above Baker Lake.
28	2974.45	Little Boulder Creek below Boulder Chain Lakes.
29	2974.50	Little Boulder Creek near mouth.
30	2974.80	Big Boulder Creek above Jim Creek.
31	2974.85	Jim Creek near mouth.
32	2975.00	Big Boulder Creek near mouth.
33	2975.30	Big Lake Creek near mouth.
34	2976.00	Herd Creek near mouth.
35	2976.70	Road Creek above Horse Basin Creek.
36	2976.80	Horse Basin Creek near mouth.
37	2977.00	Road Creek near mouth.
38	2980.00	East Fork Salmon River near mouth.
39	2985.00	Salmon River near Challis.

Station locations were selected on the basis of several criteria and primarily to assure continuity in interpretation of data among stations. Such continuity provides the difference between the collection of data at isolated locations and the evaluation of a river system. To this end, 19 stations were chosen along the main stem of the Salmon River upstream from the confluence with the East Fork Salmon River, 19 stations were chosen along the drainage of the East Fork Salmon River, and 1 station was located below the confluence of the two rivers.

To fully utilize available data, all existing data stations were incorporated into this net. These include three recording gaging stations, three crest-stage gage stations, and the five water-data stations established in 1970 on the east flank of the White Cloud Peaks. In addition, three locations were chosen at sites of previously existing gaging stations.

In general, a tributary approach was used in selecting station locations. That is, stations were located on tributary streams near their confluence with the main-stem rivers. These tributaries were selected to include all principal contributing streams and streams draining representative interfluve areas between major streams. To further define tributary characteristics, five tributary systems have two additional stations located in headwater reaches. In total, the station locations included 10 sites in headwater reaches of tributary streams, 22 sites at the mouths of principal or representative tributaries, 3 sites each along the main stems of the East Fork Salmon River and the Salmon River upstream of the East Fork, and 1 site on the Salmon River below the confluence of the East Fork and at the exit from the study area. Five of the sites included installations of the continuous-record type.

Primary data collection at each of the 39 sites included measurements of streamflow, collection of water samples for sediment and chemical-quality analysis, and surveys of channel geometry. In addition to the 39 primary water-data stations, other locations were chosen at which particular observations were made to further define characteristics of selected areas and to allow more reasonable extropolation of data from primary locations. For example, detailed chemical-quality analyses are available for 55 locations, and during near-synoptic samplings for representative values of specific conductance, more than 75 locations were visited. Miscellaneous data, for example measurements of bedload transport, were collected at some of the sites. These data, some repetitive and others one-of-a-kind, add to the interpretation of primary data and will be discussed later.

The frequency of sampling or data observation was variable among stations and during the period of study. During 1971, the first full year of the study, 8 of the 39 primary water-data stations were selected for monthly observations during the period of late spring to early fall, generally from May to October. These eight locations include the five continuous-record water-data stations. No winter observations other than streamflow measurements were made. Because of long and severe winters in the area, data collection at many locations would have been difficult if not impossible. Further, during the winter period of November to April, many operable processes in the area probably remain at such a constant rate that the fall and spring observations adequately define winter characteristics. At the other 31 primary locations, three samplings were conducted in 1971 during the high-, medium-, and low-water periods.

All primary data observations in 1971 included measurements of streamflow and temperature and retention of water samples for analysis of suspended-sediment concentration and standard chemical-quality determinations. In addition, at the 8 monthly stations and 4 other locations, the stations on the headwater reaches of Little Boulder Creek and Big Boulder Creek, water samples were collected for analysis of 21 trace elements. The frequency of miscellaneous observations was variable.

In 1972 all primary water-data stations were visited at least once, and data collection was as previously described. Several stations were sampled monthly. The trace-metal analysis was extended to five additional stations with at least one sampling at these new locations. The concentration of suspended sediment is one of the most variable of the water-quality parameters. For better definition of this parameter, additional determinations of discharge and suspended-sediment concentration were made for a number of the stations.

HORTON ANALYSIS

A drainage area, defined as that area which contributes water to a given network of stream channels, provides a convenient geomorphic unit to divide a larger area and to isolate or present on a detailed scale those components of hydrologic processes which contribute to the hydrology of the larger area. It has already been stated that isolation of the characteristics of individual or small drainage areas by data observations near the mouths of tributaries was the primary approach to an evaluation of the hydrology in the present study. The drainage net, or network of stream channels in a drainage area, relates to the pattern of contributory and main-stem streams. This drainage net may be described by such descriptive terms as trellis or palmate, but more importantly it may also be quantitatively described by the method commonly referred to as the Horton analysis (Horton, 1945). A quantitative description of stream-channel networks is desirable as a rationale in the explanation of similarities and differences in hydrologic behavior between two or more drainage areas.

The salient aspect of a Horton analysis is the relation of certain physical characteristics, primarily stream length, stream number, and other features of the drainage basin, to stream order. Stream order is defined as the position of a stream in the hierarchy of channel network. First-order streams are unbranched fingertip tributaries; second-order streams receive tributaries of the first order, but these only; third-order streams must receive one or more tributaries of the second order but may also receive first-order streams, and so on. By using this system, the order of the main stream is highest. In computing stream length, each higher order stream is considered to extend headward to the tip of the longest tributary it drains.

In determining stream order, consideration must be given to the scale of map used. Certain small-scale maps do not show all tributaries that are shown on large-scale maps, and this affects designation of order. It is estimated that the difference in using a 1:24,000-scale map instead of a 1:62,500-scale map changes the order of the Mississippi River at its mouth from a tenth-order to a twelfth-order stream. Likewise, detailed planetable mapping of a field area (Leopold and Miller, 1956) indicates that four orders of streams would have to be added to the smallest streams appearing on maps of scale 1:24,000 if the smallest rills occurring in the area were included in the stream ordering. But, for most purposes, one may restrict consideration only to the drainage net appearing on 1:24,000-scale maps.

On U.S. Geological Survey topographic maps, perennial streams are usually shown by solid blue lines and intermittent streams with dotted blue lines. Both types of streams should be included in the ordering system. If only perennial streams were included, a drainage basin containing only intermittent streams would, in essence, show 0 drainage density, although it may have a considerable degree of basin development. For further simplicity, stream length is defined as the length of the blue line on the map rather than attempting to extend the channel length to the watershed divide.

To define the drainage net in the area of present study, a Horton analysis was conducted on the 542 square miles of the East Fork Salmon River drainage area. Base maps used in the analysis were 1:24,000-scale U.S. Geological Survey topographic maps with the exception that a small part of the southernmost extreme of the area was unavailable at this map scale. Rather than use smaller scale U.S. Geological Survey topographic maps, same-scale planimetric maps available from the U.S. Forest Service were utilized. As will be shown later, use of the Forest Service maps perhaps was responsible for some inconsistencies in analysis of this area compared with the larger area. Further, the absence of topographic data precluded the computation of some channel slopes and watershed relief data in that area. However, the overall area involved is sufficiently small that generalizations of the analysis are not greatly affected.

DRAINAGE AREAS TRIBUTARY TO EAST FORK SALMON RIVER

A total of 24 tributaries to the East Fork Salmon River have well-developed stream-channel networks and are of sufficient size to warrant individual analyses of stream order. Among these principal tributaries, 25 interfluvial areas accounting for about 11.5 percent of the total drainage area were analyzed individually to complete the Horton-type analysis for the entire East Fork Salmon River drainage. Table 4 gives the 49 drainage units analyzed; parts of drainage areas 1–5 and 11 are those areas not included on map coverage by the U.S. Geological Survey.

Table 5 summarized some of the data for the individual basins. A complete Horton analysis is too detailed to present in this report, but table 5 includes values of the drainage area determined by planimetering subareas for each stream. High and low values of altitude are the high point on the watershed divide of the given drainage area and the altitude of the stream channel at the exit from the given area. Basin order is the maximum stream order in the individual drainage area. The total number of streams and the number of first-order streams are determined by count, and the total length, L_T, of streams is the sum length of streams of all orders, L_1, L_2, and so forth, as measured on the map with a pair of dividers.

TABLE 4.—*Drainage basin number and name of areas included in Horton analysis, East Fork Salmon River*

Drainage basin No.	Drainage basin name
1	South Fork East Fork Salmon River.
2	West Fork East Fork Salmon River.
3	East Fork Salmon River (South Fork and West Fork to Ibex Creek).
4	Ibex Creek.
5	East Fork Salmon River (Ibex Creek to West Pass Creek).
6	West Pass Creek.
7	East Fork Salmon River (West Pass Creek to Upper Gage).
8	East Fork Salmon River (Upper Gage to Bowery Creek).
9	Bowery Creek.
10	East Fork Salmon River (Bowery Creek to Germania Creek).
11	Germania Creek.
12	East Fork Salmon River (Germania Creek to Deer Creek).
13	Deer Creek.
14	East Fork Salmon River (Deer Creek to Little Wickiup Creek).
15	Little Wickiup Creek.
16	East Fork Salmon River (Little Wickiup Creek to Wickiup Creek)
17	Wickiup Creek.
18	East Fork Salmon River (Wickiup Creek to Sheep Creek).
19	Sheep Creek.
20	East Fork Salmon River (Sheep Creek to Little Boulder Creek).
21	Little Boulder Creek.
22	East Fork Salmon River (Little Boulder Creek to Big Boulder Creek).
23	Big Boulder Creek.
24	East Fork Salmon River (Big Boulder Creek to Baker Creek).
25	Baker Creek.
26	East Fork Salmon River (Baker Creek to Bluett Creek).
27	Bluett Creek.
28	East Fork Salmon River (Bluett Creek to Dry Gulch).
29	Dry Gulch.
30	East Fork Salmon River (Dry Gulch to Big Lake Creek).
31	Big Lake Creek.
32	East Fork Salmon River (Big Lake Creek to Pine Creek).
33	Pine Creek.
34	East Fork Salmon River (Pine Creek to Marco Creek).
35	Marco Creek.
36	East Fork Salmon River (Marco Creek to Fox Creek).
37	Fox Creek.
38	East Fork Salmon River (Fox Creek to McDonald Creek).
39	McDonald Creek.
40	East Fork Salmon River (McDonald Creek to Herd Creek).
41	Herd Creek.
42	East Fork Salmon River (Herd Creek to Dry Hollow).
43	Dry Hollow.
44	East Fork Salmon River (Dry Hollow to Road Creek).
45	Road Creek.
46	East Fork Salmon River (Road Creek to Spar Canyon).
47	Spar Canyon.
48	East Fork Salmon River (Spar Canyon to Lower Gage).
49	East Fork Salmon River (Lower Gage to Mouth).

The last column in table 5 is the drainage density and is defined as the quotient of the cumulative or total stream length and the total drainage area. It is expressed in miles of stream per square mile of drainage area. Values of drainage density can range from less than 1 to about 1,000, for the land surface varies from a nearly undissected slope to the highly rilled surfaces of fresh fill slopes (Smith, 1950). Values of drainage density for the various drainage areas contributing to the East Fork Salmon River range from about 1.5 to 4.5. The values are a little higher than most of those reported by Horton (1945) but are about the expected value for highly dissected mountainous country as determined from 1:24,000-scale maps.

The last line, or total, in table 5 is the average or representative value of the parameters for the East Fork Salmon River drainage area in its entirety. The overall drainage density is 2.61 miles of stream per

TABLE 5.—*Characteristics of Horton analysis compiled by individual drainage basins, East Fork Salmon River*

Drainage basin No.	Drainage area, *DA* (mi²)	Altitude (ft)		Basin order	Number of streams		Total length of streams (mi)[1]	Drainage density (mi/mi²)
		High	Low		Total	First order		
1	18.05	11,250	7,110	[2]5	93	68	68.45	3.79
2	8.62	11,118	7,110	4	47	34	33.80	3.92
3	5.11	10,662	6,950	[2]3	27	21	21.53	4.21
4	6.24	11,602	6,950	3	23	17	21.73	3.48
5	7.57	10,267	6,675	[2]3	26	19	23.82	3.15
6	26.06	11,714	6,675		97	76	73.61	2.82
7	3.91	9,430	6,570	[2]3	14	10	10.53	2.69
8	2.95	8,891	6,410	[2]2	5	4	5.50	1.87
9	16.98	10,883	6,410	4	39	29	41.37	2.44
10	.30	7,400	6,370	[2]0	0	0	.52	1.71
11	48.89	11,815	6,370	5	69	123	139.34	2.85
12	1.32	9,276	6,330	[2]2	2	1	2.81	2.12
13	1.32	9,276	6,330	2	5	4	3.53	2.67
14	1.82	9,423	6,275	[2]1	3	3	4.26	2.35
15	1.37	9,895	6,275	2	5	4	4.02	2.93
16	.63	7,876	6,240	[2]1	2	2	1.81	2.87
17	6.50	10,248	6,240	[2]2	8	7	11.58	1.78
18	.17	7,526	6,220	[2]0	0	0	.38	2.29
19	5.78	10,301	6,220	4	20	16	15.46	2.67
20	2.14	8,440	6,120	[2]2	6	6	6.46	3.02
21	18.13	11,815	6,120	3	22	16	28.43	1.57
22	2.82	8,773	6,050	[2]2	5	3	5.68	2.01
23	27.39	11,487	6,050	4	61	46	61.61	2.25
24	.18	6,820	6,040	[2]0	0	0	.55	3.07
25	2.55	8,820	6,040	3	9	7	7.75	3.05
26	.55	6,863	6,015	[2]0	0	0	.90	1.63
27	2.56	8,532	6,015	3	9	7	7.12	2.78
28	1.27	7,826	5,950	[2]2	4	2	5.54	4.37
29	1.87	8,283	5,950	3	12	9	8.24	4.42
30	2.87	8,102	5,900	[2]2	9	7	9.02	3.15
31	22.54	9,750	5,900	4	74	56	65.14	2.45
32	.28	10,910	5,870	[2]1	1	1	1.33	2.27
33	8.49	6,240	5,870	3	21	15	22.67	2.67
34	.05	6,240	5,860	[2]0	0	0	.24	4.53
35	4.70	8,700	5,860	3	11	7	14.27	3.03
36	4.77	8,220	5,770	[2]1	10	10	15.18	3.19
37	4.00	9,833	5,770	2	9	8	10.69	2.67
38	.10	7,200	5,755	[2]0	0	0	.45	4.37
39	6.72	10,910	5,755	3	19	16	19.53	2.90
40	1.02	7,800	5,730	[2]1	3	3	3.71	3.63
41	112.54	11,057	5,730	6	275	213	287.61	2.56
42	.91	7,400	5,700	[2]1	1	1	1.79	1.97
43	4.14	8,347	5,700	2	9	8	10.20	2.46
44	4.49	8,296	5,630	[2]2	7	5	11.79	2.63
45	84.98	9,542	5,630	5	176	136	195.19	2.30
46	7.01	8,402	5,530	[2]3	10	8	15.60	2.23
47	34.26	9,391	5,530	4	73	55	86.62	2.53
48	.85	7,559	5,520	[2]1	2	2	2.95	3.47
49	10.09	7,827	5,350	[2]2	18	14	26.10	2.59
Total or average	541.86	11,815	5,350	7	1,441	1,098	1,416.41	2.61

[1]Reflects topographic map standards and not true stream lengths to the accuracy implied by significant figures.
[2]Contains part of seventh-order main stem, East Fork Salmon River.

square mile of drainage area, or 1,416 miles of streams in 542 square miles of area. Drainage density is the most useful of the parameters for comparison of stream-channel networks among various drainage basins and their deviations from the average value for the entire drainage area. The first several drainage basins in table 5 are extreme values of drainage density. However, for these basins a different map base was used for determining stream length, and thus values of drainage density are higher for this area than is average for the region. Because these drainage basins account for less than 10 percent of the entire area, values of drainage density for these areas, even if somewhat inconsistently high, do not greatly affect average values. Other higher-than-average values of drainage density occur for very small drainage areas. As extreme examples, drainage densities for interfluvial areas 34 and 38 in table 5 have values in excess of 4 even though a part of the main-stem East Fork Salmon River is the only stream length involved. Thus, for very small drainage areas, an insufficient sampling size may yield valid, but inconsistent, values.

The lowest drainage density value is for drainage basin 21, Little Boulder Creek. It appears that this drainage basin is a victim of topography and map scale. Confining mountains and ridgelines combine to create a long, narrow drainage area with primary drainage by the centrally located main-stem channel. Map scale is such that few first-order streams are shown contributing to the main stem, especially in the lower part of the drainage basin. The total number of streams counted is the least per unit of drainage area for any of the drainage basins excluding interfluvial areas and results in a small value of total length of streams and thus in drainage density.

Further attempts to explain differences in drainage density were generally unsuccessful. Drainage density was considered a function of localized geology, but because so much of the total area is underlain by the Challis Volcanics, no correlation could be found. Topography was analyzed by plotting drainage density against maximum, minimum, and midpoint altitudes occurring within each basin. Likewise total basin relief was considered, but none of these measures of topography correlated with values of drainage density. The size of drainage basin using drainage area in square miles, degree of channel-network development using basin order, and aspect of drainage using principal flow direction in degrees from north also failed to indicate correlation with drainage density. Finally, no significant trend in drainage density is detectable as one traverses generally from southwest to northeast in the area. Precipitation and thus runoff decrease to the northeast, but the more arid basins tend to have the same degree of channel development as the wetter areas. This lack of correlation has been noted before. Although early textbooks on physiography commonly attributed differences in drainage density to differences in rainfall or relief, Horton (1945) pointed out that other factors are far more important than rainfall or relief in determining drainage density. Such factors include infiltration capacity of the soil and initial resistivity of the terrain to erosion factors not readily available for study.

A summary of stream ordering data for the entire area is given in table 6. The graphs of figures 7–9, using the data of table 6, illustrate the essential features of the Horton analysis. These graphs show that stream order is related to the number of streams, channel length, and drainage area by simple geometric relations; that is, the value of each of the variables at any given stream order is a constant multiple of the value at the next-lower order. For the number of streams, the reciprocal of this multiple is termed the bifurcation ratio, and its value from figure 7 is about 4.0; or for example, if there were 1 third-order stream in a given basin, there would be about 4 second-order streams and 16 first-order streams. Values of the ratio for the other variables may also be determined. The stream-length ratio is about 2.0, and the drainage-area ratio is about 3.6.

The altitude and slope data of table 6 may also be graphed as in figures 10–12. The watershed-relief and channel-drop data are respectively defined as the difference in altitude from the channel at its exit from the individual basin to (1) the high point in the watershed and (2) the channel altitude at its headwater (top of blue line on topographic map). The relations of stream order to watershed relief and channel drop are not single-line relations as before, but rather at a given value of stream order (and therefore at some given value of drainage area and stream length), the change in altitude difference decreases to a much lesser rate. The reason for the break in rate of change is apparent because only so much total relief exists in an area, and after the high peak of an area is included in the analysis, further increases in relief occur only by downvalley decrease in stream altitude. For watershed relief, this decrease occurs at the inclusion of a fifth-order stream or a drainage area of about 50 square miles (see fig. 10) and for channel drop at a stream order of three or a drainage area of about 3 square miles. Figure 12, the relation of stream order to channel slope, is determined by combining figures 8 and 11. The slope data of figure 12 define the characteristic concave profile of a typical stream, and the break in slope accents the concavity between very steep headwater reaches of channel and relatively flat lower reaches.

An alternative to the compilation in table 6 is a Horton-type analysis in categories by size of drainage area. Table 7 is such a compilation for sizes of drainage areas each greater than the previous size by a factor of two. For each drainage-area size category, the average value of several basin or channel parameters is provided. These data may be plotted against size of drainage area to furnish graphs which may be more

TABLE 6.—*Summary of Horton analysis data, East Fork Salmon River*

Parameter	Stream order						
	1	2	3	4	5	6	7
Number	1,098	267	57	13	4	1	1
Area (mi^2)	.213	.801	3.228	19.225	49.818	112.543	541.836
Length (mi)	.62	1.34	3.18	6.71	12.84	20.85	42.43
Slope (ft/ft)	[1].2561	[1].1793	.1621	.1052	.0530	.0342	.0230
Relief (ft)	[1]1,068	[1]1,951	2,986	3,929	4,808	5,327	6,465
Drop (ft)	[1]649	[1]1,370	2,269	3,058	3,284	3,620	5,150

[1]Does not include data from basins 1–5, 11.

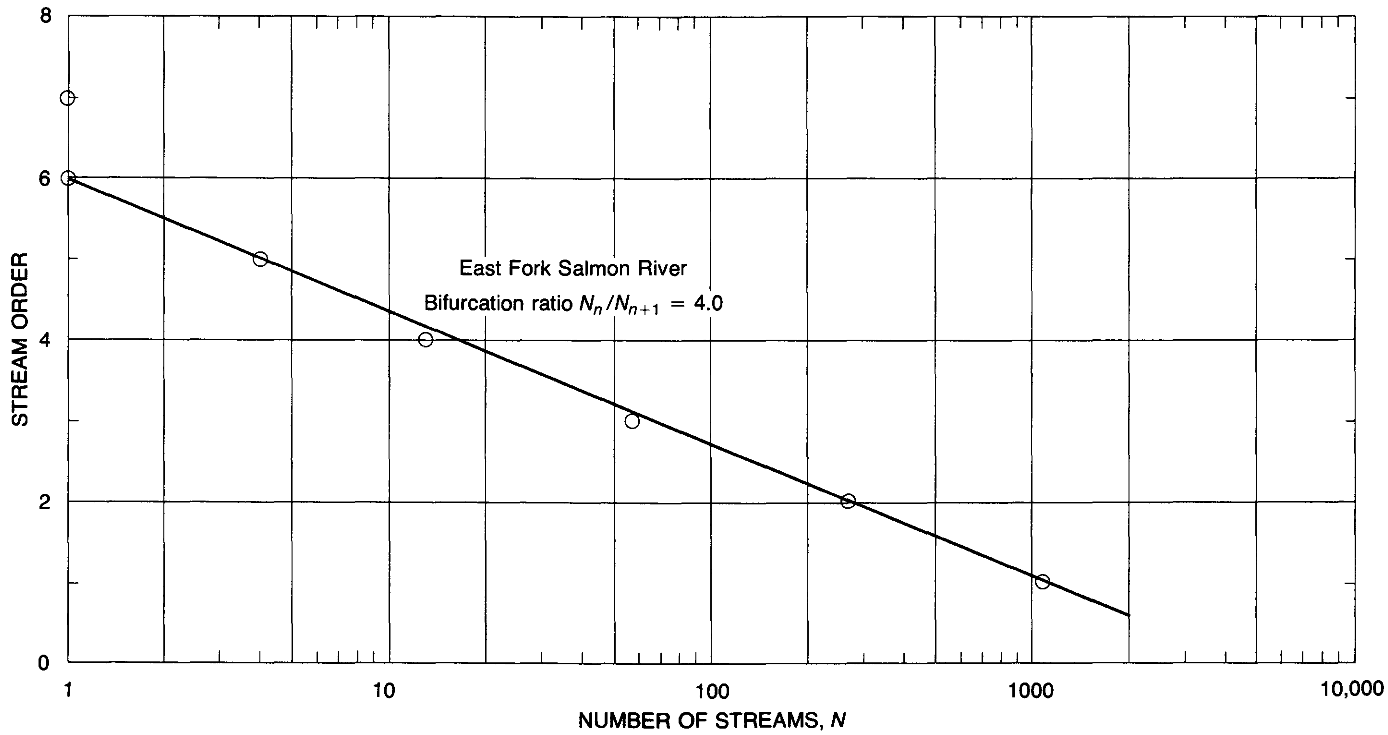

FIGURE 7.—Relation of number of streams to stream order.

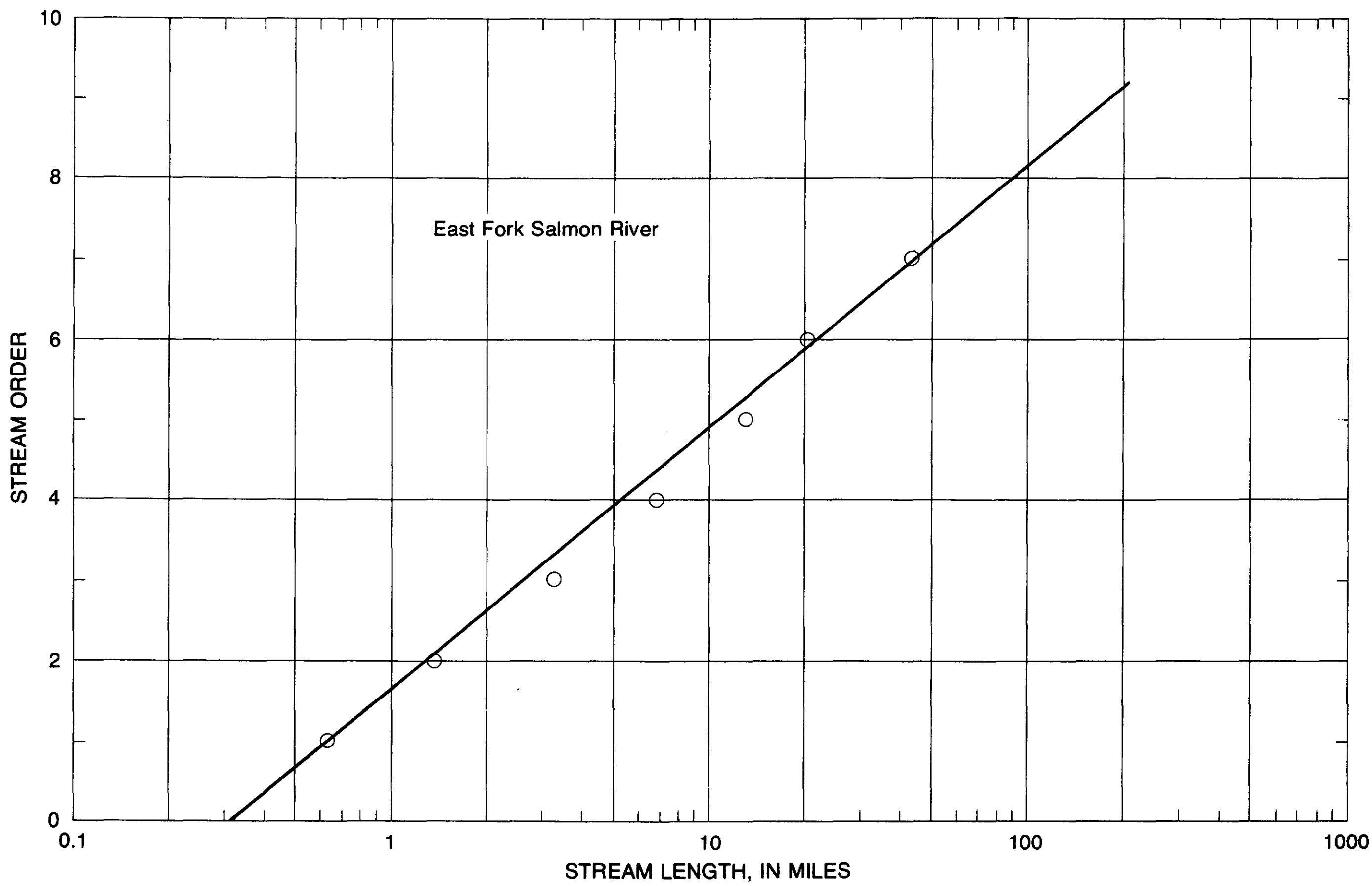

FIGURE 8.—Relation of length of streams to stream order.

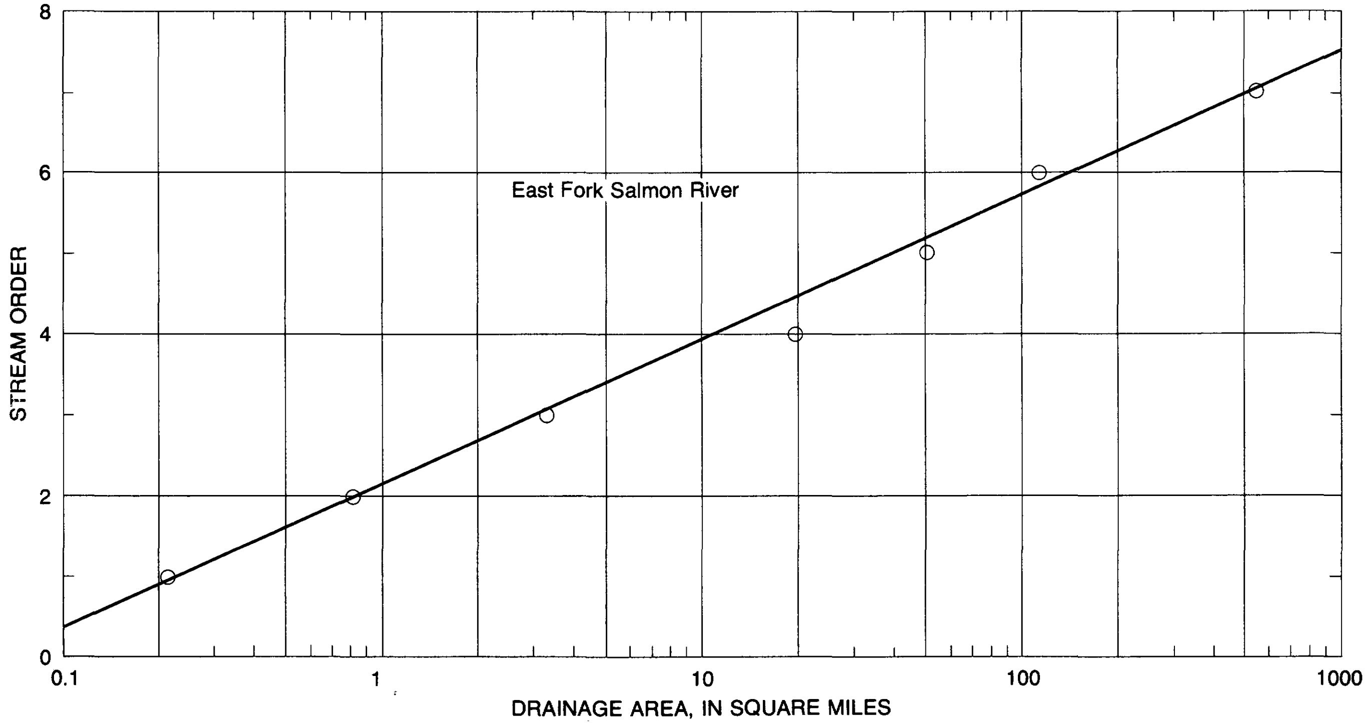

FIGURE 9.—Relation of drainage area to stream order.

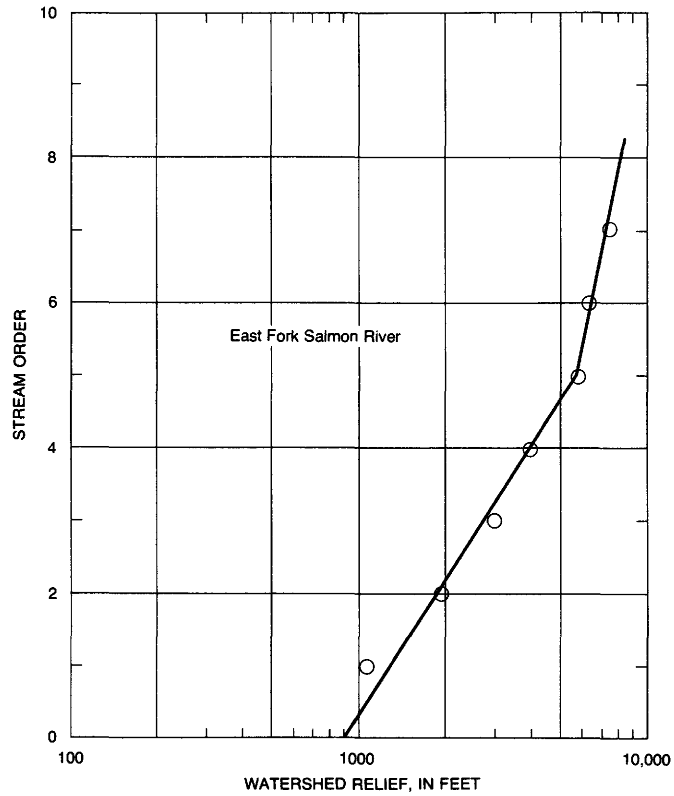

FIGURE 10.—Relation of watershed relief to stream order.

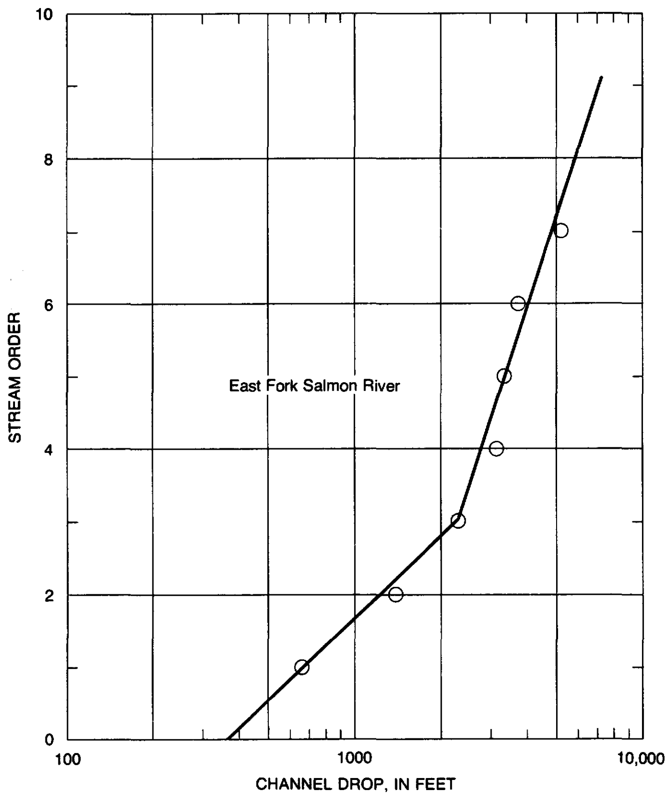

FIGURE 11.—Relation of channel drop to stream order.

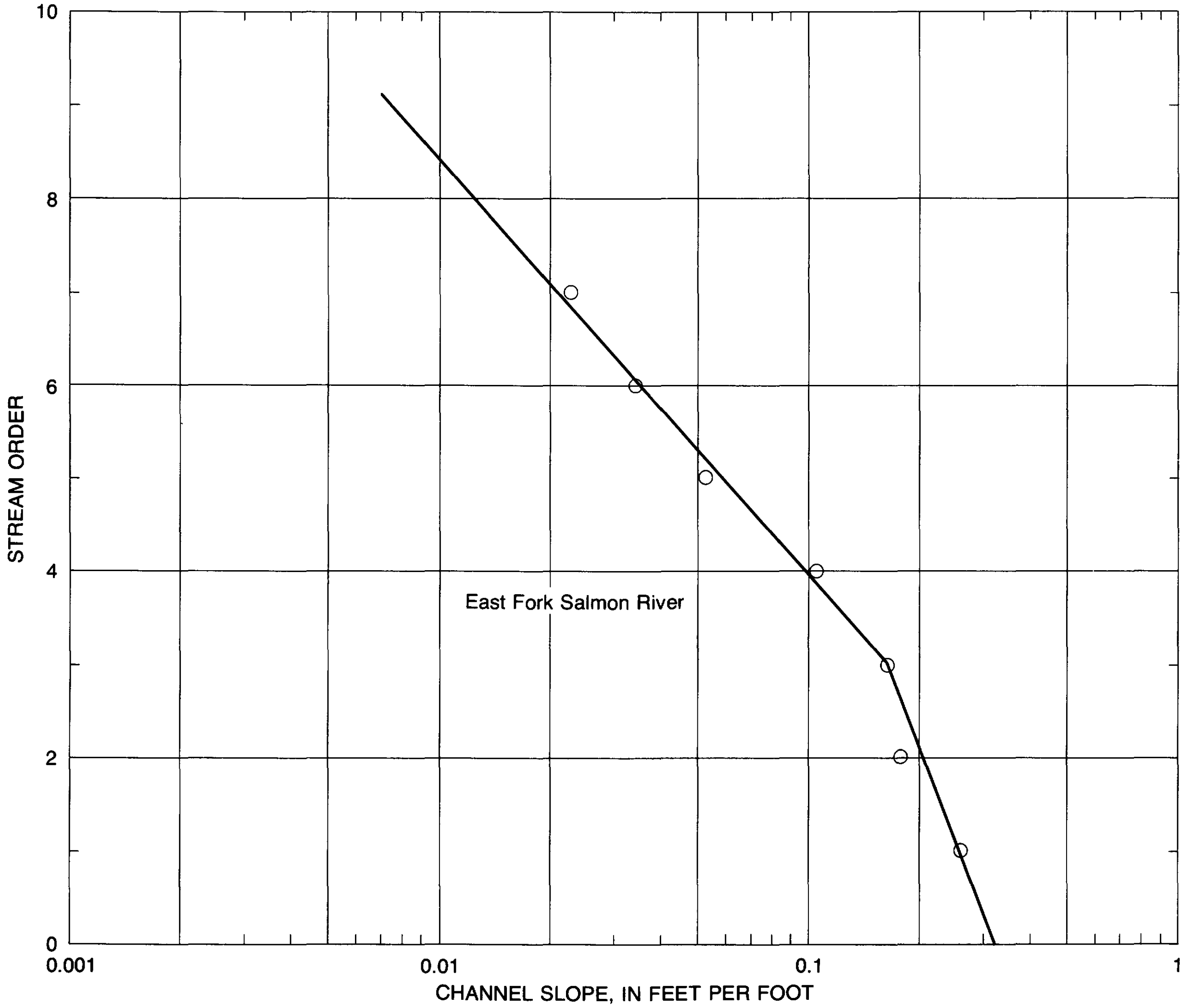

FIGURE 12.—Relation of channel slope to stream order.

TABLE 7.—*Characteristics of Horton analysis compiled by size of drainage area, East Fork Salmon River*

Drainage area size category (mi²)	Average drainage area, *DA* (mi²)	Average stream length, *L* (mi)	Average stream slope, *Sm* (ft/ft)	Average channel drop (ft)	Average watershed relief (ft)	Total number streams	Percentage of streams
0.01– .02	0.016	0.16	[1]0.4307	[1]387	[1]799	13	0.90
.02– .04	.031	.19	[1].3895	[1]477	[1]846	43	2.98
.04– .08	.063	.35	[1].3435	[1]664	[1]1,121	174	12.07
.08– .16	.119	.47	[1].2992	[1]735	[1]1,296	345	23.94
.16– .31	.227	.67	[1].2435	[1]858	[1]1,465	361	25.05
.31– .62	.427	.99	[1].2006	[1]1,012	[1]1,710	254	17.63
.62–1.25	.922	1.50	.1697	[1]1,276	[1]2,019	142	9.85
1.25–2.5	1.680	2.31	.1553	1,809	2,576	49	3.40
2.5– 5	3.238	3.17	.1258	2,083	2,816	27	1.87
5– 10	6.822	4.99	.1038	2,729	3,662	17	1.18
10– 20	15.747	7.45	.0841	3,193	4,083	6	.42
20– 40	31.030	10.58	.0585	3,279	4,381	6	.42
40– 80	48.886	14.06	.0381	2,830	5,445	1	.07
80–160	98.760	17.85	.0341	3,190	4,620	2	.14
160–320	------	----	----	----	----	0	.00
320–640	541.836	42.43	.0230	5,150	6,465	1	.07

[1]Does not include data for basins 1–5, 11.

easily visualized than those of figures 7–12. As an example, stream length is plotted as a function of size of drainage area in figure 13, whereas stream length is the average length of the highest order stream in each size category of drainage area tabulated in table 7. As a numerical example, the average 30-square-mile drainage area will have a principal stream about 10 miles in length. Data of table 6 can also be plotted in the manner of figure 13, and for stream-length and drainage-area data, the plotted points are also shown in figure 13. With little scatter of the data, the plotted points of figure 13 define a relation whose equation is

$$L = 1.5\ DA^{0.55}.$$

On the average, a drainage basin of 1 square mile will produce enough overland flow and erosion to maintain a principal channel length of 1.5 miles. The exponent in the preceding equation has a value of 0.55. If basin width and length increased in the same proportion as basin size, the exponent would be 0.50. The value of 0.55 indicates that length increases more rapidly than width, resulting in typically elongated basin shapes. Interestingly enough, however, the average value of the exponent for several regions of the United States generally lies within 0.6–0.7 and indicates that basin elongation in the East Fork Salmon River drainage area is not as pronounced as for many other regions. The less elongated shapes in the present study are attributed to the confining nature of surrounding mountains and intervening ridges.

The data of table 7 lend themselves to one particularly interesting analysis. The last two columns of the table give the total number of streams and percentage of grand total of streams included in each size category of drainage area. These data are plotted with the bar-graph distribution shown in figure 14 where each segment of the graph indicates the percentage of streams in a given drainage area size category. The

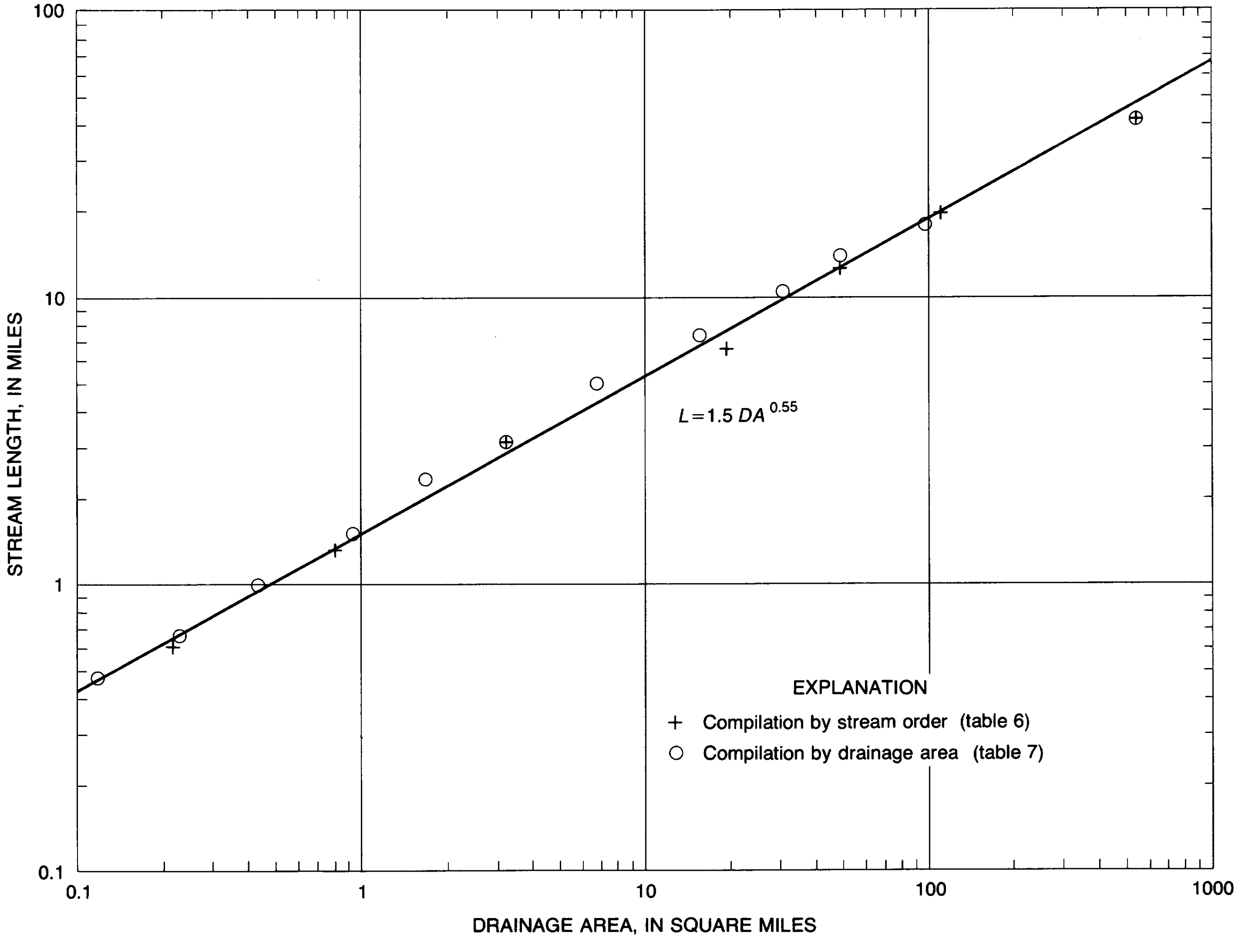

FIGURE 13.—Relation of drainage area to stream length for tributaries to East Fork Salmon River.

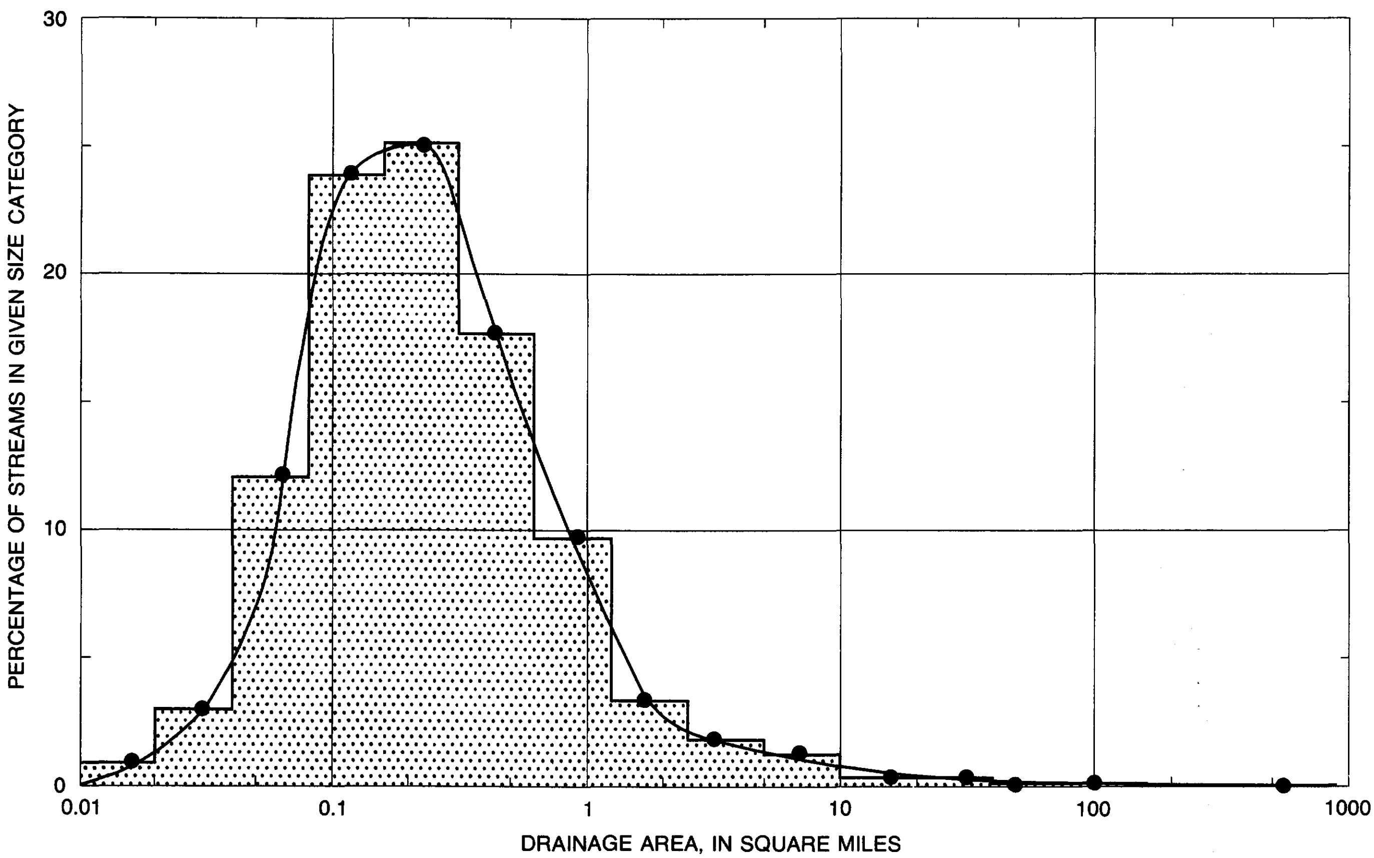

FIGURE 14.—Percentage of streams as a function of size of drainage area.

bell-shaped curve represents a smoothing of this distribution. A distinct distribution of stream frequency may be observed as well as the greatly extended tail of the curve which covers the larger drainage areas. Of the total number of streams, 25 percent have drainage areas in the single-size category of 0.16–0.31 square mile, while 65 percent of the streams have drainage areas less than 0.31 square mile. Further, 97 percent of the total number of streams have drainage areas less than 5 square miles. The percentage distribution of streams would be different when measured on maps of larger or smaller scale, but the 1:24,000-scale maps used in this analysis are believed to realistically portray the drainage net. The large percentage of very small streams is surprising when one considers that probably 97 percent of the effort to obtain stream data is spent on streams with drainage areas greater than 5 square miles. Apparently, economic benefits dictate that most investigative effort be applied to larger rivers, but the student of river morphology and behavior would do well to concern himself with the smaller streams.

MAIN-STEM EAST FORK SALMON RIVER

The discussion of the Horton analysis has thus far concerned itself with the characteristics of the individual basins analyzed. The data can be accumulated in downstream order to discuss behavior with increasing size of drainage area. Table 8 gives some of the basin and stream characteristics as they accumulate along the East Fork Salmon River. For greater detail at the small drainage areas, the first several lines in table 8 are values for subareas of drainage basin 1, the headward extension of the East Fork Salmon River.

Altitude data may be plotted as in figure 15 to illustrate the long profile of the river channel. An accelerated decrease in channel slope occurs at a downstream distance of about 5 miles on the East Fork Salmon River. This distance corresponds to about where the East Fork Salmon River is a third-order stream and thus also corresponds to the point in figure 12 which coincides with the break on the channel slope versus stream order relation. The same trend is apparent from the slope data of table 8. Slope values of incremental reaches of the East Fork Salmon River downstream from drainage basin 1 are all less than 0.02 foot per foot while upstream reaches are greater than 0.05 foot per foot. Because the upstream reaches are steep, the overall gradient decreases continually, even though lower incremental reaches of the river have about the same slope and thus a straight line profile. Close

TABLE 8.—*Characteristics of Horton analysis accumulated downstream along East Fork Salmon River*

Drainage basin No.	Channel length, L (mi)	Drainage area, DA (mi²)	Channel altitude (ft)	Channel relief (ft)	Channel slope, S_m (ft/ft) Reach	Channel slope, S_m (ft/ft) Total	Total length of streams, L_T (mi)	Drainage density (mi/mi²)
	3.00	3.085	8,250	2,250	0.1420	0.1420	10.55	3.42
	4.32	8.356	7,900	2,600	.0502	.1140	32.20	3.85
	5.62	13.616	7,350	3,150	.0801	.1062	49.20	3.61
1	6.91	18.046	7,110	3,390	.0352	.0929	68.45	3.79
2	6.91	26.665	7,110	3,390	----	.0929	102.25	3.83
3	9.21	31.778	6,950	3,550	.0132	.0730	123.78	3.90
4	9.21	38.018	6,950	3,550	----	.0730	145.51	3.83
5	12.41	45.588	6,675	3,825	.0163	.0584	169.33	3.71
6	12.41	71.650	6,675	3,825	----	.0584	242.94	3.39
7	13.99	75.559	6,570	3,930	.0125	.0532	253.47	3.35
8	16.09	78.508	6,410	4,090	.0144	.0481	258.97	3.30
9	16.09	95.489	6,410	4,090	----	.0481	300.34	3.15
10	16.61	95.793	6,370	4,130	.0146	.0471	300.86	3.14
11	16.61	144.679	6,370	4,130	----	.0471	440.20	3.04
12	17.41	146.002	6,330	4,170	.0095	.0454	443.01	3.03
13	17.41	147.325	6,330	4,170	----	.0454	446.54	3.03
14	18.34	149.140	6,275	4,225	.0112	.0436	450.80	3.02
15	18.34	150.510	6,275	4,225	----	.0436	454.82	3.02
16	19.02	151.140	6,240	4,260	.0097	.0424	456.63	3.02
17	19.02	157.640	6,240	4,260	----	.0424	468.32	2.97
18	19.40	157.806	6,220	4,280	.0100	.0418	468.59	2.97
19	19.40	163.590	6,220	4,280	----	.0418	484.05	2.96
20	21.24	165.730	6,120	4,380	.0103	.0391	490.51	2.96
21	21.24	183.860	6,120	4,380	----	.0391	518.94	2.82
22	22.51	186.683	6,050	4,450	.0104	.0374	524.62	2.81
23	22.51	214.073	6,050	4,450	----	.0374	586.23	2.74
24	23.06	214.252	6,040	4,460	.0034	.0366	586.78	2.74
25	23.06	216.797	6,040	4,460	----	.0366	594.53	2.74
26	23.96	217.348	6,015	4,485	.0053	.0355	595.43	2.74
27	23.96	219.908	6,015	4,485	----	.0355	602.55	2.74
28	26.04	221.174	5,950	4,550	.0059	.0331	608.09	2.75
29	26.04	223.040	5,950	4,550	----	.0331	616.33	2.76
30	27.50	225.908	5,900	4,600	.0065	.0317	625.35	2.77
31	27.50	252.444	5,900	4,600	----	.0317	690.49	2.74
32	28.20	252.721	5,870	4,630	.0081	.0311	691.82	2.74
33	28.20	261.214	5,870	4,630	----	.0311	714.49	2.74
34	28.44	261.267	5,860	4,640	.0079	.0309	714.73	2.74
35	28.44	265.971	5,860	4,640	----	.0309	729.00	2.74
36	31.08	270.737	5,770	4,730	.0065	.0288	744.18	2.75
37	31.08	274.736	5,770	4,730	----	.0288	754.87	2.75
38	31.53	274.840	5,755	4,745	.0063	.0285	755.32	2.75
39	31.53	281.564	5,755	4,745	----	.0285	774.85	2.75
40	32.32	282.585	5,730	4,770	.0060	.0280	778.56	2.76
41	32.32	395.128	5,730	4,770	----	.0280	1,066.17	2.70
42	33.28	396.037	5,700	4,800	.0059	.0273	1,067.96	2.70
43	33.28	400.177	5,700	4,800	----	.0273	1,078.16	2.69
44	35.13	404.662	5,630	4,870	.0072	.0263	1,089.95	2.69
45	35.13	489.639	5,630	4,870	----	.0263	1,285.14	2.62
46	37.80	496.645	5,530	4,970	.0071	.0249	1,300.74	2.62
47	37.80	530.902	5,530	4,970	----	.0249	1,387.36	2.61
48	38.15	531.751	5,520	4,980	.0054	.0247	1,390.31	2.61
49	42.43	541.836	5,350	5,150	.0075	.0230	1,416.41	2.61

inspection of the profile in figure 15 reveals that the extreme lower end of the profile may be oversteepened relative to the remainder of the lower half of the profile. That is, the lower several miles of the East Fork Salmon River appear to have a slightly convex profile, while the remainder of the general profile is concave. If indeed this is true, it relates to downcutting by the lower East Fork Salmon River to reach the base level imposed by the main stem of the Salmon River, a condition reflective of general downcutting by the Salmon River at a rate that could not be maintained by upper reaches of the East Fork Salmon River.

The increase in drainage area with channel length along the East Fork Salmon River is also shown in figure 15. As is readily apparent, large increments of drainage area are added at each point where a tributary joins the main stem. Important increments of drainage area contribute directly to the main channel, but the largest increments of drainage area are contributed at several principal tributary junctions. At least to the scale of graphs presented in figure 15, the abrupt inclusion of large drainage areas and thus the addition of large volumes of water does not abruptly influence the general profile of the main-stem river.

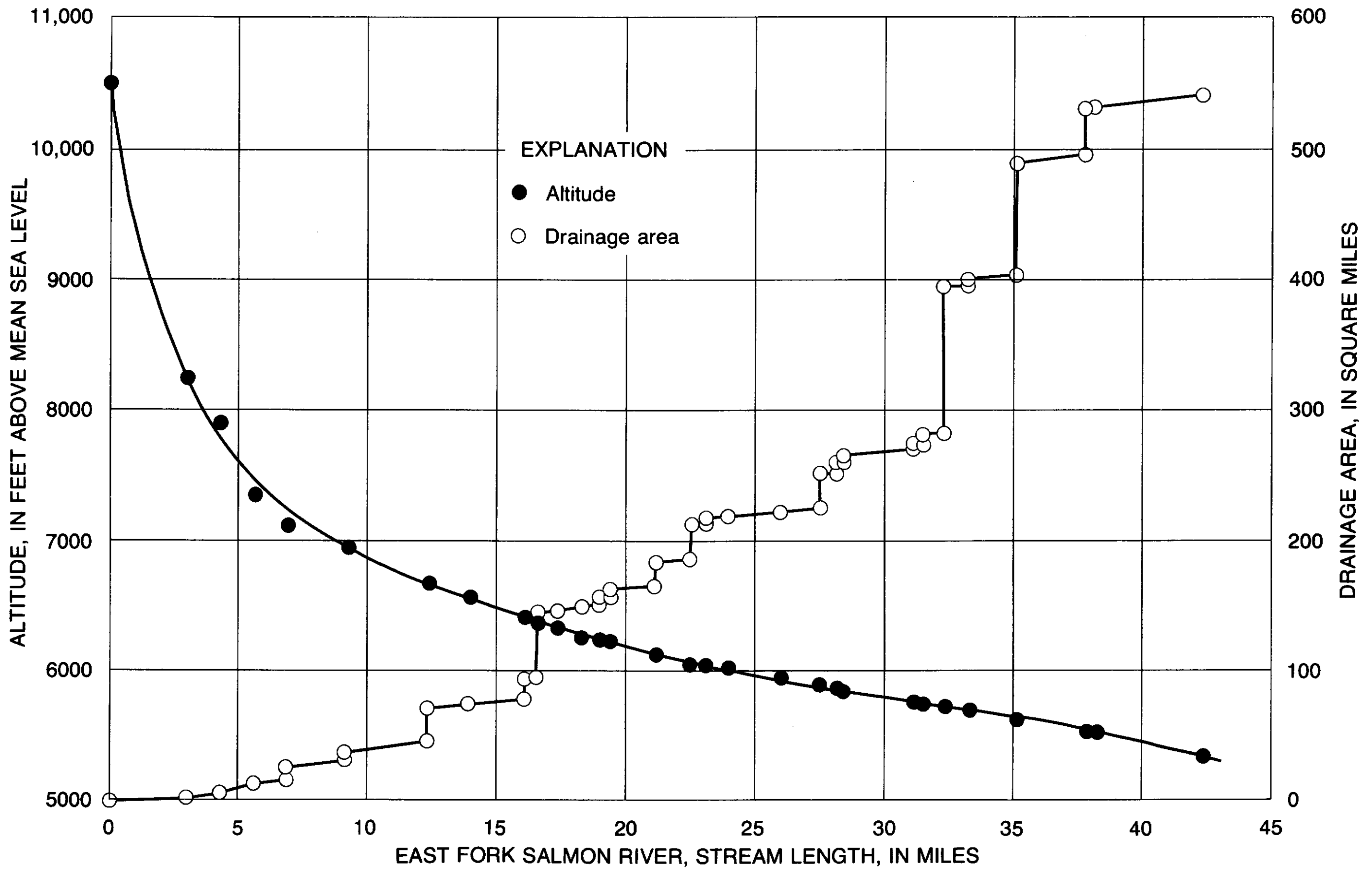

FIGURE 15.—Altitude and drainage area as a function of downstream distance along East Fork Salmon River.

Cumulative values of stream length and drainage area along the main-stem East Fork Salmon River may also be plotted on log-log coordinate paper as was done in figure 13 for individual values of stream length and drainage area. This relation is shown in figure 16. The series of discontinuous upward steps is still apparent as various tributaries add their drainage area, but the effect is damped by the logarithmic scale of the graph. The straight line relation shown in figure 16 has the same values of coefficient and exponent as the relation of figure 13. In figure 16, the relation becomes an envelope curve because the original relation was determined inclusive of all area contributing to drainage areas of given sizes.

Values of drainage density in table 8 show a general decrease in magnitude as data accumulate downstream along the East Fork Salmon River. This trend, however, is perhaps more apparent than real. It is more likely that the first several values of drainage density in the table are inconsistenly high compared with the others, for the first values were obtained from maps of different standards. As previously discussed, most drainage basins have values of drainage density randomly higher or lower than the mean value for the area, and further, the mean value is not greatly affected by the inclusion of several inconsistent values. It is only a chance happening that the data obtained from maps of different standards appear first in table 8 and create the impression of downstream decrease in values of drainage density. By way of comparison, if drainage density were to be computed in the upstream direction, the initial drainage density would be 2.59, the cumulative or mean value would remain at 2.61, and in no instance would the progressive accumulative mean value deviate by more than 10 percent from the mean value.

SUMMARY DISCUSSION OF DRAINAGE NET

The East Fork Salmon River is a seventh-order stream, has a length of about 42 miles, and has a drainage area of about 542 square miles. The bifurcation ratio, or multiple number of each lower order stream, is 4.0, or more exactly, the drainage net of the East Fork Salmon River consists of 1,441 different stream channels. The average length of a first-order stream is about 0.6 mile. The length ratio, or multiple of length of each higher order stream, is 2.0; thus a total of about 1,416 miles of stream channel are within the drainage area of the East Fork Salmon River. The drainage area ratio is about 3.6, yielding an average size drainage area for first-order streams of about 0.2 square mile. These data combine to indicate that about

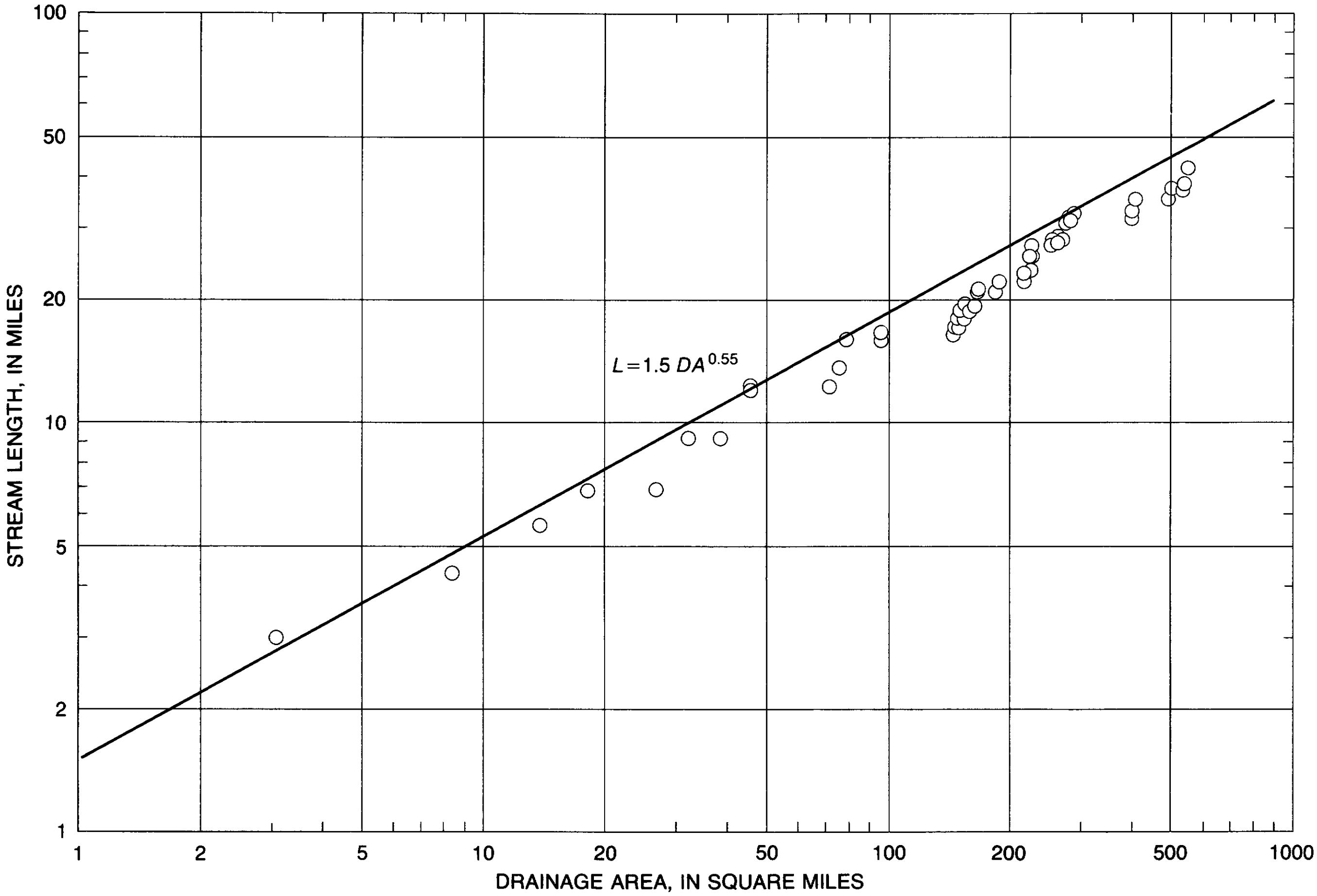

FIGURE 16.—Stream length as a function of drainage area for the main-stem East Fork Salmon River.

90 percent of the streams have drainage areas less than 1 square mile and about 97 percent of the streams have drainage areas less than 5 square miles. In these computations, the size of drainage area is inclusive of all upstream area contributing to the stream. Channel slopes are generally very steep for third-order streams and smaller. Larger streams, those with drainage areas greater than about 5 square miles, have less steep slopes.

This quantitative description of the East Fork Salmon River drainage area should be transferable to other regions within the upper Salmon River area, for cursory examination of topographic maps does not indicate any areal differences in drainage patterns or densities. The drainage-net data thus provide considerable insight into the following discussions of hydrologic characteristics of various rivers of various sizes.

COLLECTION AND ANALYSIS OF STREAMFLOW DATA

All sites where data observations and measurements were made are referred to as water-data stations. The principal water-data stations are presented in table 3, and brief descriptions in table 9. These stations include active recording-hydrograph gaging stations, usually with monthly streamflow observations to maintain updated records; crest-stage gages with devices to record peak stages of flow and generally with sufficient streamflow observations to provide a relation of gage height to water discharge; and miscellaneous stations where only discharge measurements are made.

For many purposes of streamflow analysis, continuous-record hydrographs or values of daily mean discharge are necessary. Extensive data of this type are available from the records of discontinued but previously continuous-recording gaging stations. Later sections of this report utilize these records, and in subsequent tables of data, these stations are identified by their respective U.S. Geological Survey gaging-station number. Table 10 identifies the active and discontinued gaging stations whose streamflow records were used in this study but whose locations may not have been data-collection sites. It also gives several crest-stage gage stations because those stations provide data useful in determining flow frequency. Overall utility of station streamflow data my be limited by the

TABLE 9.—*Summary of water-data station information*

U.S. Geological Survey station No.	Latitude (°N)	Longitude (°W)	Drainage area, DA (mi²)	Altitude (ft)	Channel slope	
					Surveyed, S_s (ft/ft)	Map, S_m (ft/ft)
13–2922.00	43°53′03″	114°45′47″	17.5	7,340	0.0118	0.0133
2924.00	43°55′10″	114°48′48″	15.5	7,125	.0152	.0161
2932.00	44°01′39″	114°49′54″	17.5	6,820	.0162	.0230
2934.00	44°01′48″	114°49′54″	18.5	6,795	.0263	.0303
2950.00	44°13′21″	114°55′49″	147	6,220	.0040	.0030
2956.50	44°15′47″	114°49′03″	51	6,060	.0099	.0101
2960.00	44°17′15″	114°43′11″	195	6,060	.0036	.0122
2965.00	44°16′06″	114°43′55″	802	5,900	.0041	.0091
2970.00	44°14′50″	114°40′11″	79	5,900	.0089	.0205
2971.00	44°15′50″	114°38′50″	8.0	6,000	.0510	.0649
2972.50	44°15′19″	114°33′48″	31.0	5,660	.0260	.0253
2973.00	44°14′52″	114°31′43″	6.0	5,600	.0520	.0631
2973.10	44°17′26″	114°33′25″	22.5	6,040	.0128	.0244
2973.20	44°17′18″	114°32′49″	2.5	6,000	.0810	.0909
2973.30	44°15′36″	114°30′50″	30.0	5,650	.0148	.0199
2973.40	44°18′05″	114°28′36″	60	5,780	.0107	.0124
2973.50	44°17′56″	114°28′50″	6.0	5,840	.0369	.0529
2973.60	44°15′35″	114°27′27″	80	5,550	.0124	.0137
2973.80	44°15′59″	114°19′34″	1,170	5,350	.0046	.0036
2973.84	43°55′44″	114°33′15″	18.05	7,300	.0157	.0458
2973.88	43°55′46″	114°33′18″	8.62	7,300	.0307	.0523
2973.96	43°59′07″	114°29′15″	26.06	6,705	.0208	.0275
2974.00	44°00′23″	114°28′48″	75.56	6,570	.0106	.0126
2974.04	44°02′21″	114°27′40″	48.89	6,375	.0130	.0252
2974.18	44°03′42″	114°27′43″	6.50	6,260	.0755	.2040
2974.25	44°04′58″	114°26′56″	163.59	6,190	.0143	.0122
2974.40	44°03′30″	114°34′27″	2.83	8,840	.0009	.0399
2974.45	44°03′56″	114°32′31″	9.94	8,090	.0025	.0149
2974.50	44°05′57″	114°26′56″	18.13	6,160	.0460	.0758
2974.80	44°07′47″	114°31′33″	12.70	7,230	.0495	.0522
2974.85	44°07′54″	114°31′43″	3.43	7,320	.0625	.1033
2975.00	44°05′58″	114°26′24″	27.39	6,150	.0350	.0541
2975.30	44°09′30″	114°22′43″	26.54	6,035	.0604	.0329
2976.00	44°09′11″	114°17′54″	112.54	5,750	.0169	.0194
2976.70	44°10′36″	114°12′03″	37.86	6,120	.0165	.0505
2976.80	44°10′40″	114°12′07″	32.59	6,160	.0130	.0280
2977.00	44°11′15″	114°17′09″	84.98	5,650	.0356	.0344
2980.00	44°13′29″	114°17′06″	531.75	5,500	.0080	.0066
2985.00	44°22′43″	114°15′18″	1,800	5,165	.0018	.0031

TABLE 10—*Water-data stations with records available for streamflow frequency and duration analyses*

U.S. Geological Survey station No.	Period of record	Station name
Continuous-record stations		
13–2925.00	1940–53	Salmon River near Obsidian, Idaho.
2930.00	1940–53	Alturas Lake Creek near Obsidian, Idaho.
2950.00	1921–72	Valley Creek at Stanley, Idaho.
2955.00	1925–60	Salmon River below Valley Creek at Stanley, Idaho.
2960.00	1921–48	Yankee Fork Salmon River near Clayton, Idaho.
2965.00	1921–72	Salmon River below Yankee Fork near Clayton, Idaho.
2973.50	1971–72	Bruno Creek near Clayton, Idaho.
2974.50	1970–72	Little Boulder Creek near Clayton, Idaho.
2975.00	1926–30	Big Boulder Creek near Clayton, Idaho.
2980.00	1928–39	East Fork Salmon River near Clayton, Idaho.
2985.00	1928–72	Salmon River near Challis, Idaho.
Crest-stage gage stations		
13–2924.00	1963–72	Beaver Creek near Stanley, Idaho.
2971.00	1962–72	Peach Creek near Clayton, Idaho.
2973.00	1962–72	Holman Creek near Clayton, Idaho.
2983.00	1962–72	Malm Gulch near Clayton, Idaho.

length of record. The period of operation of each station is given in table 10.

Discharge-measurement notes, hydrograph-recorder charts, and other field data obtained from routine operation of water-data stations are on file in the Idaho District Office, U.S. Geological Survey. Summaries of streamflow data my be found in publications of the U.S. Geological Survey (1956, 1963, 1971), and annual data since 1966 may be found in other Survey publications (U.S. Geological Survey, 1966–72).

STREAM-GAGING MEASUREMENTS

Measurements to determine quantity of streamflow, though one of the more routine observations made by the Geological Survey, provide a basis for all subsequent interpretation and presentation of data in this report. Streamflow measurements define the relation of water discharge to gage height or water-surface altitude. This relation allows computations of daily mean discharge from records of water-surface altitudes at continuous-record stations. The tabulation of mean daily discharges allows statistical manipulation of data to describe streamflow characteristics.

Values of streamflow are equally important for an adequate description of water quality. For perhaps a few officials, such as public health officers, it may be that constituent concentration is adequate for such purposes as defining toxicity levels. However, as will be shown later, values of concentration generally are dependent on values of discharge. Thus streamflow characteristics become necessary to define how often and by how much various concentration levels are exceeded. Streamflow also becomes important with consideration of magnitude. A small but highly contaminated tributary stream may have less overall impact on water quality than a larger but only moderately contaminated stream. Otherwise stated, values of streamflow are necessary for determination of dissolved and suspended loads transported by the streams.

Measurements of streamflow were made at every water-data station at each time of data collection. A nearly complete list of discharge measurements made in the 2-year period 1971–72 is included as part of the "Summary of data," tables 40, 41, and 42, at the end of this report.

STREAMFLOW RUNOFF

During the 3-year period 1970–72, five water-data stations were operating as partial- or continuous-record stations. Hydrographs of water discharge throughout these years are illustrated in figures 17–21. Peak discharges were generally highest in 1972 and lowest in 1970. Annual volume of runoff, represented by the area under the curves in figures 17–21, was generally greatest in 1971 and lowest in 1970. Comparison of the yearly volume of runoff to values of mean annual runoff for those stations with adequate record to define a mean value indicates that the year 1970 had about 10 percent greater runoff than the average year. Since this was the lowest annual volume of runoff for any of the 3 years, all years during the principal period of study had higher-than-average runoff.

Mean annual runoff in the study area is controlled mostly by the amount of winter precipitation falling as snow. In 1972, a warmer-than-average spring, perhaps aided by a few warm rains, created a sufficient rate of snowmelt to produce the highest peak rate of runoff of the 3 years, although 1971 had the greatest volume of runoff.

Peak discharges in the years 1970–72 had recurrence intervals on the order of 3 years, 8 years, and 25 years, respectively. The last value represents a discharge that can be expected to occur four times in a century, a relatively rare eccurrence. Such a rare discharge does not affect any of the hydraulic measurements made during its occurrence but rather can be considered a fortunate happening which allowed data to be collected over an extended range in discharge. For some water-quality aspects, slight effects may occur if one considers that the consistently high runoff may be likened to a flushing action in the river system. However, as will be shown later, the chemical composition of stream water is so dependent on magnitude and frequency of streamflow that the extended range of

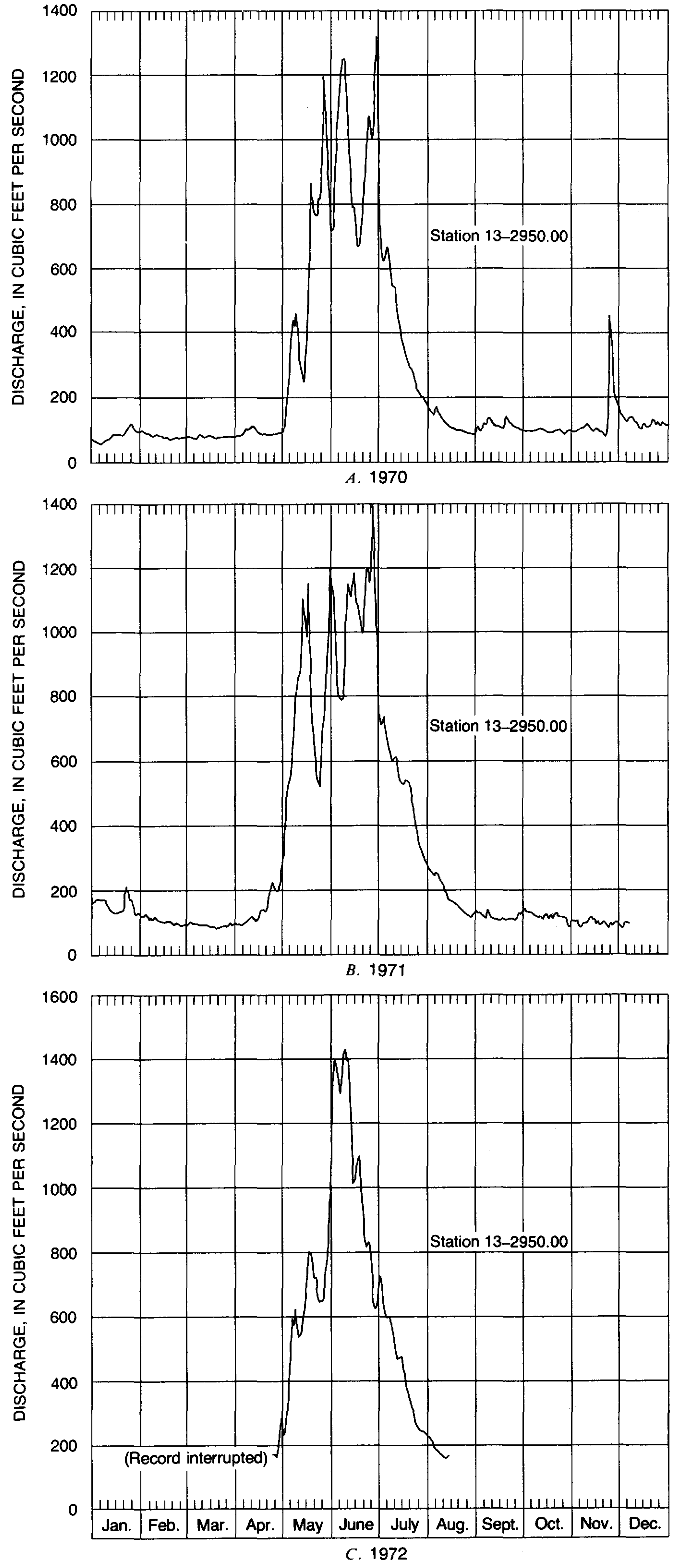

FIGURE 17.—Streamflow hydrograph, 1970–72, Valley Creek at Stanley, Idaho. *A*, 1970. *B*, 1971. *C*, 1972.

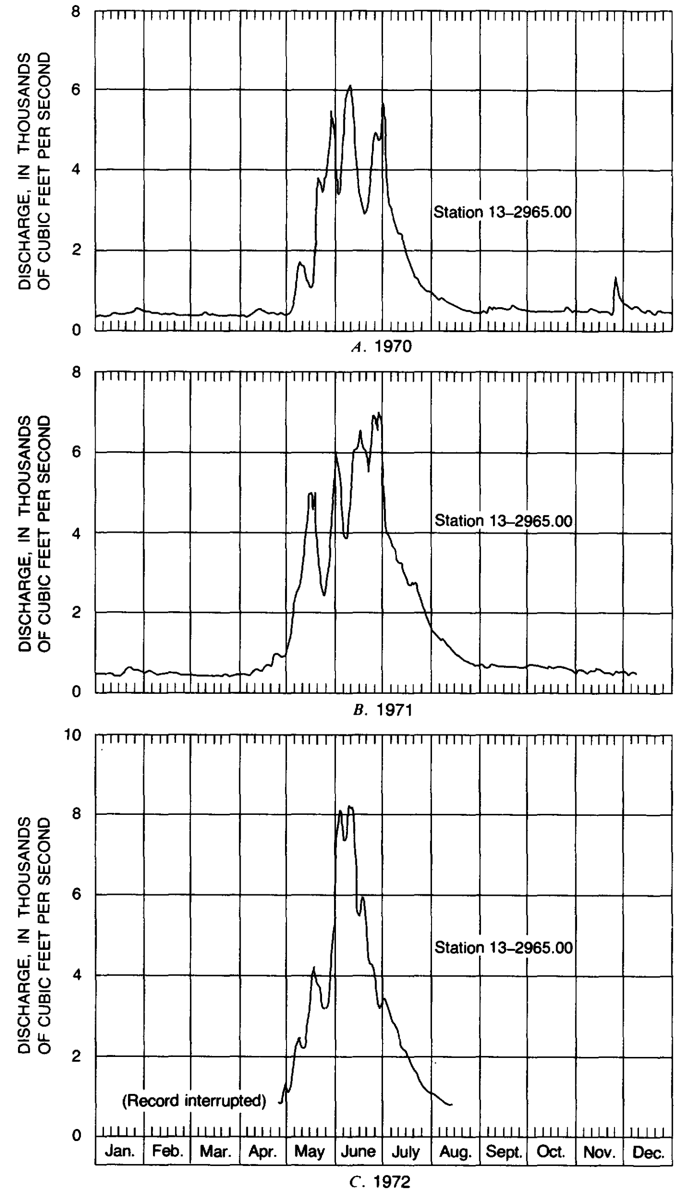

FIGURE 18.—Streamflow hydrograph, 1970–72, Salmon River below Yankee Fork, Idaho. *A*, 1970. *B*, 1971. *C*, 1972.

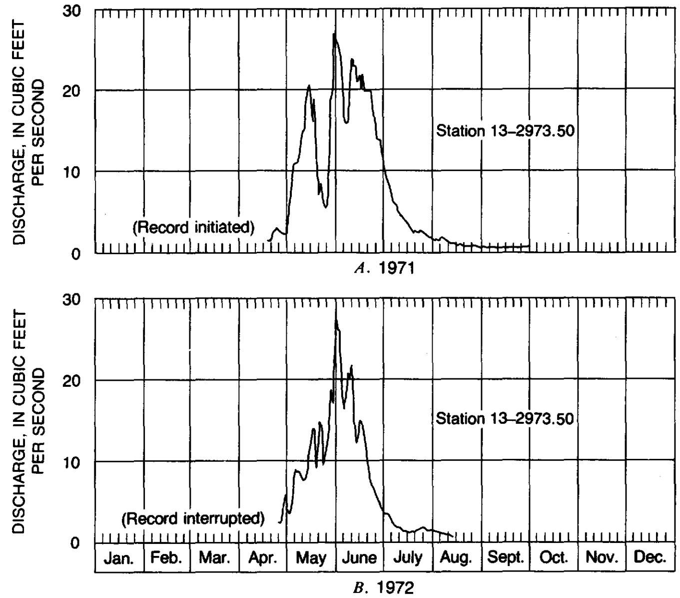

FIGURE 19.—Streamflow hydrograph, 1971–72, Bruno Creek near Clayton, Idaho. *A*, 1971. *B*, 1972.

water-quality data provided by the rare discharges reduces to an insignificant level the effects introduced by the consecutive years of high runoff.

HYDRAULIC GEOMETRY

The term hydraulic geometry was used by Leopold and Maddock (1953) with reference to the many variations in hydraulic characteristics of river channels as the channels carry a wide range of streamflow. Such descriptions are equally valid whether applied to a given cross section of channel and referred to as at-a-station characteristics, or when applied to channels in the downstream direction. With few exceptions, the subsequent discussion follows the procedures suggested by Leopold and Maddock.

AT-A-STATION HYDRAULIC CHARACTERISTICS

As a given cross section of channel transmits varying amounts of water, changes in values of the mean velocity, V, mean depth, D, and surface width, W, of the flowing water reflect the hydraulic characteristics of that cross section. To define these characteristics, field notes of individual discharge measurements at a given station are scanned to select about 5–10 sets of notes which are representative of the full range of discharges measured. Values of mean velocity, mean depth, and surface width are obtained from the measurement notes and are plotted as a function of discharge, Q, on logarithmic graph paper. Figure 22 illustrates such plots with data for the gaging station Salmon River near Challis, Idaho (13–2985.00). It is the at-a-station curves of figure 22 which allow determination of the hydraulic variables for any desired discharge.

The graphs of figure 22, as for most river channels, indicate straight-line relations. For the given cross section, values of the hydraulic characteristics vary with discharge as simple power functions:

$$W=aQ_b$$
$$D=cQ_f$$
$$V=kQ_m.$$

Further, from the continuity equation,

$$W \times D \times V=Q,$$

it can easily be shown that

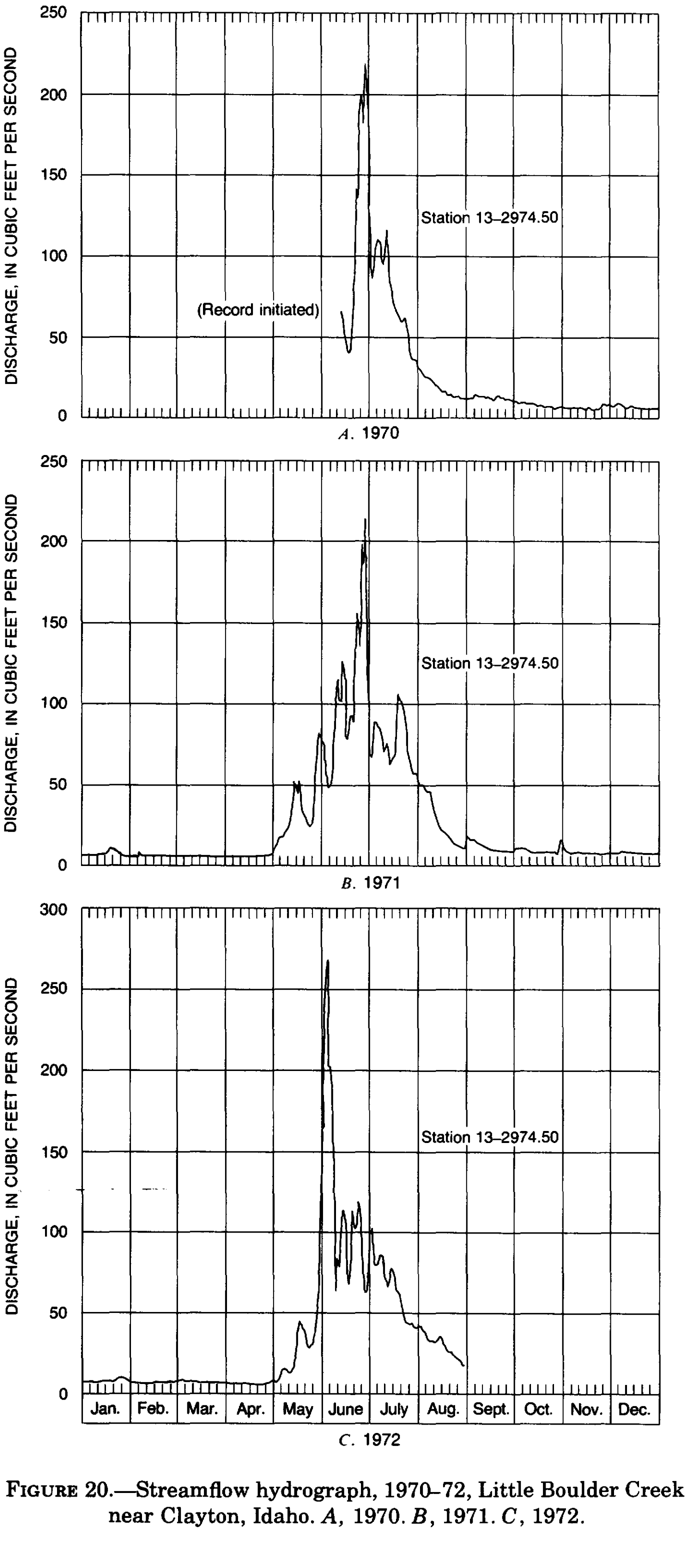

FIGURE 20.—Streamflow hydrograph, 1970–72, Little Boulder Creek near Clayton, Idaho. *A*, 1970. *B*, 1971. *C*, 1972.

$$a \times c \times k = 1$$

and

$$b + f + m = 1.$$

Values of the coefficients, *a*, *c*, and *k*, and the exponents,

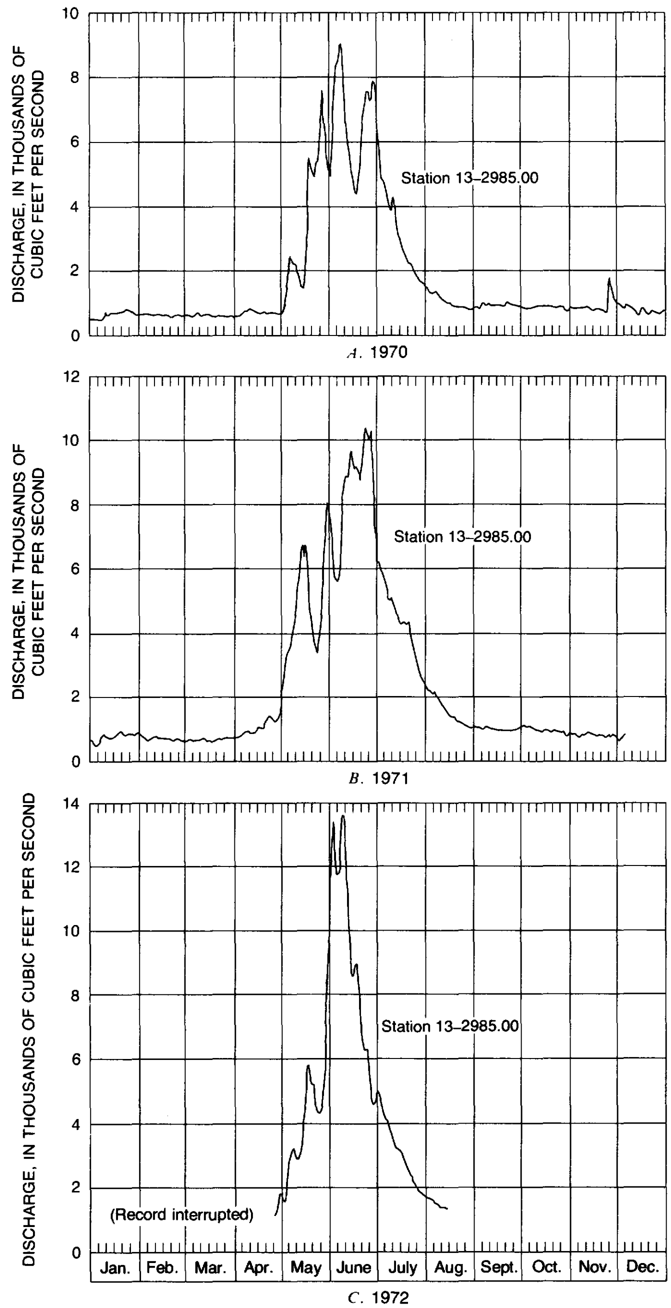

FIGURE 21.—Streamflow hydrograph, 1970–72, Salmon River near Challis, Idaho. *A*, 1970. *B*, 1971. *C*, 1972.

b, *f*, and *m*, may be determined by applying log-transformed linear regression techniques to the field data. For the example of figure 22, values of *b*, *f*, and *m* were determined as 0.12, 0.40, and 0.48, respectively. These values of *b*, *f*, and *m* corresponding to the slope of the respective curves are shown in figure 22.

Adequate data to prepare curves of hydraulic geometry for all the principal water-data stations given in table 3 were provided by discharge measurements. Analyses of these data provided values of the exponents

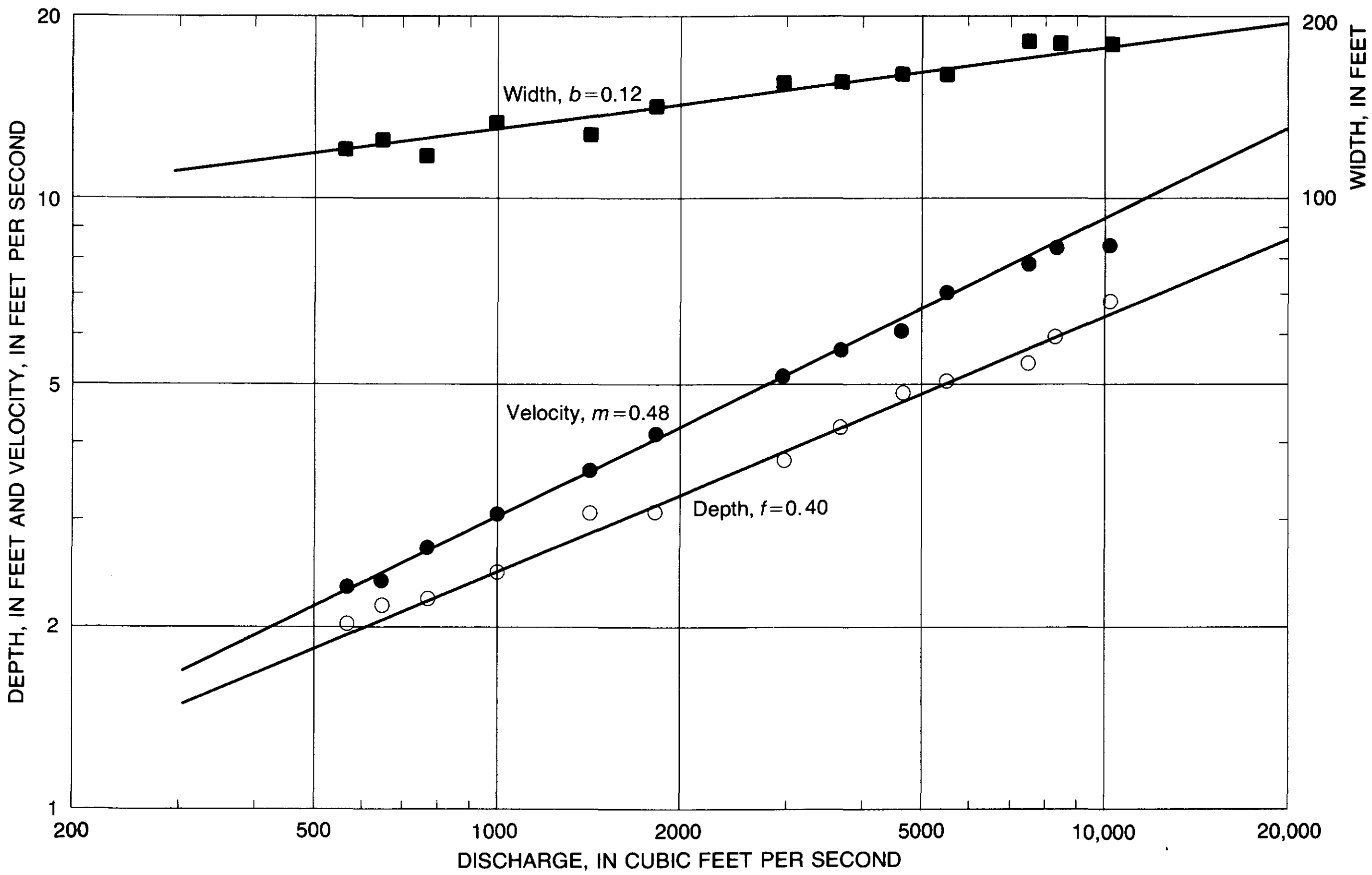

FIGURE 22.—At-a-station curves of hydraulic geometry, Salmon River near Challis, Idaho.

of the hydraulic-geometry equations, and for all stations these exponents are given in table 11. For all 39 stations, the mean and median values of *b, f,* and *m* are 0.14, 0.40, 0.46 and 0.12, 0.40, 0.48, respectively. Although there is considerable variability in values of *b, f,* and *m* among individual streams, the average values for a group of streams are generally consistent. For comparison, the average values for 158 gaging stations in the United States are $b=0.12, f=0.45$, and $m=0.43$ (Leopold and others, 1964).

The at-a-station curves of hydraulic geometry for some rivers may show a break in slope at bankfull discharge. That is, at stages just over bankfull, width increases rapidly as the flood plain becomes inundated, and there is corresponding decrease in the rate of increase in depth and sometimes in velocity. In the present study, however, at some locations the flood plain was too narrow to allow this, and at other locations no overbank discharge measurements were available to document a break in slope. Thus for the entire range of streamflow, single curves with slope values of *b, f,* and *m* were used to define the relations of *W, D,* and *V* to *Q* for each stream.

Variability among stations in the values of *b, f,* and *m* in table 11 can be partly explained by the techniques of data collection. At some locations, for example the East Fork Salmon River near Clayton, Idaho (13–2980.00), discharge measurements were obtained at a bridge crossing. For all stages of flow, the width of the stream was confined by the bridge revetments. This constraint, or fixed width of channel, yields a value of $b=0.00$. To compensate, depth increases more rapidly than average and has an exponent value of $f=0.55$. At other locations where wading measurements were made, the original cross section was not always used during subsequent measurements. Because of inherent variabilities from section to section even within a short reach of channel, a scatter is introduced to data of the type plotted in figure 22 and makes the definition of the hydraulic geometry equations more tenuous. And, in some instances, the definition may become biased. For example, at Beaver Creek near Stanley, Idaho (13—2924.00), wider than average sections were used at high discharges to obtain shallow enough depths for wading. This creates the impression that width increases more rapidly than average, $b=0.24$, and is compensated by depths increasing less rapidly than average, $f=0.31$. Induced variability among station data, such as in these two examples, displays sufficient randomness in its effect that it is reasonable to expect that the mean or

TABLE 11.—*Exponents of hydraulic-geometry equations for width, depth, and velocity*

U.S. Geological Survey station No.	b ($W \propto Q^b$)	f ($D \propto Q^f$)	m ($V \propto Q^m$)
13–2922.00	0.03	0.57	0.40
2924.00	.24	.31	.45
2932.00	.16	.39	.45
2934.00	.07	.41	.52
2950.00	.07	.35	.58
2956.50	.04	.48	.48
2960.00	.16	.43	.41
2965.00	.19	.31	.50
2970.00	.00	.36	.64
2971.00	.35	.30	.35
2972.50	.00	.48	.52
2973.00	.06	.52	.42
2973.10	.25	.35	.40
2973.20	.27	.39	.34
2973.30	.29	.23	.48
2973.40	.18	.40	.42
2973.50	.15	.30	.55
2973.60	.15	.32	.53
2973.80	.13	.49	.38
2973.84	.05	.35	.60
2973.88	.03	.39	.58
2973.96	.05	.35	.60
2974.00	.25	.38	.37
2974.04	.02	.40	.58
2974.18	.03	.36	.61
2974.25	.00	.40	.60
2974.40	.00	.43	.57
2974.45	.24	.45	.31
2974.50	.33	.16	.51
2974.80	.21	.39	.40
2974.85	.12	.44	.44
2975.00	.00	.45	.55
2975.30	.18	.37	.45
2976.00	.00	.52	.48
2976.70	.16	.53	.31
2976.80	.36	.54	.10
2977.00	.34	.41	.25
2980.00	.00	.55	.45
2985.00	.12	.40	.48
Mean	.14	.40	.46
Median	.12	.40	.48

median values are not greatly affected. And, at some locations, it is likely that the mean values more closely approximate natural values than the individual station data.

In summary, the data of table 11 indicate that the average river channel accommodates about 40 percent of an increase in discharge by an increase in depth, about 10–15 percent by an increase in width, and about 45–50 percent by an increase in velocity.

Values of the coefficients *a*, *c*, and *k* have less significance than the exponents. Values of the coefficients are determined as the intercept values for a value of discharge equal to unity, or 1 cubic foot per second. Since river channels with sizable drainage areas do not have discharges this low, extrapolation of data corresponding to a discharge of unity has no physical significance and is not valid.

DOWNSTREAM HYDRAULIC CHARACTERISTICS

Comparison of the hydraulic characteristics at various sections along the length of a stream may be made in much the same manner as for the at-a-station analyses. Whereas in the previous analysis increases in discharge were due to increases in water stage, in the downstream direction increases in discharge are due to tributary contributions. Because it would be improper to compare the hydraulic characteristics of some reaches at low flow with other reaches at high flow, the comparison must be made for a flow of given frequency. As Leopold, Wolman, and Miller (1964) emphasized, the most meaningful discharge for any discussion of channel morphology is that which forms or maintains the channel. They further state that the effective discharge can be approximated by bankful discharge.

The next section of this report contains a discussion of bankfull discharge, its determination, and its importance. For the present discussion, it is important to know only that bankfull discharge was determined for each of the principal water-data stations given in table 3. With the values of bankfull discharge, Q_B, known, individual station graphs of at-a-station hydraulic geometry such as figure 22 provide corresponding bankfull values of surface width, W_B, mean depth, D_B, and mean velocity, V_B. These bankfull data are given in table 12. It may be noted that the combined data of tables 11 and 12 are sufficient to prepare the at-a-station curves of hydraulic geometry for each of the 39 water-data stations.

Data of table 12 are unique for the purpose of illustrating downstream hydraulic geometry. To date, they represent the largest assembly of bankfull data for a given river system. Although all the water-data stations are not successively at downstream locations, all are within the tributary system of the upper Salmon River. Tributary stations can be considered as alternate headward extensions of the main-stem river. Data of table 12 are plotted in figures 23–26 to define the downstream curves of hydraulic geometry. Figure 26, the plot of bankfull flow area, A_B, is essentially a plot of the multiplication of the width and depth plots of figures 23 and 24 ($A = W \times D$). Log-transformed linear regression equations (least-squares technique) were fitted to the data. With the correlation coefficient shown in parentheses, the following relations were determined:

$$W_B = 1.37\,Q_B^{0.54} \quad (r = 0.917),$$
$$D_B = 0.25\,Q_B^{0.34} \quad (r = 0.887),$$
$$V_B = 2.88\,Q_B^{0.12} \quad (r = 0.486),$$
$$A_B = 0.35\,Q_B^{0.88} \quad (r = 0.972).$$

These relations show values of $b = 0.54$, $f = 0.34$, and $m = 0.12$. By comparison, Leopold and Maddock (1953) found the average value for a number of streams in the midwestern United States to be $b = 0.50$, $f = 0.40$, and

TABLE 12.—*Summary of bankfull-stage data from channel-geometry surveys*

U.S. Geological Survey station No.	Surface width, W_B (ft)	Mean depth, D_B (ft)	Mean velocity, V_B (ft/sec)	Flow area, A_B (ft²)	Discharge, Q_B (ft³/sec)	Runoff, R_B (ft³/sec/mi²)
13-2922.00	40	1.8	5.0	72.0	360	20.6
2924.00	33	1.2	4.9	39.6	194	12.5
2932.00	25	1.2	6.5	30.0	195	11.1
2934.00	25	1.5	5.3	39.0	207	11.2
2950.00	80	2.5	5.0	200.0	1,000	6.8
2956.50	32	2.7	5.5	86.4	475	9.3
2960.00	53	3.2	4.2	169.6	712	3.7
2965.00	116	6.2	5.2	719.2	3,740	4.7
2970.00	45	1.7	7.9	76.5	604	7.7
2971.00	28	1.2	6.6	33.6	222	27.7
2972.50	21	1.0	5.7	21.0	120	3.9
2973.00	9	1.5	7.2	13.5	97.2	16.2
2973.10	33	1.2	5.2	39.6	206	9.2
2973.20	16	.8	4.2	12.8	53.8	21.5
2973.30	40	1.1	6.2	44.0	273	9.1
2973.40	30	2.1	5.2	63.0	328	5.5
2973.50	8	.9	7.4	7.2	53.3	8.9
2973.60	28	2.4	6.8	67.2	457	5.7
2973.80	165	4.2	7.4	693.0	5,128	4.4
2973.84	29	1.8	6.0	52.2	313	17.4
2973.88	14	1.7	5.2	23.8	124	14.4
2973.96	23	1.7	5.6	39.1	219	8.4
2974.00	49	2.4	7.6	117.6	894	11.8
2974.04	32	2.0	6.4	64.0	410	8.4
2974.18	7	1.2	8.0	8.4	67.2	10.3
2974.25	44	2.5	10.0	110.0	1,100	6.7
2974.40	17	.9	3.9	15.3	59.7	21.1
2974.45	32	2.4	3.5	76.8	269	27.0
2974.50	44	1.3	5.5	57.2	315	17.4
2974.80	42	1.0	4.4	42.0	185	14.6
2974.85	9	1.3	6.8	11.7	79.6	23.2
2975.00	20	1.6	6.9	32.0	221	8.1
2975.30	23	1.5	7.0	34.5	242	9.1
2976.00	28	2.5	8.4	70.0	588	5.2
2976.70	9	1.3	3.2	11.7	37.4	1.0
2976.80	9	1.0	2.1	9.0	18.9	.6
2977.00	23	1.2	3.1	27.6	85.6	1.0
2980.00	52	4.2	8.5	218.4	1,856	3.5
2985.00	165	4.9	6.8	808.5	5,498	3.1

m=0.10. In a study of Alaskan channels, Emmett (1972a) reported values of b=0.50, f=0.35, and m=0.15.

The data just given indicate that in the upper Salmon River area, downstream increases in discharge are accommodated by increases in width, depth, and velocity. Increases in width absorb 54 percent of the increase in discharge, depth absorbs 34 percent, and velocity absorbs 12 percent. Downstream increases in velocity are the most surprising because, without measurements, tumbling waters in headwater reaches of channels appear to have faster velocities than the apparent sluggish waters in downstream reaches. This phenomenon is only a deception by the eye, and the velocity data are generally consistent with downstream increases in velocity in other river systems (Leopold, 1953).

At stages of flow greater than bankfull, channel width increases rapidly as water flows over the full width of the flood plain, and velocities increase less rapidly or not at all as increased resistance to flow is encountered. Since extent of flood plains generally increases downstream, this effect is more pronounced in the downstream direction. The net effect is that for floodflows of rarity greater than about once in 5 years, velocities tend to remain about constant in the downstream direction. Sufficient data are not available to illustrate this constancy of downstream floodflow velocities in the upper Salmon River, but that trend has been shown for limited data in other river basins (Leopold and others, 1964).

Values of the coefficients a, c, and k, in the hydraulic-geometry equations assume more physical significance in downstream hydraulic geometry than in analyses of at-a-station hydraulic geometry. In the downstream case, the coefficients represent values of width, depth, and velocity at that upstream reach where bankfull discharge is unity. Although in reality this represents an upstream reach with a drainage area so small that definite channels are nonexistent, it provides for a downstream comparison of channel shape. At the upstream reach of channel where the bankfull discharge is unity, the channel width-depth ratio is 1.37:0.25, or about 5.5. This width-depth ratio increases significantly downstream, and at the exit from the study area (drainage area=1.800 square miles, bankfull discharge=5,500 cubic feet per second), the width-depth ratio of the Salmon River is 30. Although many factors actually control the shape of channels (see, for example,

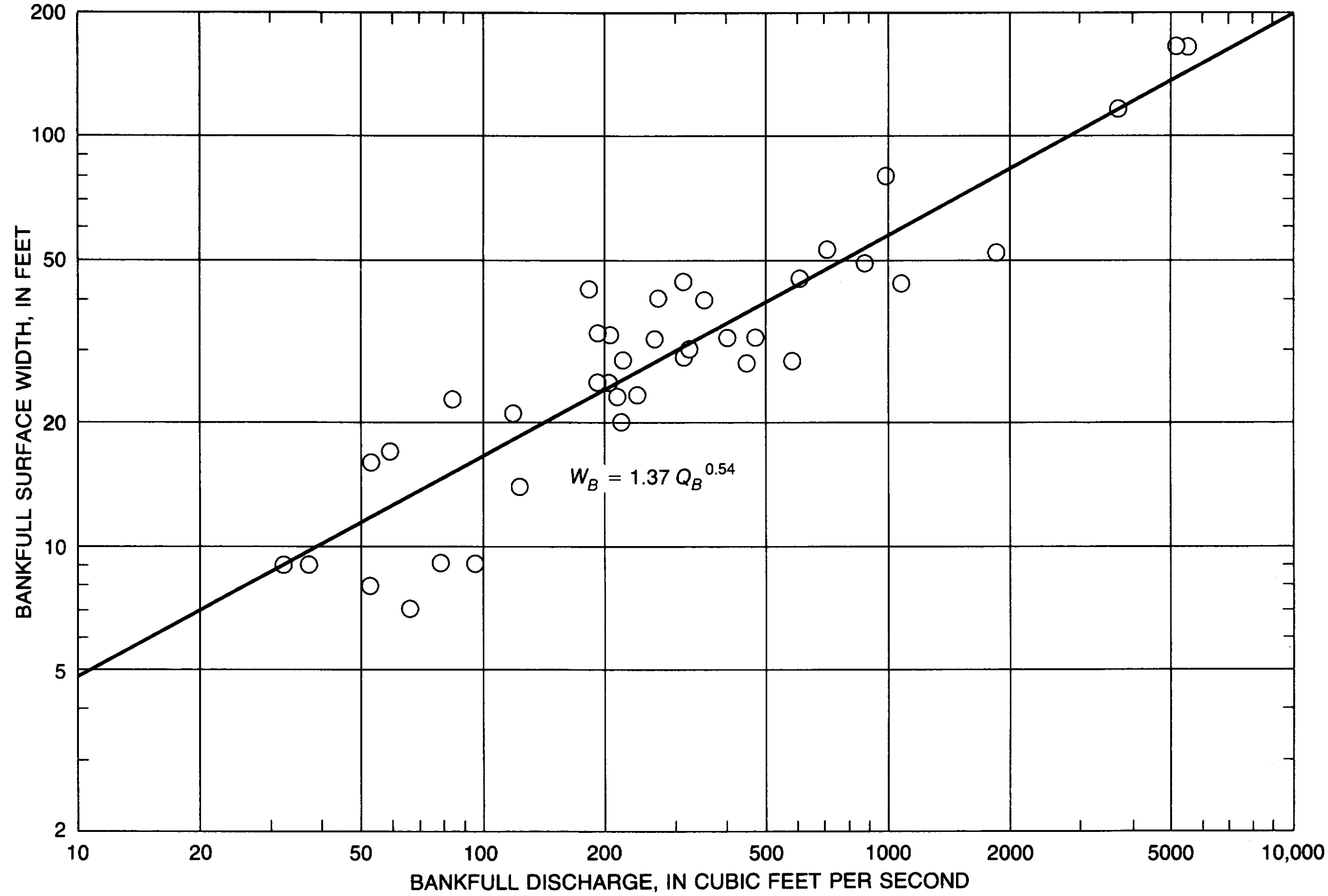

FIGURE 23.—Bankfull surface width as a function of bankfull discharge.

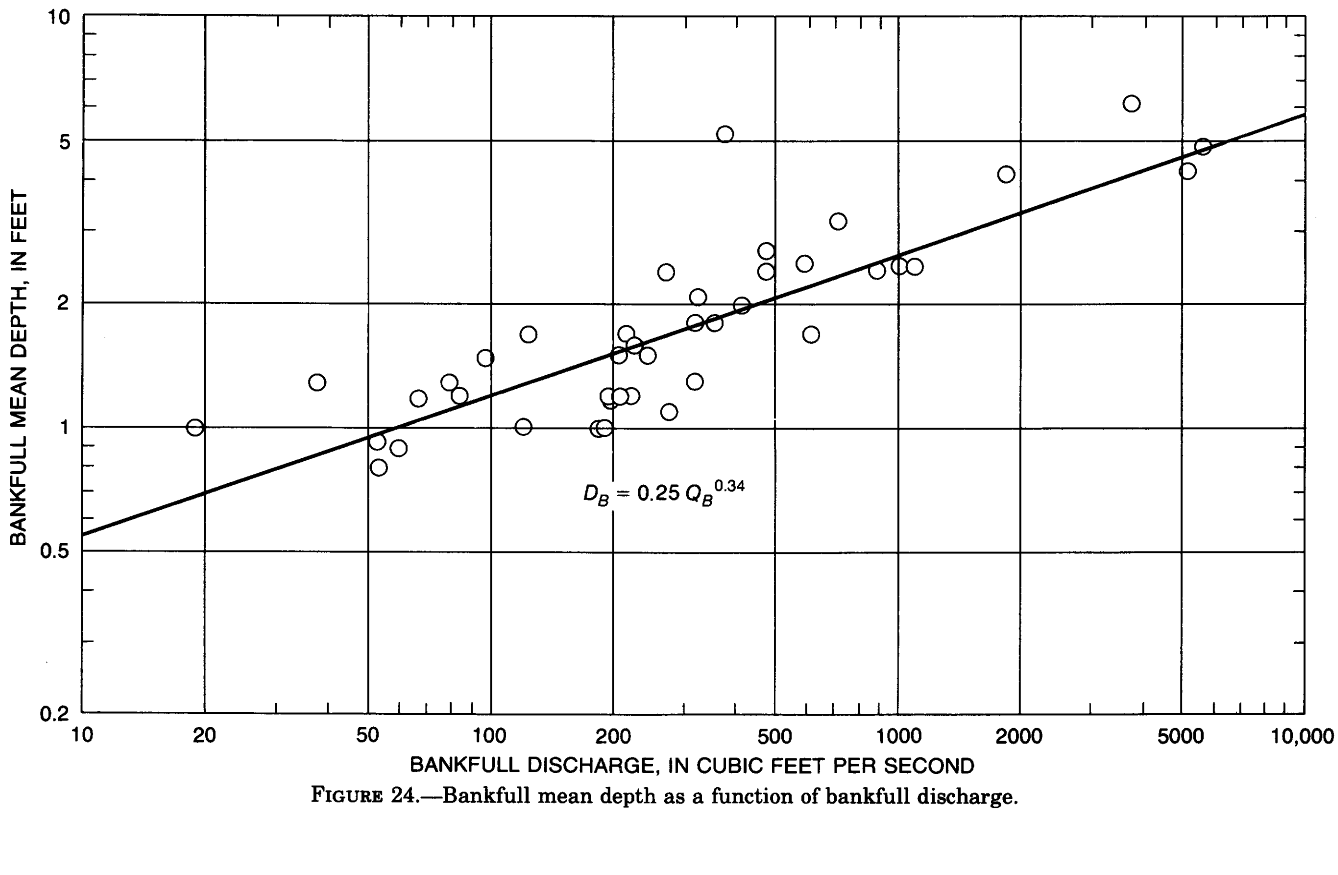

FIGURE 24.—Bankfull mean depth as a function of bankfull discharge.

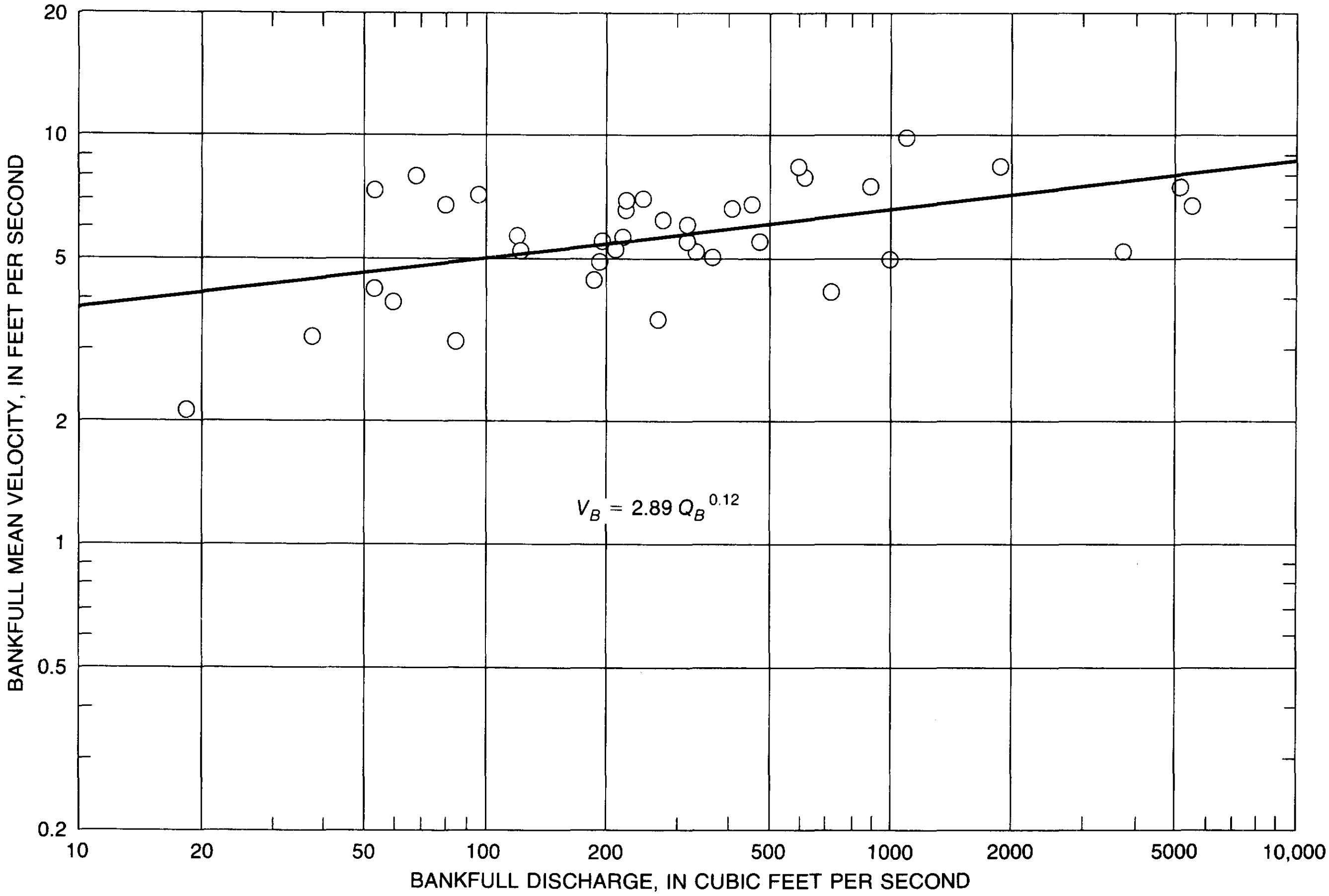

FIGURE 25.—Bankfull mean velocity as a function of bankfull discharge.

Schumm, 1960), the downstream curves of hydraulic geometry illustrate that even the largest rivers are not overly deep.

Evaluation of the correlation coefficients of each of the equations fitted to the downstream hydraulic geometry data indicates a relatively high correlation (a good fit) of the width and depth data. The highest correlation is determined for the fit of the relation of flow area to discharge. Rationalization implies that as width increases or decreases from the predicted value, depth responds in the opposite direction. Flow area, the product of width and depth, remains near the predicted value. Thus, of measurements of width, depth, and flow area, values of flow area would be the most reliable in predictions of bankfull discharge. Although the product of flow area and velocity is discharge, known values of mean velocity are generally insufficient for the prediction of discharge. The small value of the exponent for velocity, m, reflects only slight dependency of velocity on discharge, and thus the velocity equation has a low correlation coefficient.

CHANNEL GEOMETRY

Much of the analysis of data in this report is based on the assumption that river channels are shaped by, and to accommodate, a dominant discharge. This is analogous to the statement that rivers which nominally transmit little water have small channels and rivers which nominally convey lots of water have large channels. Further, this statement appears more logical than other statements such as rivers which convey lots of water have large drainage areas because the amount of water depends more on the amount of precipitation—and other factors—than on the size of drainage area.

The discharge which appears most pertinent as a dominant discharge is bankfull discharge (Leopold and others, 1964; Wolman and Miller, 1960). Bankfull discharge is defined as that water discharged when stream water just begins to overflow onto the active flood plain; the active flood plain is defined as a flat area adjacent to the channel, constructed by the river, and overflowed by the river at a recurrence interval of about 2 years or a little less (Wolman and Leopold, 1957). Bankfull discharge tends to have a constant frequency of occurrence among rivers, and furthermore discharges equal to a given percentage of bankfull discharge also appear to have a given frequency of occurrence. These characteristics of bankfull discharge have tended to be

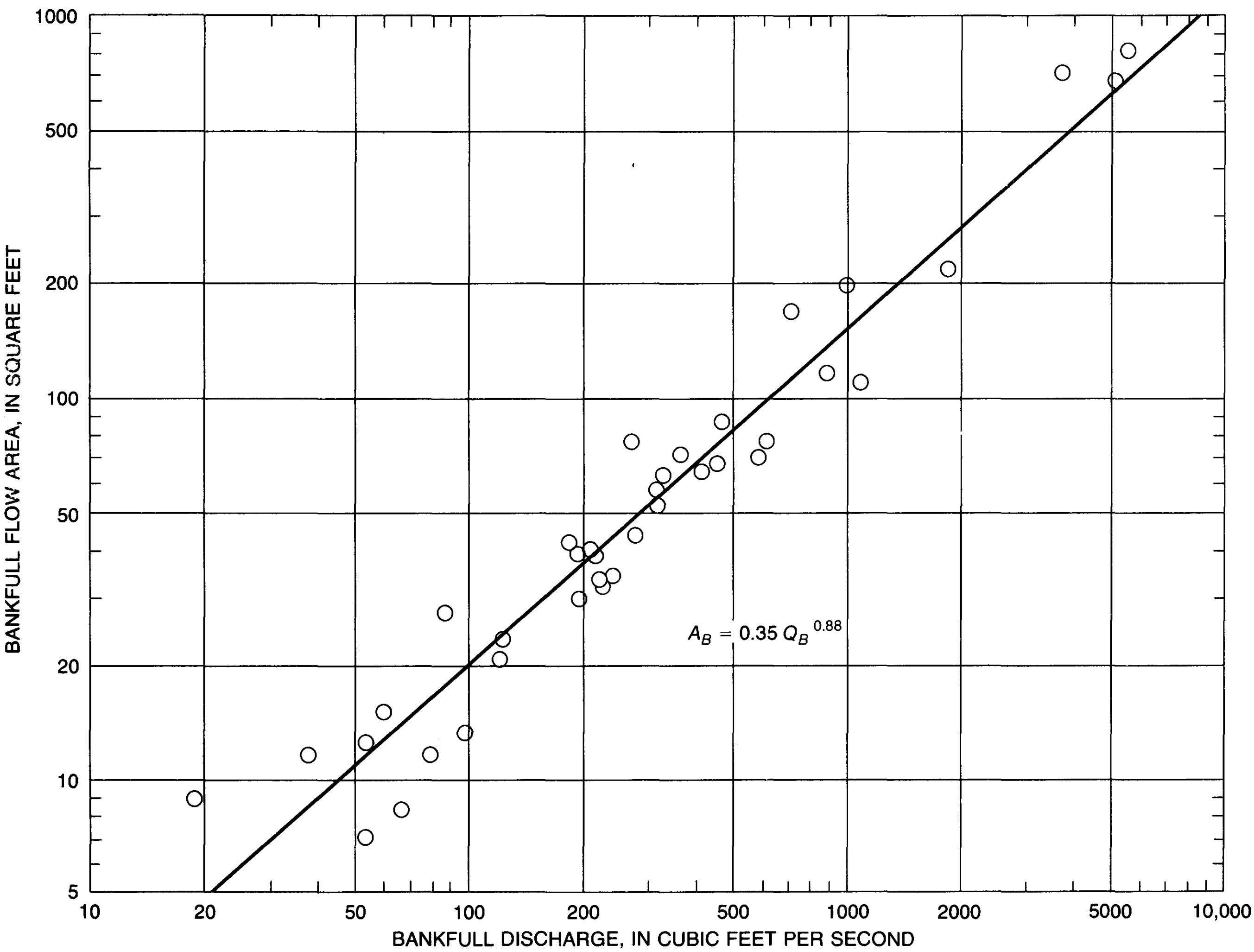

FIGURE 26.—Bankfull flow area as a function of bankfull discharge.

substantiated in the recent literature; see, for examples, Emmett (1972a), Brown (1971), Leopold and Skibitzke (1967), Woodyer (1968), Kilpatrick and Barnes (1964), Dury (1961), and Nixon (1959).

The determination of bankfull discharge for each stream of interest involves field surveys of channel geometry and utilization of stream-gaging data. The technique is transferable to provide approximations of bankfull discharge in ungaged areas. Perhaps the most complete discussion of channel geometry surveys appears in Emmett (1972a), a summary of which follows.

FIELD SURVEYS AND OBSERVATIONS

The principal channel feature involved in the survey of channel geometry is the bankfull stage, or the stage at which the channel just begins to overflow onto the flood plain. Thus, a flood plain on one or both banks is a basic criterion for site selection. The river must be unconfined by rock walls; if terraces exist they must be distinguishable from the active flood plain.

In the upper Salmon River area, the flood plain was often difficult to recognize in the field. Generally because of steep channel gradients and at other locations because of canyonlike confinement, the flood plain along many reaches of stream channel was extremely narrow or absent. At a few locations in the smaller drainage areas surveyed, the channels appeared to carry insufficient volumes of water to construct and maintain a flood plain. When the flood plain is difficult to recognize in the field, other evidence is useful to help distinguish it (Emmett, 1972a). Vegetation on surfaces lower than the flood plain is either absent or annual. On the flood plain, vegetation may be perennial but is generally limited to typical streamside types such as young willow and alder. The higher altitude surfaces, including terraces, support more mature woody vegetation; where trees grow along nearly vertical banks leading to these higher surfaces, the bottom of the tree line is often indicative of the flood plain.

Principal measurements of channel geometry consist of surveying the long profiles of riverbed, water surface, and flood plain. In addition, if terraces and high-water marks exist, the long profiles of these features are also surveyed. The riverbed survey is conducted along the approximate center of the channel for a distance equivalent to about 20 river widths. Sightings are spaced at no greater than one river width apart. This distance and spacing is generally sufficient to average out variability due to pools and riffles and to determine the mean slope for the surveyed reach of river. The water-surface profile is determined at the same time by the rodman's observing the depth of water at each shot location and adding this value to the bed elevation. A similar traverse is conducted downvalley on the flood plain through the same distance. Profiles of terrace and high-water marks are surveyed the same as for the flood plain.

In places where wading was not possible, the riverbed profile was omitted, and water-surface elevations were determined from along one or both banks. All surveying is tied into the gage datum or reference point of the stream-gaging measurements.

In addition to the channel surveys, the particle-size distribution of the bed and bank material is determined. These data are necessary not only for a complete description of the stream channel but are often required in various formulas describing river-channel behavior. Particle-size distribution of bed material from streams with coarse particles is best sampled by pebble counting (Wolman, 1954; Leopold, 1970). A count of 100 particles is taken by pacing a reach of river and randomly picking up a pebble at each step. The intermediate axis of the pebble is measured, and the size distribution is expressed in percentage by number of particles. To obtain greater definition of the finer grained bed material, a bulk sample, excluding coarse particles, from the bed surface is obtained for sieve analysis, and the size distribution is expressed in percentage by weight. The compatibility and collating of data from these two techniques has been discussed by Kellerhals and Bray (1971), but for most purposes the particle-size distribution determined by pebble count is adequate.

Representative samples of bank material are also obtained for sieve analysis. The bank considered for sampling was flood-plain material and was always composed of relatively fine-grained particles. A summary of the bed and bank material particle-size analyses is included in table 13.

TABLE 13.—*Summary of channel-material particle-size analyses*

U.S. Geological Survey station No.	Pebble count of bed material					Sieve analysis	
	d_{16} (mm)	d_{50} (mm)	d_{84} (mm)	d_{50}/d_{16}	d_{84}/d_{50}	Bed fines d_{50} (mm)	Bank d_{50} (mm)
13–2922.00	5.5	20.0	48	3.64	2.40	11.0	0.06
2924.00	6.0	27.5	71	4.58	2.58	8.0	.10
2932.00	4.0	11.0	64	2.75	5.82	2.8	.08
2934.00	4.0	19.0	100	4.75	5.26	.5	.08
2950.00	8.0	30.0	48	3.75	1.60	1.8	.10
2956.50	7.0	30.0	61	4.29	2.03	2.3	.15
2960.00	5.5	28.5	70	5.18	2.46	1.4	.15
2965.00	15.5	58.0	114	3.74	1.97	1.1	.31
2970.00	17.0	40.0	64	2.35	1.60	1.4	.06
2971.00	7.0	27.0	64	3.96	2.37	1.4	.17
2972.50	16.0	43.0	74	2.69	1.72	7.5	3.00
2973.00	6.0	15.5	54	2.58	3.48	2.2	.12
2973.10	11.5	42.0	70	3.65	1.67	1.7	.12
2973.20	11.5	29.0	61	2.52	2.10	2.7	.20
2973.30	13.0	30.5	61	2.35	2.00	2.5	.11
2973.40	11.0	31.0	64	2.82	2.06	1.2	.10
2973.50	9.5	24.0	44	2.53	1.83	.2	.20
2973.60	12.0	37.5	65	3.13	1.73	2.1	.12
2973.80	19.0	56.0	125	2.95	2.23	1.8	.15
2973.84	15.0	52.0	86	3.47	1.65	1.5	3.50
2973.88	8.5	46.0	135	5.41	2.93	3.2	.10
2973.96	17.0	53.0	88	3.12	1.66	.2	.85
2974.00	23.0	51.0	100	2.22	1.96	1.5	.07
2974.04	9.0	27.5	73	3.06	2.65	1.8	3.10
2974.18	13.5	34.0	98	2.52	2.88	1.7	.18
2974.25	15.0	55.0	112	3.67	2.04	1.8	.12
2974.40	2.0	42.0	96	21.00	2.29	1.5	.13
2974.45	5.0	12.0	20	2.40	1.67	4.3	.11
2974.50	9.5	31.0	98	3.26	3.16	4.0	1.90
2974.80	2.5	30.5	64	12.20	2.10	1.7	.43
2974.85	2.5	24.5	46	9.80	1.88	.4	.62
2975.00	14.0	37.5	80	2.68	2.13	.3	.85
2975.30	7.5	19.5	44	2.60	2.26	3.2	.08
2976.00	14.0	37.0	92	2.64	2.49	.5	.13
2976.70	18.5	40.0	63	2.16	1.58	.5	.10
2976.80	5.0	19.0	36	3.80	1.89	3.3	.13
2977.00	5.0	17.5	50	3.50	2.86	.9	.18
2980.00	15.0	41.0	108	2.73	2.63	.2	.09
2985.00	2.0	45.0	114	22.50	2.53	.2	.18
Mean	10.1	33.7	75	3.34	2.23	2.24	.47
Median	9.5	30.5	65	3.21	2.13	1.7	.13

DETERMINATION OF BANKFULL DISCHARGE

The longitudinal profile data from the channel-geometry surveys are plotted on arithmetic coordinate graph paper, and straight-line profiles are drawn through each set of points. These straight lines generally must be parallel for riverbed, water surface, and flood plain, and this criterion is considered when determining the best fit. In determining the best fit, bias or prominence is given to a surface containing the most surveyed points or extending for the greatest length of survey. Where the plotted profiles pass the channel stationing or location of the gage, the gage height corresponding to the elevation of each channel feature can be determined. Of primary interest is the gage height at bankfull stage or the average altitude of the flood plain at the location of the gage. Although only the flood-plain profile is used to determine bankfull stage, usually all profiles, especially the water surface, are instrumental in determining the best-fit line to the flood-plain data.

Bankfull discharge is determined from the stage-discharge relation developed for the station, and as mentioned previously, sufficient data existed to establish stage-discharge relations for each of the 39 primary water-data stations utilized in the present study. With bankfull discharge known, this value is entered in the at-a-station curves of hydraulic geometry, such as figure 22, and bankfull values of surface width, mean depth, and mean velocity may be obtained. These are the bankfull values of the hydraulic parameters given in table 12. As previously noted, the values of the hydraulic parameters given in table 12 and the values of the exponents of hydraulic geometry compiled in table 11 are sufficient to prepare at-a-station curves of hydraulic geometry for each station.

DIMENSIONLESS RATING CURVE

If the at-a-station hydraulic geometry data are expressed as nondimensional ratios to bankfull data, dimensionless curves of at-a-station hydraulic geometry may be expressed as

$$W/W_B=(Q/Q_B)^b,$$
$$D/D_B=(Q/Q_B)^f,$$
$$V/V_B=(Q/Q_B)^m,$$

and

$$A/A_B=(Q/Q_B)^{b+f}.$$

These equations are valid for streams having the same values of b, f, and m or may serve as average equations for the region with values for the exponents of $b=0.14$, $f=0.40$, and $m=0.46$ (table 11).

The foregoing equations may be considered forms of a dimensionless rating curve and, excluding the velocity equation, lend themselves to determination of bankfull discharge for ungaged areas. A single discharge measurement yields values of discharge, surface width, mean depth, and flow area. A channel-geometry survey including cross-section data will supply values of surface width, mean depth, and flow area at bankfull stage. These data are then sufficient to compute values of bankfull discharge from the appropriate equations, using the average values of the hydraulic exponents.

The analysis of downstream hydraulic geometry has indicated that flow area is the channel-geometry parameter most correlative with values of bankfull discharge. Although depth is somewhat less correlative, statistically, than flow area, it perhaps offers a better visual indication of the amount of water in a channel. Figure 27 illustrates the dimensionless rating curves of depth and cross-sectional area of flow to discharge. These curves provide insight to the relations between hydraulic geometry and channel geometry. For exam-

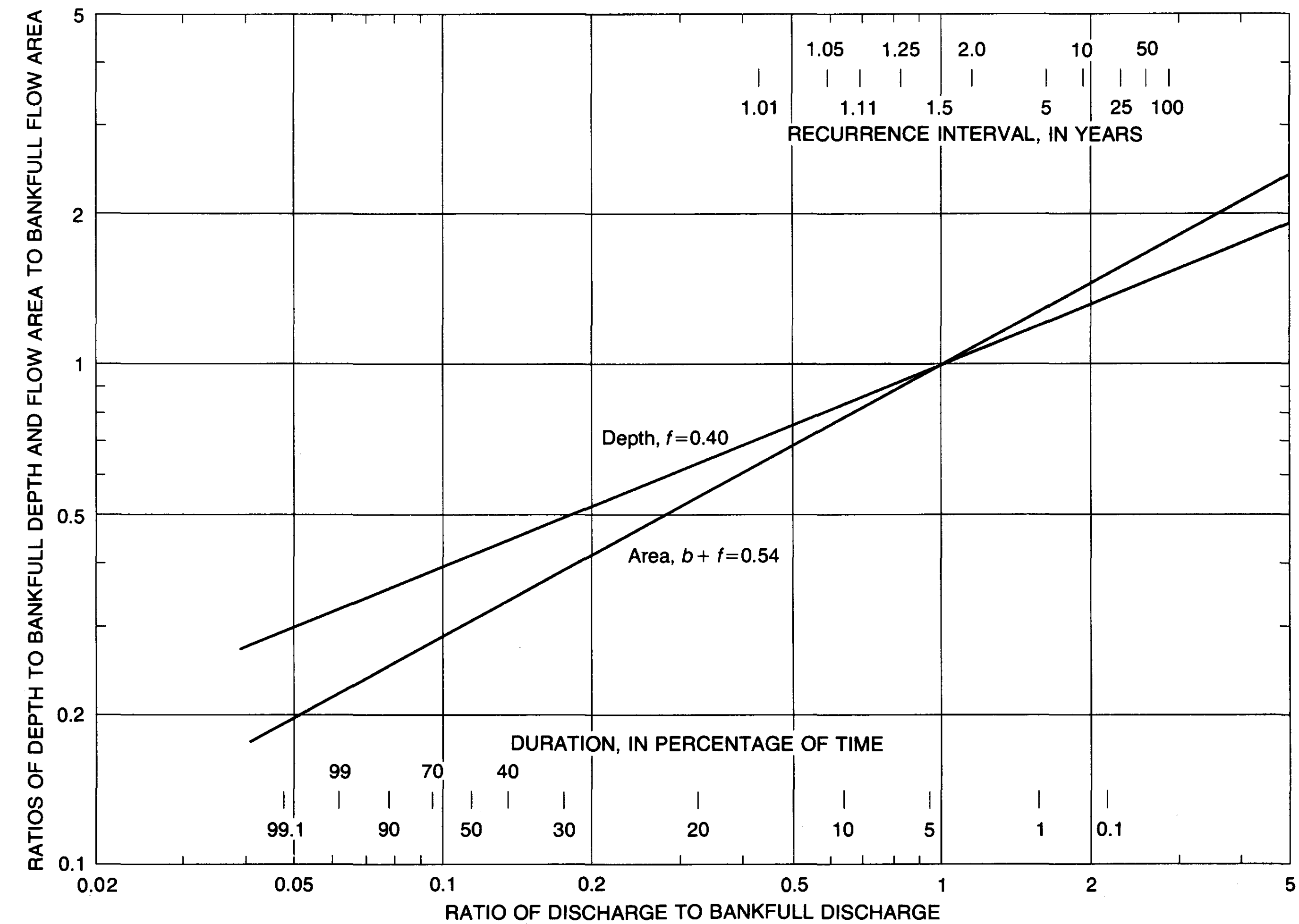

FIGURE 27.—Dimensionless rating curves of depth and flow area as functions of discharge.

ple, at a discharge of 30 percent of bankfull discharge (Q/Q_B=0.3) the channel is 52 percent full (A/A_B=0.52) and is at 62 percent of bankfull depth (D/D_B=0.62).

The dimensionless rating curves are as reliable as the maximum scatter in the values of b and f (table 11). Generally if the value of b is somewhat less than average, the value of f is somewhat greater. Thus, the values of $b+f$ among rivers are somewhat more consistent than f alone, and the flow-area curve of figure 27 may be considered a little more reliable average rating than the depth curve. This is consistent with the downstream hydraulic geometry finding that flow area is the more correlative of the two parameters.

Values of bankfull discharge will be used extensively later in this report. Inaccuracies in determining values of bankfull discharge can occur, and these inaccuracies could affect later analyses involving use of bankfull discharge or the ratio of discharge to bankfull discharge. For example, and especially true for small streams with poor definition of the flood-plain surface, small errors in determination of bankfull stage may give rise to more significant percentage errors in determination of bankfull discharge. Such errors are probably random in occurrence. The use of data from 39 water-data stations provides a large enough sample that mean or median values of any parameter are not greatly affected by random errors in measurement. Thus, relations established between various hydrologic parameters and the dimensionless ratio of discharge to bankfull discharge may be considered valid for the region of study.

FREQUENCY OF FLOWS

Depending on the manner of data collection and the length of record, flow frequency or the recurrence interval between events may be assigned to certain of the water-data stations. In simplicity, flow frequency is determined by arraying the flow events in order of magnitude and assigning the highest probability of recurrence to the median flow and the least probability of recurrence to the highest and lowest flows. A minimum of 10 years of record is desirable for predictions of flow frequency. Generally, flow frequency may be reasonably extrapolated to a recurrence interval of about twice the length of record. Flood frequency is determined by arraying annual peak discharges, and this requires data from continuous-record gaging stations or crest-stage gages.

Within the study area, nine locations meet the criteria of annual peak-discharge tabulation and adequate length of record. The period of record for station 13–2975.00 was extended to 35 years (1926–60) by correlating it with the record for station 13–2965.00, and the period of record for station 13–2980.00 was extended to 32 years (1929–60) by correlating it with the records for stations 13–2965.00 and 13–2985.00. By using data of these stations, values of flow frequency were computed by the log-Pearson method, a technique analogous to the simple definition of flow frequency already given (U.S. Water Resources Council, 1967; Benson, 1968). It is a practice of some hydrologists to modify results of log-Pearson computations (Thomas and others, 1973), but to assure consistency in application, all data in the present report are unmodified. Values of streamflow for various recurrence intervals are given in table 14 for the nine stations. Values of discharge for recurrence intervals greater than the true or synthesized period of record were extended by the log-Pearson method. However, values in this range are not necessarily reliable estimates of rare-event floods and should be considered with caution.

Data of table 14 are plotted in figure 28 to provide flow-frequency curves for the several stations with adequate records. The similar shape of the curves suggests similarity of flow-frequency behavior among stations. Presentation of values of streamflow as values of the ratio of discharge to bankfull discharge reduces

TABLE 14.—*Flow-frequency data: value of discharge at various recurrence intervals for water-data stations with adequate records*

Recurrence interval (yr)	Water-data station No.								
	13–2924.00	13–2925.00	13–2950.00	13–2955.00	13–2960.00	13–2965.00	13–2975.00	13–2980.00	13–2985.00
1.01	66	270	380	1,200	430	1,820	51	710	2,830
1.05	83	330	510	1,610	620	2,490	70	900	3,830
1.11	93	360	590	1,870	750	2,930	83	1,020	4,470
1.25	105	410	700	2,220	940	3,530	100	1,140	5,350
2.0	140	510	960	3,020	1,440	4,930	135	1,400	7,390
5	175	640	1,290	3,990	2,180	6,690	180	1,850	9,920
10	200	720	1,490	4,550	2,690	7,760	210	2,200	11,450
25	230	820	1,730	5,200	3,350	9,010	230	2,750	13,250
50	250	880	1,890	5,640	3,850	9,880	250	3,250	14,500
100	270	950	2,050	6,060	4,370	10,700	270	3,800	15,700
200	290	1,010	2,200	6,440	4,890	11,500	280	4,500	16,800
Mean annual		81	199	664	197	990	----	----	1,470
Bankfull	194	----	1,000	----	712	3,740	221	1,856	5,498

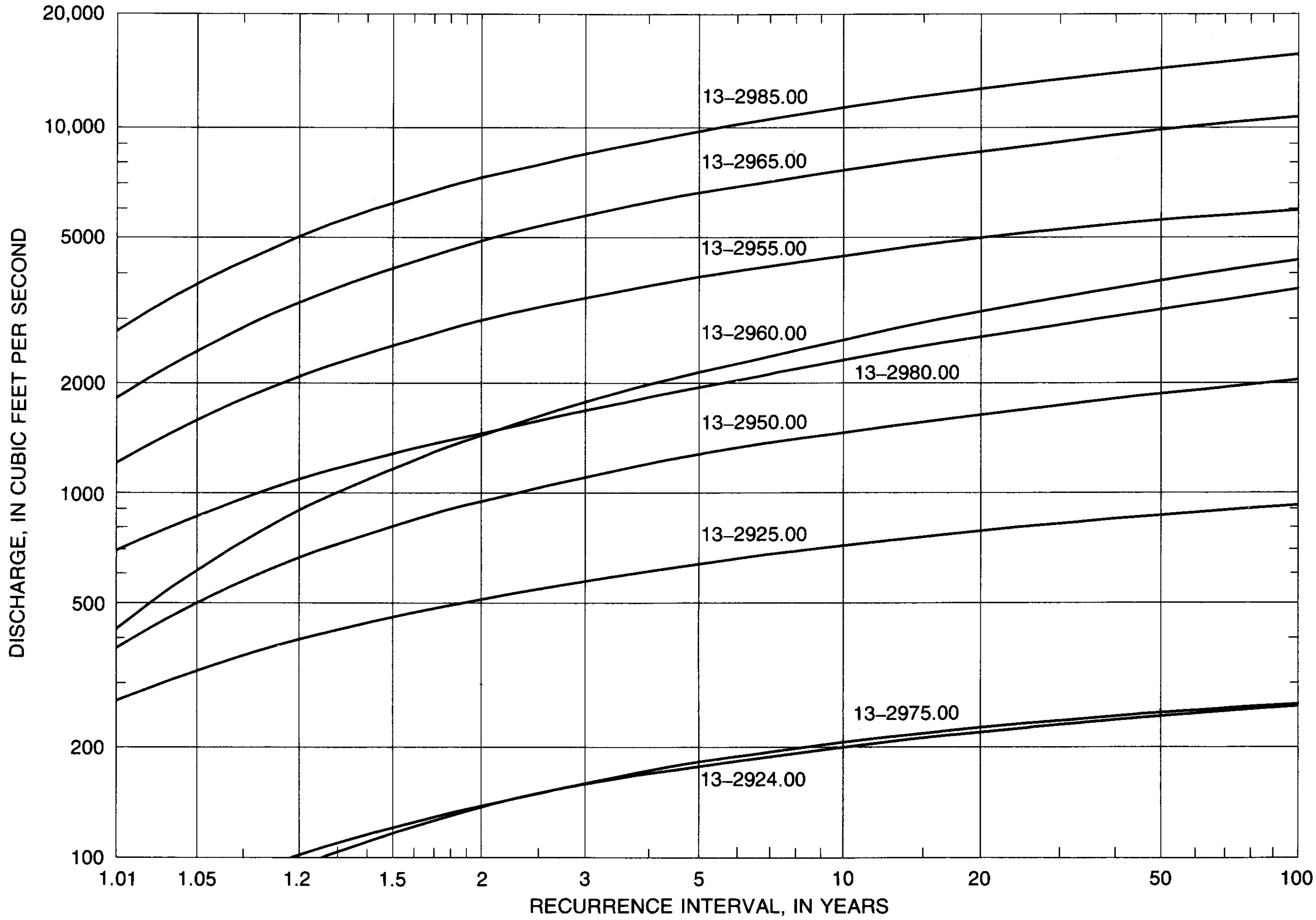

FIGURE 28.—Flow-frequency curves for selected stream-gaging stations in the upper Salmon River area.

the data to a single curve defined by a surprisingly narrow range in values. This procedure is applicable only for those stations with channel-geometry surveys. For additional accuracy, only those stations with more than 10 years of record were considered. For all stations thus analyzed, values of the discharge ratio at selected recurrence intervals and the mean values for all stations are given in table 15. Mean values from the table are plotted in figure 29 and provide an average flow-frequency relation for the area. Data of table 15 are also superposed in figure 27 to provide frequency of occurrence for the regionalized dimensionless rating curves.

The flow-frequency data related to the dimensionless discharge ratio greatly increase streamflow information. It has already been shown that bankfull discharge can be determined for any stream. With bankfull discharge known, flow frequency for any discharge and for any stream may now be approximated. The recurrence interval for bankfull discharge is determined from figure 29 as about 1.5 years. This is in close agreement with the frequency of bankfull discharge reported from other studies (Leopold and others, 1964; Emmett, 1972a).

FLOW DURATION

Flow duration is determined in much the same manner as flow frequency. The values of daily mean discharge are arrayed in order of magnitude, and the number of days of occurrence for each magnitude of flow determines the percentage of time or duration of each flow and the cumulative percentage of time a discharge equals or exceeds a certain value. Data are available only from continuous-record gaging stations and should have a minimum length of record of at least several years to minimize variability due to years of abnormally high or low runoff.

Daily mean discharges adequate to define flow duration are available for seven water-data stations in the area. Values of flow duration and discharge for these stations are given in table 16 and are plotted in figure 30. The curves in figure 30 are not as consistent among stations as are the curves in figure 28, but the probability units on the abscissa of figure 30 greatly

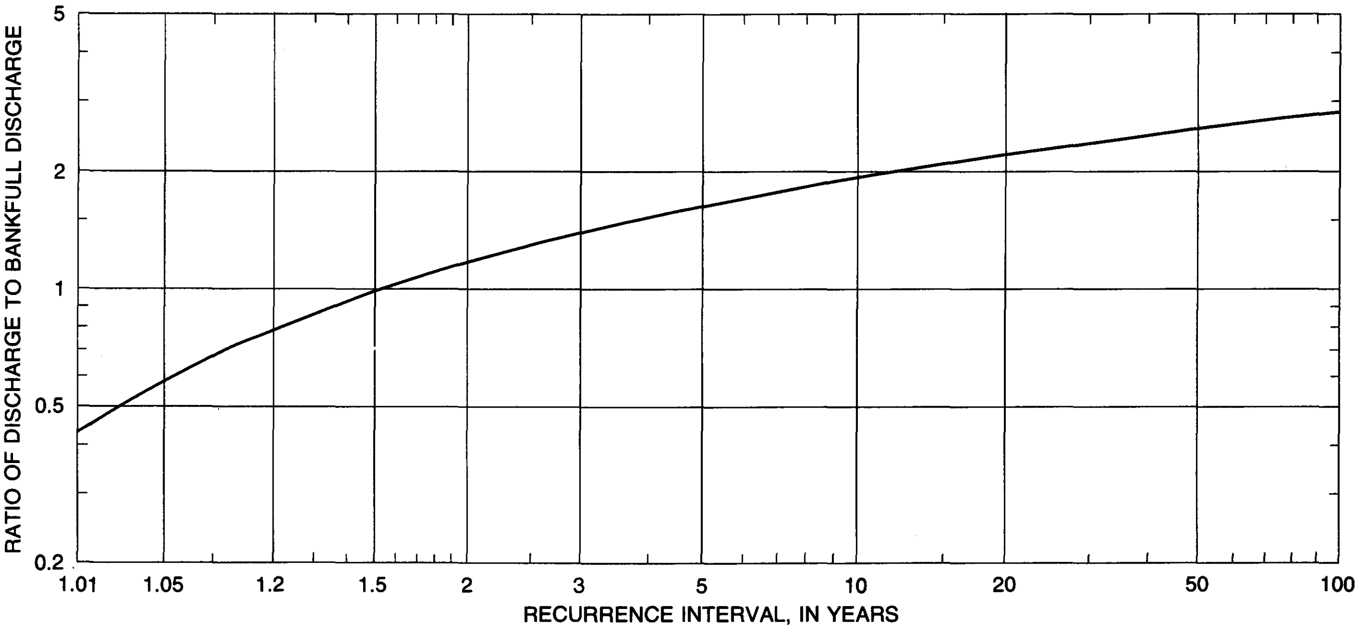

FIGURE 29.—Dimensionless flow-frequency curve for streamflow in the upper Salmon River area.

TABLE 15.—*Flow-frequency data: value of discharge ratio, Q/Q_B, at various recurrence intervals for water-data stations with more than 10 years of record and channel survey available*

Recurrence interval (yr)	Water-data station No.						Mean
	13–2950.00	13–2960.00	13–2965.00	13–2975.00	13–2980.00	13–2985.00	
1.01	0.38	0.60	0.49	0.23	0.38	0.51	0.43
1.05	.51	.87	.67	.32	.48	.70	.59
1.11	.59	1.05	.78	.38	.55	.81	.69
1.25	70	1.32	.94	.45	.61	.97	.83
2.0	.96	2.02	1.32	.61	.75	1.34	1.17
5	1.29	3.06	1.79	.81	1.00	1.80	1.63
10	1.49	3.78	2.07	.95	1.19	2.08	1.93
25	1.73	4.71	2.41	1.04	1.48	2.41	2.30
50	1.89	5.41	2.64	1.13	1.75	2.64	2.58
100	2.05	6.14	2.86	1.22	2.05	2.86	2.86
200	2.20	6.87	3.07	1.27	2.42	3.06	3.15
Mean annual	.20	.28	.26	----	----	.27	.25

exaggerate the duration or abscissa scale. Between flow durations of about 2–98 percent of the time, reasonable consistency exists among the various flow-duration curves.

For stations with channel-geometry surveys available and with at least 10 years of record, table 17 gives values of flow durations and the ratio of discharge to bankfull discharge. The mean values of these data are plotted in figure 31 to provide an average flow-duration curve for the area. The data are also superimposed in figure 27 to designate flow duration on the dimensionless rating curves. Bankfull discharge appears to have a duration of about 4 percent of the time.

Mean annual discharge can be determined from

TABLE 16.—*Flow-duration data: discharge that is equaled or exceeded during percentage of time indicated, for water-data stations with adequate records*

Percentage of time	Water-data station No.						
	13–2925.00	13–2950.00	13–2955.00	13–2960.00	13–2965.00	13–2980.00	13–2985.00
0.1	650	1,300	4,440	2,300	7,500	2,750	11,500
.5	580	1,140	3,700	1,950	6,200	2,000	9,200
1.0	530	1,040	3,250	1,650	5,500	1,600	8,000
2	460	920	2,800	1,350	4,700	1,200	6,800
4	370	770	2,350	960	3,800	850	5,500
6	310	660	2,050	780	3,250	660	4,750
8	270	580	1,800	640	2,900	530	4,150
10	240	510	1,600	540	2,500	440	3,600
14	190	400	1,300	380	2,000	330	2,850
18	130	310	1,030	280	1,500	280	2,200
22	90	240	800	200	1,150	220	1,700
26	60	185	630	150	880	160	1,350
30	50	150	530	115	710	135	1,120
35	45	130	460	92	620	120	980
40	40	115	420	82	560	110	870
45	37	105	400	74	530	100	810
50	34	98	380	68	500	93	750
55	32	93	360	63	470	87	720
60	30	90	340	59	450	82	690
65	28	86	320	55	430	77	660
70	27	82	310	52	410	73	640
75	25	78	300	49	390	69	610
80	24	75	285	46	370	66	580
85	21	71	270	43	360	62	550
90	16	68	255	40	340	59	530
95	8	62	235	36	320	54	490
98	6	56	215	33	290	51	450
99	5	52	195	31	280	49	430
99.5	4	48	155	29	260	47	400
99.9	3	44	125	20	220	33	330

water-data stations with continuous records, and for the available stations the ratio of mean annual discharge to bankfull discharge is 0.25. Actually, values of the ratio range from about 0.20 for smaller drainage areas to 0.27 for larger drainage areas, but within accuracies involved in determination of bankfull discharge and

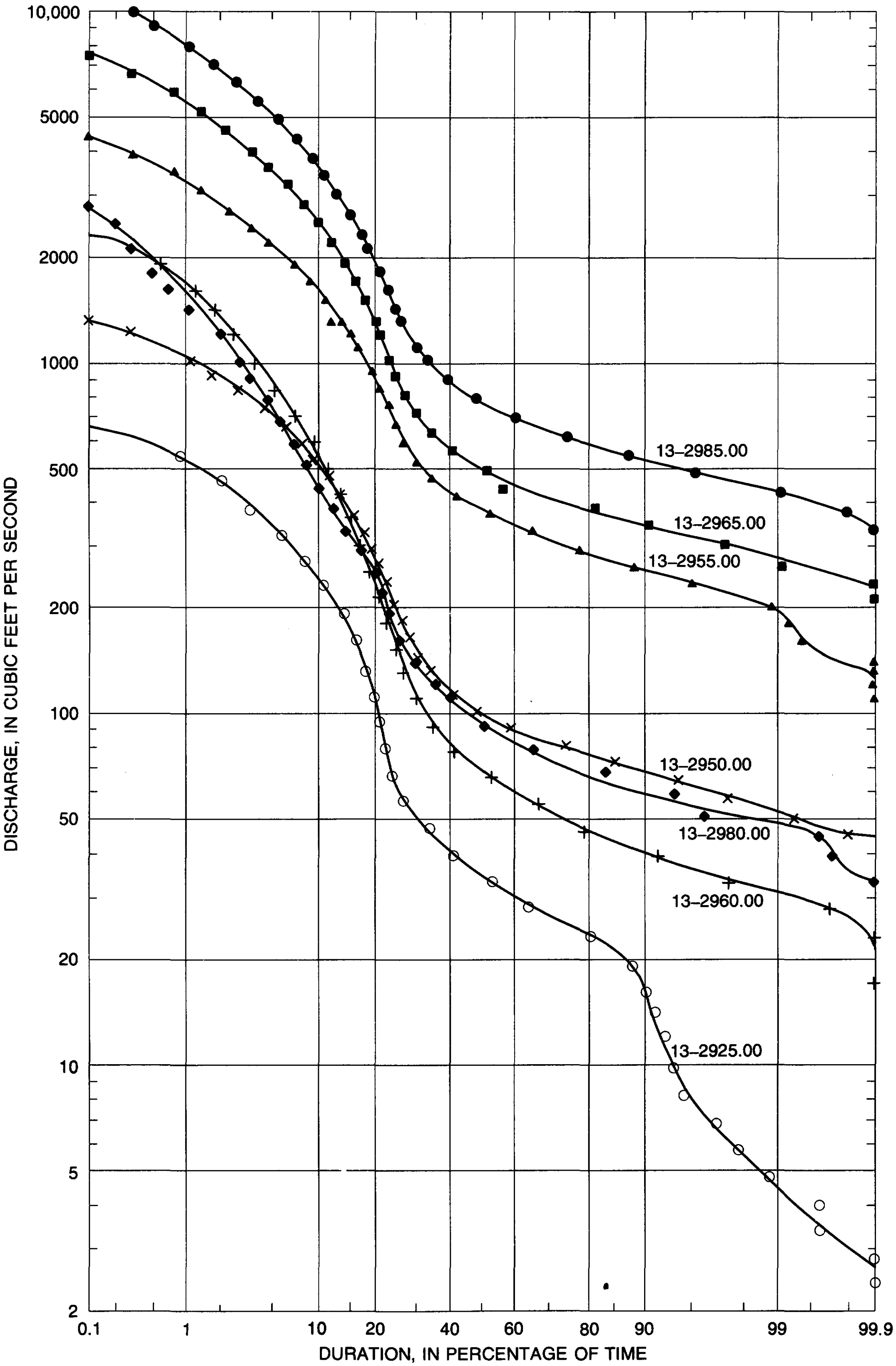

FIGURE 30.—Flow-duration curves for selected stream-gaging stations in the upper Salmon River area.

TABLE 17.—*Flow-duration data: discharge ratio, Q/Q_B, that is equaled or exceeded during percentage of time indicated, for water-data stations with more than 10 years of record and channel survey available*

Percentage of time	13-2950.00	13-2960.00	13-2965.00	13-2985.00	Mean
0.1	1.300	3.230	2.005	2.092	2.157
.5	1.140	2.739	1.668	1.673	1.803
1.0	1.040	2.317	1.471	1.455	1.571
2	.920	1.896	1.257	1.237	1.328
4	.770	1.348	1.016	1.000	1.034
6	.660	1.096	.869	.864	.872
8	.580	.899	.775	.755	.752
10	.510	.758	.668	.655	.648
14	.400	.534	.535	.518	.497
18	.310	.393	.401	.400	.376
22	.240	.281	.307	.309	.284
26	.185	.211	.235	.246	.219
30	.150	.162	.190	.204	.177
35	.130	.129	.166	.178	.151
40	.115	.115	.150	.158	.135
45	.105	.104	.142	.147	.125
50	.098	.096	.134	.136	.116
55	.093	.088	.126	.131	.110
60	.090	.083	.120	.126	.102
65	.086	.077	.115	.120	.100
70	.082	.073	.110	.116	.095
75	.078	.069	.104	.111	.091
80	.075	.065	.099	.105	.086
85	.071	.060	.096	.100	.082
90	.068	.056	.091	.096	.078
95	.062	.051	.086	.089	.072
98	.056	.046	.078	.082	.066
99	.052	.044	.075	.078	.062
99.5	.048	.041	.070	.073	.058
99.9	.044	.028	.059	.060	.048

within limits of available data, it appears appropriate to consider mean annual discharge as about one-fourth of bankfull discharge. Figure 28 indicates that a discharge of this magnitude has a flow duration of about 25 percent, or for approximately one-fourth of the year, streamflow is equal to or greater than the average annual discharge.

The extremes of the flow-duration data presented in table 16 and illustrated in figure 30 are less consistent among stations than is the middle range of data. The cause of the inconsistency is probably related to a number of factors but predominantly is a function of size of drainage area. Small drainage areas are more likely to have flash-flood runoff than large drainage areas and thus have larger values of Q/Q_B at flow durations less than 2 percent. Likewise, the small drainage areas are more likely to nearly dry up at low flow and thus have smaller values of Q/Q_B at flow durations greater than 98 percent. This reasoning is explained by the fact that for a large drainage area to behave as erratically as a small drainage area, all small areas contributing to the large area must be identically and simultaneously acting erratically. The likelihood of this happening is remote. Further, other circumstances may contribute to inconsistent streamflow behavior. For example, a large lake near the downstream end of a small drainage area may sufficiently damp high-flow runoff and contribute to low-flow runoff that overall runoff may be more similar to runoff from a large area than a small area. Adequate leeway in the interpretation of data should be allowed for the variability in behavior from channel to channel. Still, the thesis of this report is based on the concept of a dominant discharge, and this discharge is adjusted to all upstream contributing factors. Thus, the technique not only provides average regionalized relations but also approximates streamflow characteristics for most individual streams.

OTHER STREAMFLOW CHARACTERISTICS

Computer storage and manipulation of streamflow data have greatly shortened analytical time and opened new doors in presentation of streamflow characteristics. One technique now commonly available is determination of the frequency of occurrence of cumulative streamflow events such as consecutive numbers of days of high and low flows. The need for data descriptive of such streamflow characteristics assumes great importance in many management decisions regarding regulatory controls on water use. For examples, the fishery biologist would be concerned with low-flow characteristics as related to in-stream needs of the aquatic biota. The irrigator or reservoir manager might be concerned with high-flow characteristics as related to the availability of water.

Data sufficient to describe such streamflow characteristics are available only from gaging stations with continuous records. Generally, prediction of the frequency of occurrence is limited to a time interval twice the length of record. Thus, a long period of record is a valued asset. Within the study area, four streams have adequate data to define high- and low-flow characteristics. The data are summarized in table 18. Data are grouped by the number of days in the flows. Values of discharge are mean values for the number of consecutive days of that grouping. The recurrence interval is the expected frequency of occurrence for various mean values of discharge.

For selected groupings of data, figure 32 illustrates high- and low-flow characteristics at the gaging station Salmon River near Challis, Idaho (13–2985.00). Explanation of the curves is best accomplished by an example. For a recurrence interval of 2 years, there will be 30 consecutive days of high flow with a mean discharge of about 5,000 cubic feet per second or greater. At the same frequency of occurrence, there will be a 90 consecutive-day period with a mean discharge of about 3,500 cubic feet per second or greater. By contrast, there will be a 90 consecutive-day period of low flow with a mean discharge of 600 cubic feet per second or less and a 30-day low flow with a mean discharge of 550 cubic feet per second or less.

Because a recurrence interval of 2 years represents an every-other-year, or average, characteristic (half the years will be higher, half will be lower), the curves of 365-day high and low flow must cross at this recurrence

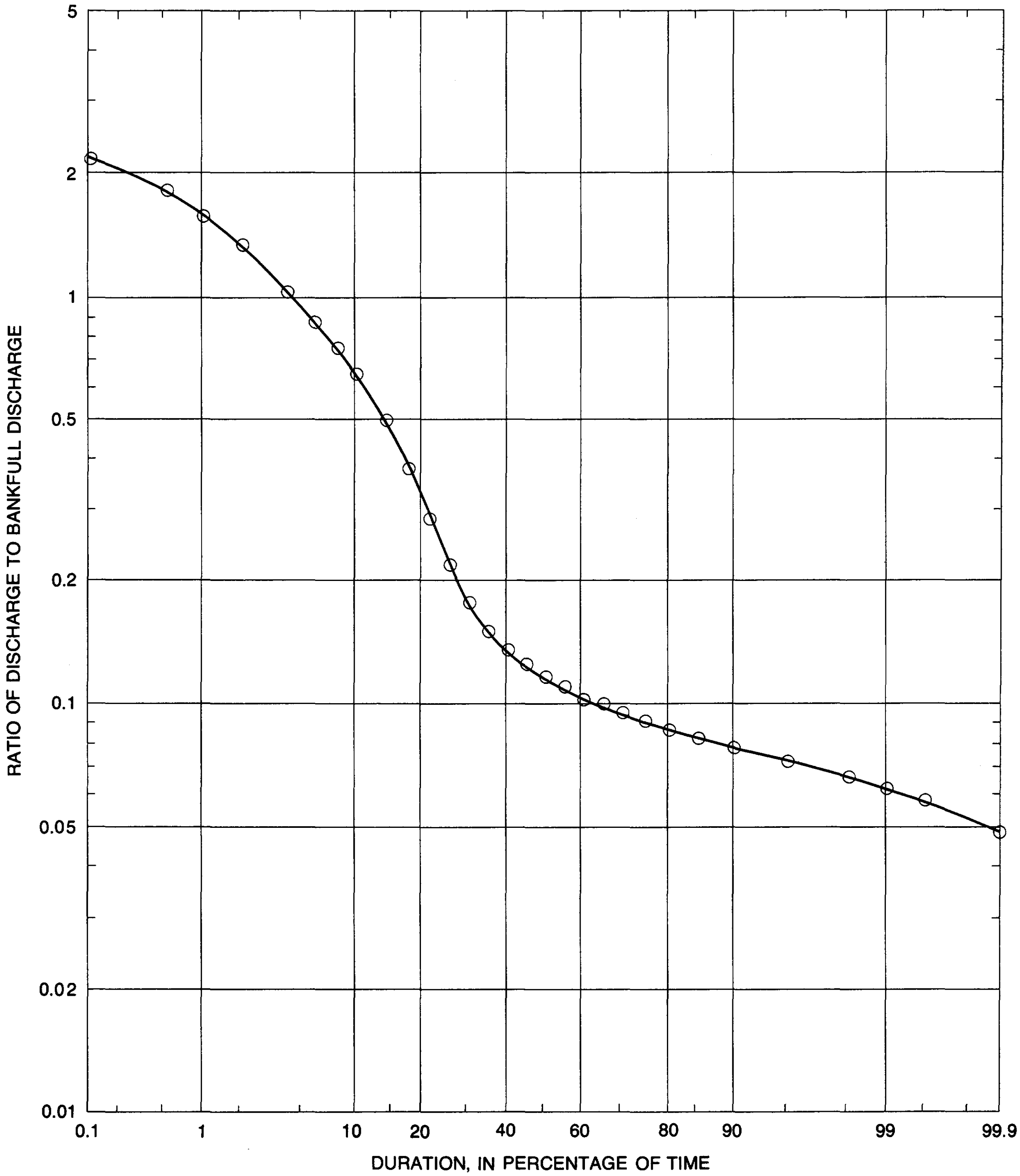

FIGURE 31.—Dimensionless flow-duration curve for streamflow in the upper Salmon River area.

interval, and the value of discharge represents the mean annual value.

Preparation of curves similar to figure 32 for the other stations of record indicated that presentation of data on a dimensionless discharge basis would yield a single set of curves valid for all locations in the study area. The curves would be analogous to the dimensionless flow-frequency curve in figure 29 which utilizes annual peak discharges.

Values of discharge in table 18 may be transformed to the dimensionless ratio discharge to bankfull discharge, and these values are given in table 19.

DIMENSIONLESS HIGH-FLOW CHARACTERISTICS

Mean values of the high-flow characteristics from table 19 are given in table 20 and plotted in figure 33 to provide dimensionless curves of high-flow characteristics for stream channels in the upper Salmon River

TABLE 18.—*High- and low-flow characteristics: value of discharge for given number of consecutive days at various recurrence intervals*

[Significant figures for values of discharge taken from computer analysis]

A. High flow

Recurrence interval (yr)	1 day	3 days	7 days	15 days	30 days	90 days	365 days
Salmon River near Challis (13–2985.00)							
1.01	2,770	2,708	2,538	2,356	2,231	1,583	821
1.05	3,703	3,588	3,357	3,075	2,861	1,992	950
1.11	4,299	4,150	3,882	3,536	3,260	2,250	1,030
1.25	5,124	4,929	4,611	4,179	3,811	2,605	1,140
2	7,060	6,764	6,337	5,719	5,109	3,438	1,400
5	9,538	9,134	8,586	7,764	6,800	4,523	1,740
10	11,077	10,619	10,006	9,082	7,873	5,213	1,970
25	12,919	12,411	11,730	10,708	9,185	6,060	2,240
50	14,224	13,691	12,969	11,895	10,134	6,675	2,450
100	15,479	14,929	14,174	13,063	11,063	7,278	2,660
200	16,696	16,138	15,355	14,223	11,979	7,876	2,860
Salmon River below Yankee Fork (13–2965.00)							
1.01	1,807	1,774	1,647	1,505	1,444	1,031	522
1.05	2,460	2,399	2,238	2,039	1,913	1,345	625
1.11	2,877	2,799	2,617	2,382	2,210	1,541	687
1.25	3,456	3,352	3,143	2,857	2,617	1,806	770
2	4,806	4,645	4,374	3,975	3,558	2,404	955
5	6,512	6,285	5,936	5,402	4,739	3,131	1,180
10	7,555	7,292	6,896	6,284	5,462	3,564	1,317
25	8,786	8,485	8,035	7,334	6,316	4,066	1,478
50	9,647	9,323	8,833	8,075	6,915	4,412	1,592
100	10,645	10,122	9,595	8,783	7,486	4,738	1,701
200	11,250	10,892	10,328	9,468	8,036	5,048	1,806
Yankee Fork (13–2960.00)							
1.01	425	393	363	329	308	200	83
1.05	603	565	520	471	435	279	108
1.11	724	682	626	567	518	330	123
1.25	901	852	780	705	637	400	143
2	1,355	1,284	1,172	1,056	930	567	190
5	2,010	1,897	1,728	1,550	1,324	777	247
10	2,457	2,308	2,100	1,878	1,578	905	282
25	3,032	2,828	2,573	2,292	1,890	1,056	322
50	3,465	3,214	2,924	2,198	2,116	1,160	350
100	3,902	3,599	3,274	2,901	2,336	1,259	378
200	4,344	3,985	3,626	3,205	2,552	1,354	404
Valley Creek (13–2950.00)							
1.01	381	367	339	302	286	216	106
1.05	497	476	441	398	372	278	126
1.11	570	544	506	459	426	316	139
1.25	671	637	594	542	499	368	155
2	903	853	800	736	668	484	192
5	1,194	1,126	1,062	980	878	625	236
10	1,372	1,295	1,225	1,129	1,006	709	264
25	1,583	1,495	1,420	1,306	1,157	807	296
50	1,731	1,638	1,559	1,431	1,263	874	319
100	1,873	1,775	1,692	1,551	1,364	938	341
200	2,010	1,907	1,823	1,666	1,461	999	362

B. Low flow

Recurrence interval (yr)	1 day	3 days	7 days	14 days	30 days	90 days	365 days
Salmon River near Challis (13–2985.00)							
1.01	585	591	648	680	704	763	2,649
1.02	566	578	635	667	691	748	2,462
1.04	544	563	619	651	675	730	2,269
1.11	509	537	592	623	648	700	2,000
1.25	476	510	564	595	620	669	1,777
2	413	453	505	536	561	604	1,415
5	351	391	440	471	497	534	1,127
10	320	358	406	436	462	495	1,001
20	296	331	377	407	433	463	907
100	252	281	323	353	378	404	754
Salmon River below Yankee Fork (13–2965.00)							
1.01	423	418	436	461	488	523	1,707
1.02	414	413	431	453	477	510	1,606
1.04	403	406	425	443	463	495	1,498
1.11	383	391	411	425	440	471	1,339
1.25	362	374	393	405	417	446	1,201
2	314	329	347	357	368	394	963
5	260	273	289	301	314	339	760
10	232	242	254	270	286	310	668
20	208	215	226	244	263	286	598
100	166	167	174	196	220	242	482

TABLE 18.—*High- and low-flow characteristics: value of discharge for given number of consecutive days at various recurrence intervals*—Con.

B. Low flow—Continued

Recurrence interval (yr)	1 day	3 days	7 days	15 days	30 days	90 days	365 days
Yankee Fork (13–2960.00)							
1.01	48	46	52	53	56	60	387
1.02	48	46	50	52	54	58	358
1.04	47	45	49	50	52	57	327
1.11	46	45	46	47	49	53	283
1.25	43	43	43	44	46	50	247
2	36	37	38	39	41	44	187
5	25	28	32	33	35	38	140
10	20	23	29	30	32	35	119
20	16	18	27	28	30	32	104
100	9	11	22	24	25	28	80
Valley Creek (13–2950.00)							
1.01	87	90	95	101	104	116	334
1.02	84	87	91	96	99	110	315
1.04	80	83	87	92	94	104	294
1.11	74	77	81	84	87	95	264
1.25	69	72	75	78	81	88	238
2	59	61	63	66	69	76	193
5	50	52	53	54	58	66	154
10	46	47	48	49	53	61	137
20	42	43	44	45	49	57	124
100	36	36	36	37	42	51	101

area. Interpretation of the curves in figure 33 is the same as for the station curves in figure 32; however, it should be remembered that the curves in figure 33 are average curves for the area, and thus individual streams may deviate somewhat from the average. It may be noted that the 365-day high-flow curve for the average year has a discharge ratio value of about 0.25. This value of discharge ratio corresponds to the value at mean annual discharge and is in agreement with an earlier determination of the mean annual discharge being approximated by a discharge ratio of 0.25.

The number of available water-data stations contributing to the information presented in figure 33 is less than the number of available stations contributing to the dimensionless peak-flow frequency relation in figure 29. This difference in number of stations does not affect the concepts of analysis but does provide slight inconsistencies in results. For example, the curve in figure 29 indicates that instantaneous bankfull discharge has a frequency of occurrence of about 1.5 years. However, figure 33 indicates that 1-day bankfull discharge (a slightly rarer event than instantaneous bankfull discharge) has a frequency of occurrence of about 1.3 years. Such inconsistencies are sufficiently minor that it is justified to use all available data for any given analysis rather than a select set of data common to all analyses.

DIMENSIONLESS LOW-FLOW CHARACTERISTICS

In the same manner as for high-flow characteristics, dimensionless values of discharge for low-flow characteristics are given in table 21, and mean values are

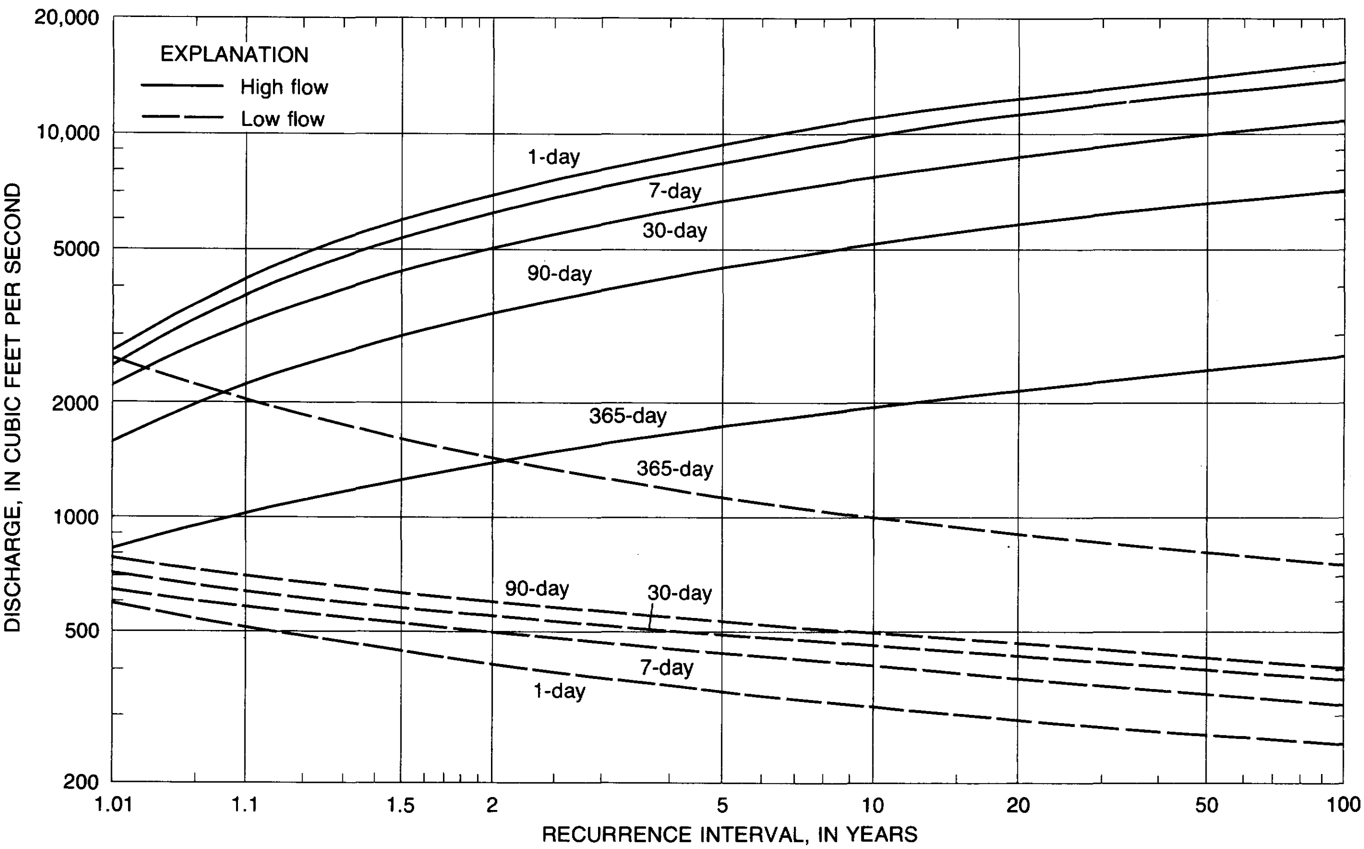

FIGURE 32.—High- and low-flow characteristics, Salmon River near Challis, Idaho.

plotted in figure 34. The 365-day low-flow curve, which represents the annual mean values of discharge, again shows a value of mean annual discharge ratio of about 0.25 at a recurrence interval of 2 years. The 365-day low-flow curve is the inverse of the 365-day high-flow curve, and either of these curves can be utilized to illustrate some average characteristics of runoff. For example, at a 100-year recurrence interval, maximum daily mean discharge will be at least 3.2 times as large as bankfull discharge. There will be a 30 consecutive-day period with a mean discharge at least 2.2 times as large as bankfull discharge, a 90 consecutive-day period with a discharge ratio of about 1.3 or larger, and a maximum mean annual discharge about 40 percent of bankfull discharge. Likewise at the same 100-year recurrence interval, the lowest daily mean discharge is about 3.5 percent of bankfull discharge. The mean value of discharge for 30 consecutive days is less than 5.1 percent of bankfull, for 90 consecutive days is less than 5.7 percent of bankfull, and the lowest mean annual discharge is about 12 percent of bankfull discharge.

SUMMARY DISCUSSION OF STREAMFLOW DATA

Discharge measurements made at 39 locations were sufficient to define streamflow-rating curves for each station and allowed preparation of at-a-station hydraulic-geometry curves of surface width, mean depth, and mean velocity as functions of discharge. Channel-geometry surveys allowed determination of bankfull discharge; bankfull values of the other hydraulic- and channel-geometry parameters were determined from the at-a-station curves. These bankfull values when plotted as functions of bankfull discharge constitute downstream curves of hydraulic geometry and, in essence, allow the prediction of bankfull discharge for any measured values of bankfull width, depth, or flow area.

Alternative to this presentation (figs. 23–26), bankfull values of the hydraulic- and channel-geometry parameters may be plotted against size of drainage area, which itself may be considered a measure of downstream location. Figure 35 illustrates bankfull discharge as a function of drainage area, and figure 36 shows the same data expressed as a unit discharge or runoff, R, in cubic feet per second per square mile. Values of the other hydraulic parameters are shown as functions of drainage area in figures 37–40. Comparison of these figures with the similar downstream curves of hydraulic geometry indicates one significant fact. This is that the scatter of data is less in the downstream

TABLE 19.—*High- and low-flow characteristics: value of discharge ratio,* Q/Q_B*, for given number of consecutive days at various recurrence intervals*

A. High flow

Recurrence interval (yr)	1 day	3 days	7 days	15 days	30 days	90 days	365 days
Salmon River near Challis (13–2985.00)							
1.01	0.504	0.493	0.462	0.429	0.406	0.288	0.149
1.05	.674	.653	.611	.559	.520	.362	.173
1.11	.782	.755	.706	.643	.593	.409	.187
1.25	.932	.897	.839	.760	.693	.474	.207
2	1.284	1.267	1.153	1.040	.929	.625	.255
5	1.735	1.661	1.562	1.412	1.237	.823	.316
10	2.015	1.931	1.820	1.652	1.432	.948	.358
25	2.350	2.257	2.136	1.918	1.671	1.102	.407
50	2.587	2.490	2.359	2.164	1.843	1.214	.446
100	2.815	2.715	2.578	2.376	2.012	1.324	.484
200	3.037	2.935	2.793	2.587	2.179	1.433	.520
Salmon River below Yankee Fork (13–2965.00)							
1.01	0.483	0.474	0.440	0.402	0.386	0.276	0.140
1.05	.658	.641	.598	.545	.511	.360	.167
1.11	.769	.748	.700	.637	.591	.412	.184
1.25	.924	.896	.840	.764	.670	.483	.206
2	1.285	1.242	1.170	1.063	.951	.643	.255
5	1.741	1.680	1.587	1.444	1.267	.837	.316
10	2.020	1.950	1.844	1.686	1.460	.953	.352
25	2.349	2.269	2.148	1.961	1.689	1.087	.395
50	2.579	2.493	2.362	2.159	1.849	1.180	.426
100	2.798	2.706	2.566	2.348	2.002	1.267	.455
200	3.008	2.912	2.761	2.532	2.149	1.350	.483
Yankee Fork (13–2960.00)							
1.01	0.597	0.552	0.510	0.462	0.432	0.281	0.117
1.05	.847	.794	.730	.662	.611	.392	.152
1.11	1.017	.958	.879	.796	.728	.463	.173
1.25	1.265	1.197	1.096	.990	.895	.562	.201
2	1.903	1.803	1.646	1.483	1.306	.796	.267
5	2.823	2.664	2.427	2.177	1.860	1.091	.347
10	3.451	3.242	2.949	2.638	2.216	1.271	.396
25	4.258	3.972	3.614	3.219	2.654	1.483	.452
50	4.867	4.514	4.107	3.649	2.972	1.629	.492
100	5.480	5.055	4.598	4.074	3.281	1.768	.531
200	6.101	5.597	5.093	4.501	3.584	1.901	.567
Valley Creek (13–2950.00)							
1.01	0.381	0.367	0.339	0.302	0.286	0.216	0.106
1.05	.497	.476	.441	.398	.372	.278	.126
1.11	.570	.544	.506	.459	.426	.316	.139
1.25	.671	.637	.594	.542	.499	.368	.155
2	.903	.853	.800	.736	.668	.484	.192
5	1.194	1.126	1.062	.980	.878	.675	.236
10	1.372	1.295	1.225	1.129	1.006	.709	.264
25	1.583	1.495	1.420	1.306	1.157	.807	.296
50	1.731	1.638	1.559	1.431	1.263	.874	.319
100	1.873	1.775	1.692	1.551	1.364	.938	.341
200	2.010	1.907	1.823	1.666	1.461	.999	.362

B. Low flow

Recurrence interval (yr)	1 day	3 days	7 days	14 days	30 days	90 days	365 days
Salmon River near Challis (13–2985.00)							
1.01	0.106	0.107	0.118	0.124	0.128	0.139	0.482
1.02	.103	.105	.115	.121	.126	.136	.448
1.04	.099	.102	.113	.118	.123	.133	.413
1.11	.093	.098	.108	.113	.118	.127	.364
1.25	.087	.093	.103	.108	.113	.122	.323
2	.025	.082	.092	.097	.102	.110	.257
5	.064	.071	.080	.086	.090	.097	.205
10	.058	.065	.074	.079	.084	.090	.182
20	.054	.060	.069	.074	.079	.084	.165
100	.046	.051	.059	.064	.069	.073	.137
Salmon River below Yankee Fork (13–2965.00)							
1.01	0.113	0.112	0.117	0.123	0.130	0.140	0.456
1.02	.111	.110	.115	.121	.128	.136	.429
1.04	.108	.109	.114	.118	.124	.132	.401
1.11	.102	.105	.110	.113	.118	.126	.358
1.25	.097	.100	.105	.108	.111	.119	.321
2	.084	.088	.093	.095	.098	.105	.257
5	.070	.073	.077	.080	.084	.091	.203
10	.062	.068	.068	.072	.076	.083	.179
20	.056	.074	.060	.065	.070	.076	.160
100	.044	.047	.046	.052	.059	.065	.129

TABLE 19.—*High- and low-flow characteristics: value of discharge ratio,* Q/Q_B*, for given number of consecutive days at various recurrence intervals*—Continued

B. Low flow—Continued

Recurrence interval (yr)	1 day	3 days	7 days	15 days	30 days	90 days	365 days
Yankee Fork (13–2960.00)							
1.01	0.067	0.065	0.073	0.074	0.079	0.084	0.544
1.02	.067	.065	.070	.073	.076	.081	.502
1.04	.066	.063	.069	.070	.073	.080	.459
1.11	.065	.063	.065	.066	.069	.074	.397
1.25	.060	.060	.060	.062	.065	.070	.347
2	.051	.052	.053	.055	.058	.062	.263
5	.035	.039	.045	.046	.049	.053	.197
10	.028	.032	.041	.042	.045	.049	.167
20	.022	.025	.038	.039	.042	.045	.146
100	.013	.015	.031	.034	.035	.039	.112
Valley Creek (13–2950.00)							
1.01	0.087	0.090	0.095	0.101	0.104	0.116	0.334
1.02	.084	.087	.091	.096	.099	.110	.315
1.04	.080	.083	.087	.092	.094	.104	.294
1.11	.074	.077	.081	.084	.087	.095	.264
1.25	.069	.072	.075	.078	.081	.088	.238
2	.059	.061	.063	.066	.069	.076	.193
5	.050	.052	.053	.054	.058	.066	.154
10	.046	.047	.048	.049	.053	.061	.137
20	.042	.043	.044	.045	.049	.057	.124
100	.036	.036	.036	.037	.049	.051	.101

TABLE 20.—*High-flow characteristics: mean value of discharge ratio,* Q/Q_B*, for given number of consecutive days at various recurrence intervals for water-data stations with more than 10 years of record and channel survey available*

Recurrence interval (yr)	1 day	3 days	7 days	15 days	30 days	90 days	365 days
1.01	0.491	0.472	0.438	0.399	0.378	0.265	0.128
1.05	.669	.641	.595	.541	.504	.348	.155
1.11	.785	.751	.698	.634	.585	.400	.171
1.25	.948	.907	.842	.764	.689	.472	.192
2	1.344	1.291	1.192	1.081	.964	.637	.242
5	1.873	1.783	1.660	1.503	1.211	.844	.304
10	2.215	2.105	1.960	1.775	1.529	.970	.343
25	2.635	2.498	2.330	2.101	1.793	1.120	.388
50	2.941	2.784	2.597	2.351	1.982	1.224	.421
100	3.242	3.063	2.859	2.587	2.165	1.324	.453
200	3.539	3.338	3.118	2.822	2.343	1.421	.483

TABLE 21.—*Low-flow characteristics: mean value of discharge ratio,* Q/Q_B*, for given number of consecutive days of various recurrence intervals for water-data stations with more than 10 years of record and channel survey available*

Recurrence interval (yr)	1 day	3 days	7 days	14 days	30 days	90 days	365 days
1.01	0.093	0.094	0.101	0.106	0.110	0.120	0.454
1.02	.091	.092	.098	.103	.108	.116	.424
1.04	.088	.090	.096	.100	.104	.112	.392
1.11	.084	.086	.091	.094	.098	.106	.346
1.25	.078	.081	.086	.089	.093	.100	.307
2	.070	.071	.075	.078	.082	.088	.243
5	.055	.059	.064	.067	.070	.077	.190
10	.049	.053	.058	.061	.065	.071	.166
20	.044	.051	.053	.056	.060	.066	.149
100	.035	.037	.043	.047	.051	.057	.120

curves of hydraulic geometry than in the curves relating to size of drainage area. Several data points in figures 37–40 consistently account for the largest scatter in data, and these are data from the Road Creek basin (stations 13–2976.70 to 13–2977.00). The expla-

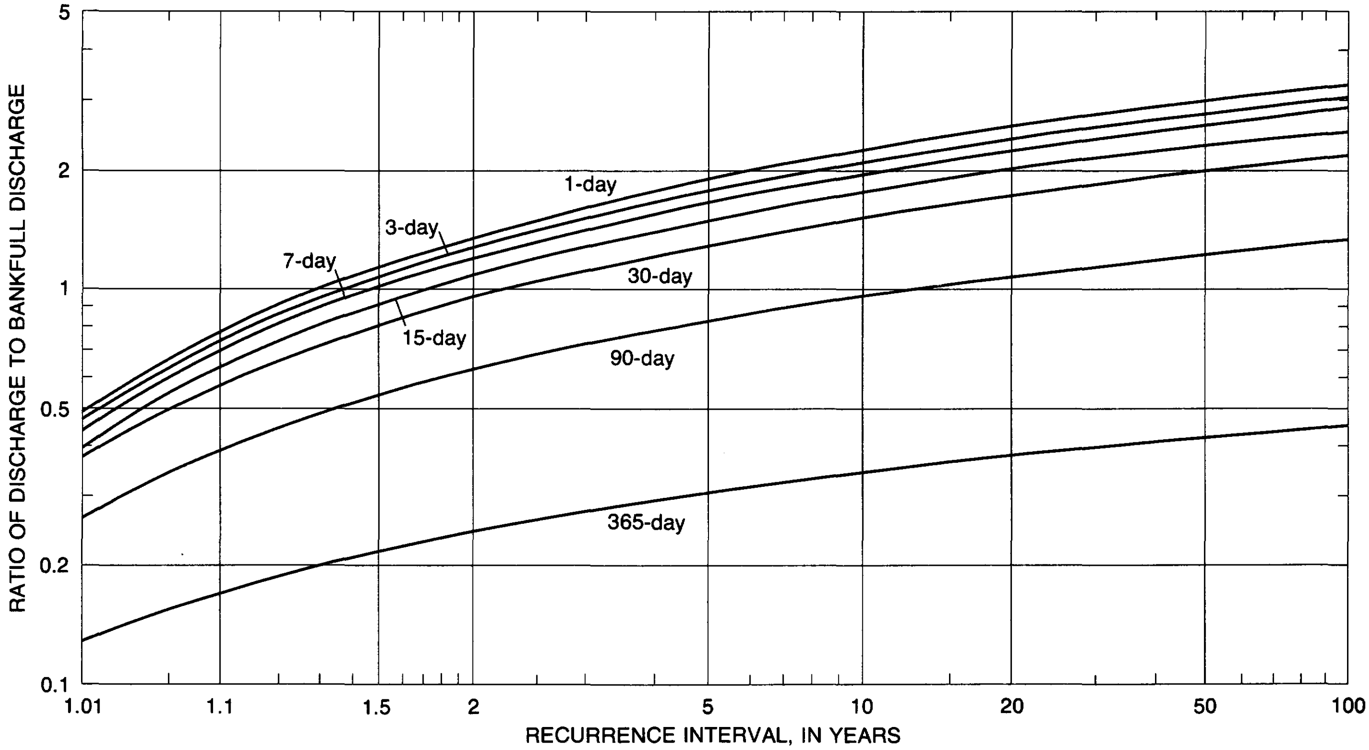

FIGURE 33.—High-flow characteristics for upper Salmon River area.

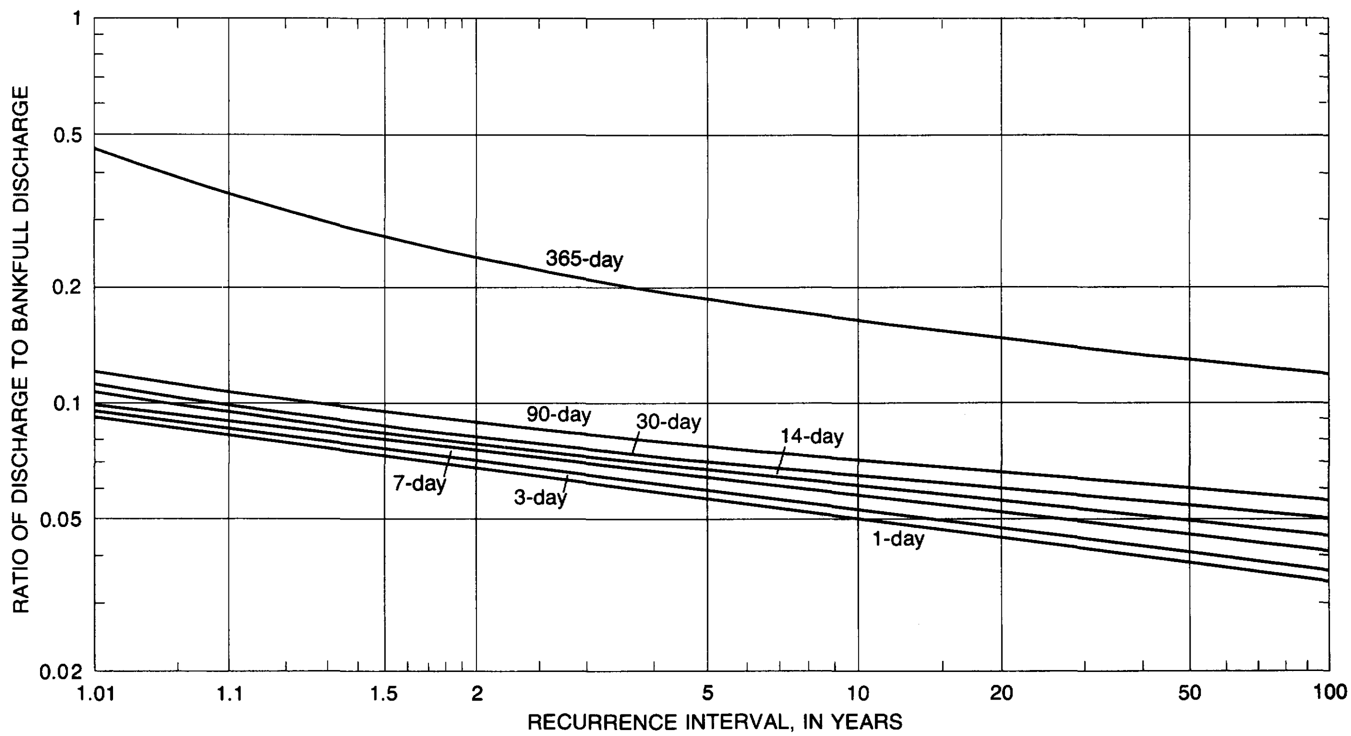

FIGURE 34.—Low-flow characteristics for upper Salmon River area.

nation is that this basin is wholly in the extreme northeast part of the study area and receives much lower amounts of precipitation than other areas. The result is significantly lower values of runoff, and this is reflected in the graphs of figures 37–40. Stream channels in this area of lower runoff are still dependent on a dominant discharge for their size and shape. Because of the lower runoff, the channel size is smaller,

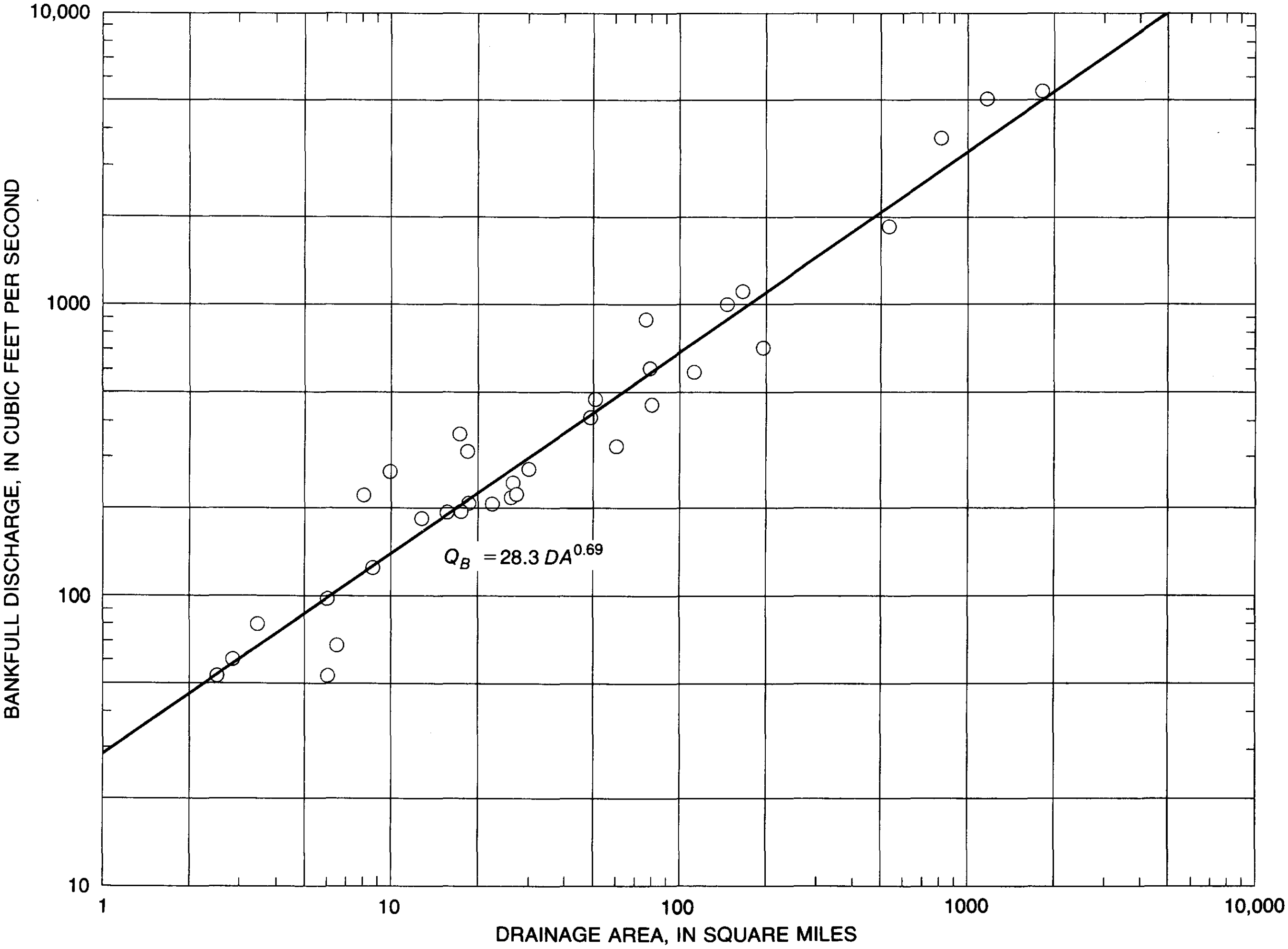

FIGURE 35.—Bankfull discharge as a function of drainage area.

and this is illustrated by the several data points which plot low in the figures.

Because the hydraulic- and channel-geometry parameters are plotted against dominant discharge (bankfull discharge) in the downstream curves of hydraulic geometry, a scatter to the data because of the reasons just discussed does not occur in the graphs of figures 23–26. It appears then that the size of the stream channel is a more accurate measure of bankfull discharge than is the size of drainage area, and this fact further reinforces the concepts of channel geometry and bankfull discharge as used in this paper.

Excluding the Road Creek basin data, log-transformed regression equations were fitted to the data of figures 35–40. The equations and their respective correlation coefficients are

$$W_B=8.1\ DA^{0.38} \quad (r=0.844),$$

$$D_B=0.69\ DA^{0.27} \quad (r=0.879),$$

$$A_B=5.6\ DA^{0.65} \quad (r=0.924),$$

$$V_B=5.1\ DA^{0.05} \quad (r=0.324),$$

$$Q_B=28.3\ DA^{0.69} \quad (r=0.959),$$

or

$$R_B=28.3\ DA^{-0.31} \quad (r=0.831).$$

Data other than the Road Creek basin data fit these equations fairly well and indicate that other than in the northeast corner of the study area, physiographic factors are sufficiently homogeneous to allow drainage area to be correlative with other hydraulic- and channel-geometry parameters. But this statement does not override the fact that for any drainage area and physiographic setting, channel size is a better determinant of discharge than drainage area size.

Exponents in the foregoing equations indicate the rate of increase in the various parameters as size of drainage area increases. Because the product of width, depth, and velocity is discharge, the rate of increase of the three individual parameters as functions of discharge (downstream hydraulic geometry) is in about the same ratio as their rate of increase as functions of drainage area size.

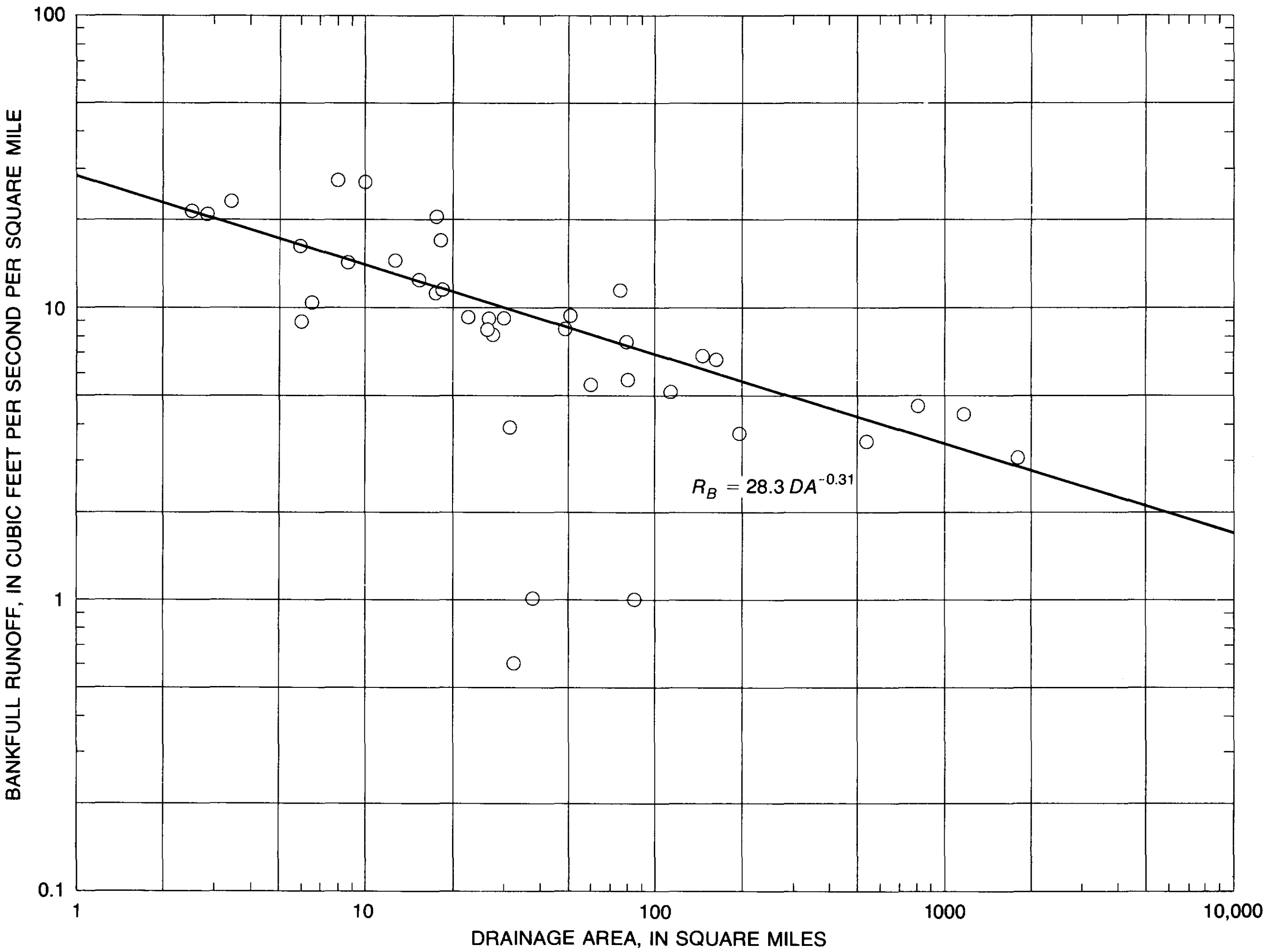

FIGURE 36.—Bankfull runoff as a function of drainage area.

Within the study area, seven current and discontinued gaging stations provide records to determine average annual discharge. These records indicate that average annual discharge relates to size of drainage area according to

$$Q_A = 2.49\ DA^{0.87} \quad (r = 0.974).$$

Comparison of this equation with the equation for bankfull discharge allows the expression

$$Q_A/Q_B = 0.088\ DA^{0.173},$$

which for a drainage area of 10 square miles yields a Q_A/Q_B value of 0.13, for 100 square miles a value of 0.20, and for 1,000 square miles a value of 0.29. The same type analysis using only those gaging stations with paired data for which values of both average annual discharge and bankfull discharge are available provides the expression

$$Q_A/Q_B = 0.163\ DA^{0.069}.$$

This equation gives a Q_A/Q_B value of 0.22 for a drainage area of 100 square miles and 0.26 for a drainage area of 1,000 square miles.

It is normally expected that the ratio Q_A/Q_B increases with increases in size of drainage area, and the foregoing equations indicate the range in values of Q_A/Q_B expected in the area of study. The only data available to confirm these values are given in table 15 and range from a Q_A/Q_B value of 0.20 for 147 square miles to 0.27 for 1,800 square miles. The mean Q_A/Q_B value of all data is 0.25. For convenience and simplicity of analysis, the ratio Q_A/Q_B is considered to be 0.25 for all sizes of drainage areas, or in the upper Salmon River area, average annual discharge is about 25 percent of bankfull discharge. This value will be used in the water-quality data section of this report. It should be noted, however, that the Q_A/Q_B value of 0.25 cannot be used indiscriminately. For example, values of bankfull runoff given in table 12 cannot be multiplied by 0.25 to obtain exact values of mean annual flow.

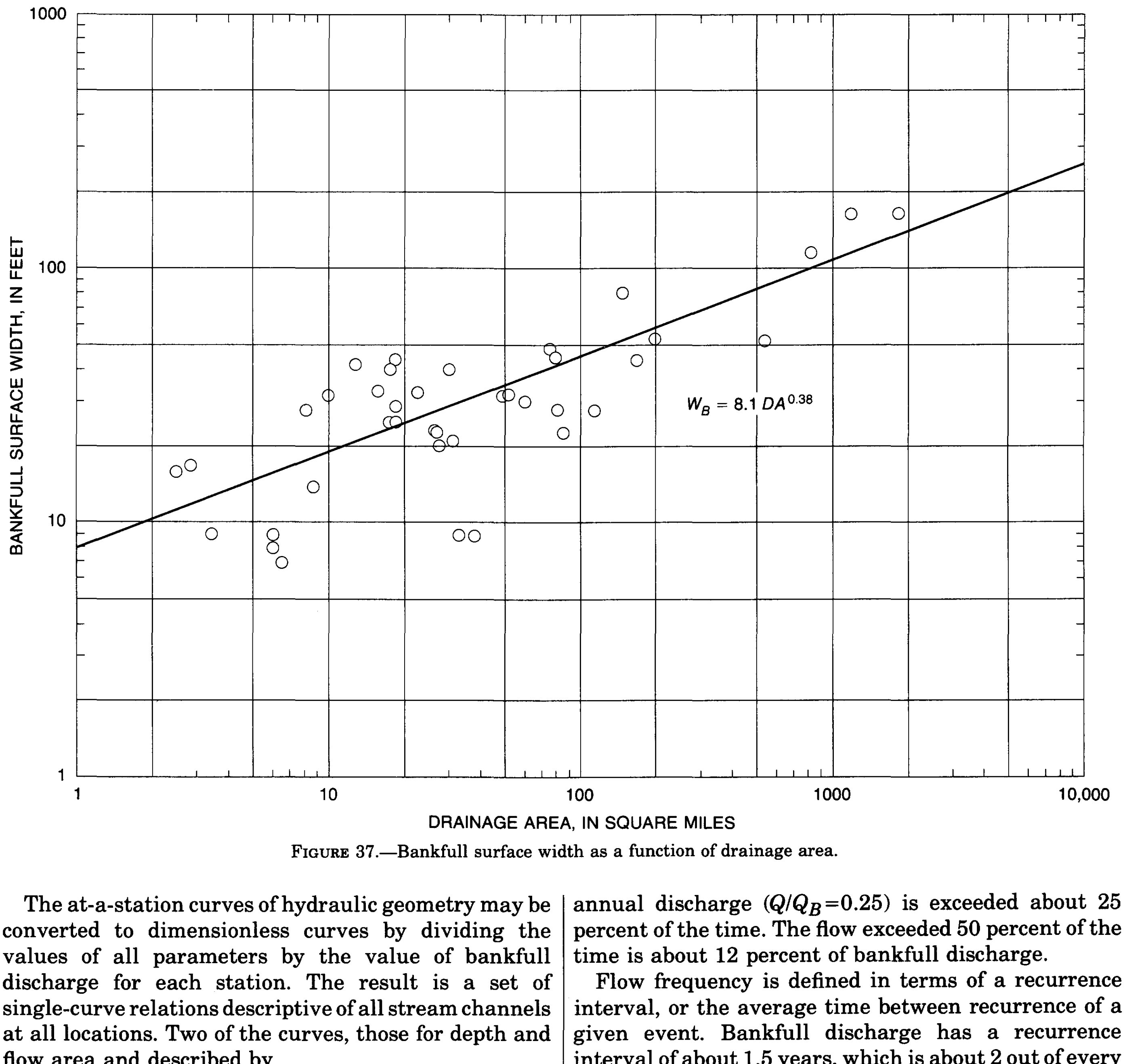

FIGURE 37.—Bankfull surface width as a function of drainage area.

The at-a-station curves of hydraulic geometry may be converted to dimensionless curves by dividing the values of all parameters by the value of bankfull discharge for each station. The result is a set of single-curve relations descriptive of all stream channels at all locations. Two of the curves, those for depth and flow area and described by

$$D/D_B=(Q/Q_B)^{0.40}$$

and

$$A/A_B=(Q/Q_B)^{0.54},$$

may be considered forms of a dimensionless rating curve and are useful in predicting values of bankfull discharge in ungaged areas.

Flow duration is defined as the percentage of time a given flow is equaled or exceeded. On a dimensionless basis, flows of magnitude $Q/Q_B=2.0$ are exceeded about 0.2 percent of the time, bankfull stage ($Q/Q_B=1.0$) is exceeded about four percent of the time, and average annual discharge ($Q/Q_B=0.25$) is exceeded about 25 percent of the time. The flow exceeded 50 percent of the time is about 12 percent of bankfull discharge.

Flow frequency is defined in terms of a recurrence interval, or the average time between recurrence of a given event. Bankfull discharge has a recurrence interval of about 1.5 years, which is about 2 out of every 3 years. Every year should have a flow of at least one-half of bankfull discharge, while a flow of magnitude $Q/Q_B=3.0$ occurs only once in every 100 years. A recurrence interval of 2 years implies a normal year; that is, half the years should experience higher flows and the other half should experience lower flows. The normal or median year can expect a peak streamflow of about 120 percent of bankfull discharge.

Likewise, the median year can expect 30 consecutive days with a mean discharge of about 90 percent or more of bankfull and 90 consecutive days with a mean discharge of about 60 percent or more of bankfull. Conversely, in the low-flow season, the median year can

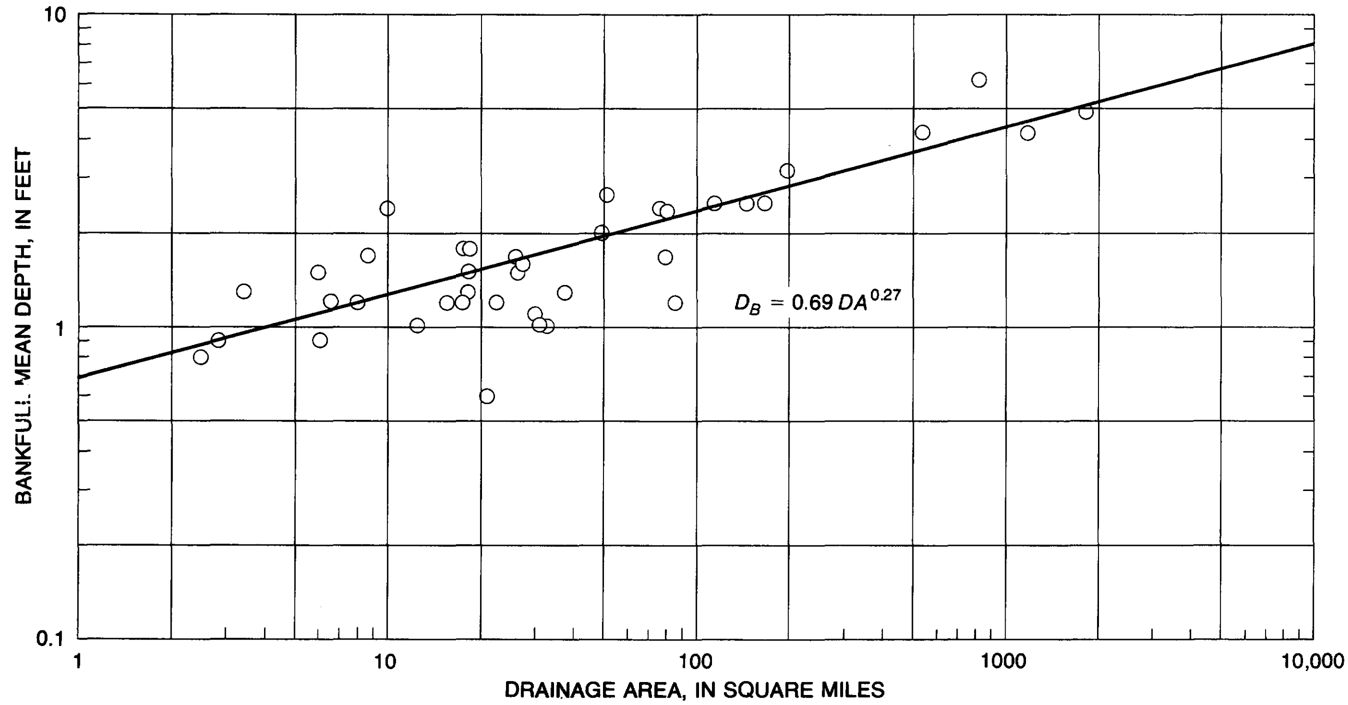

FIGURE 38.—Bankfull mean depth as a function of drainage area.

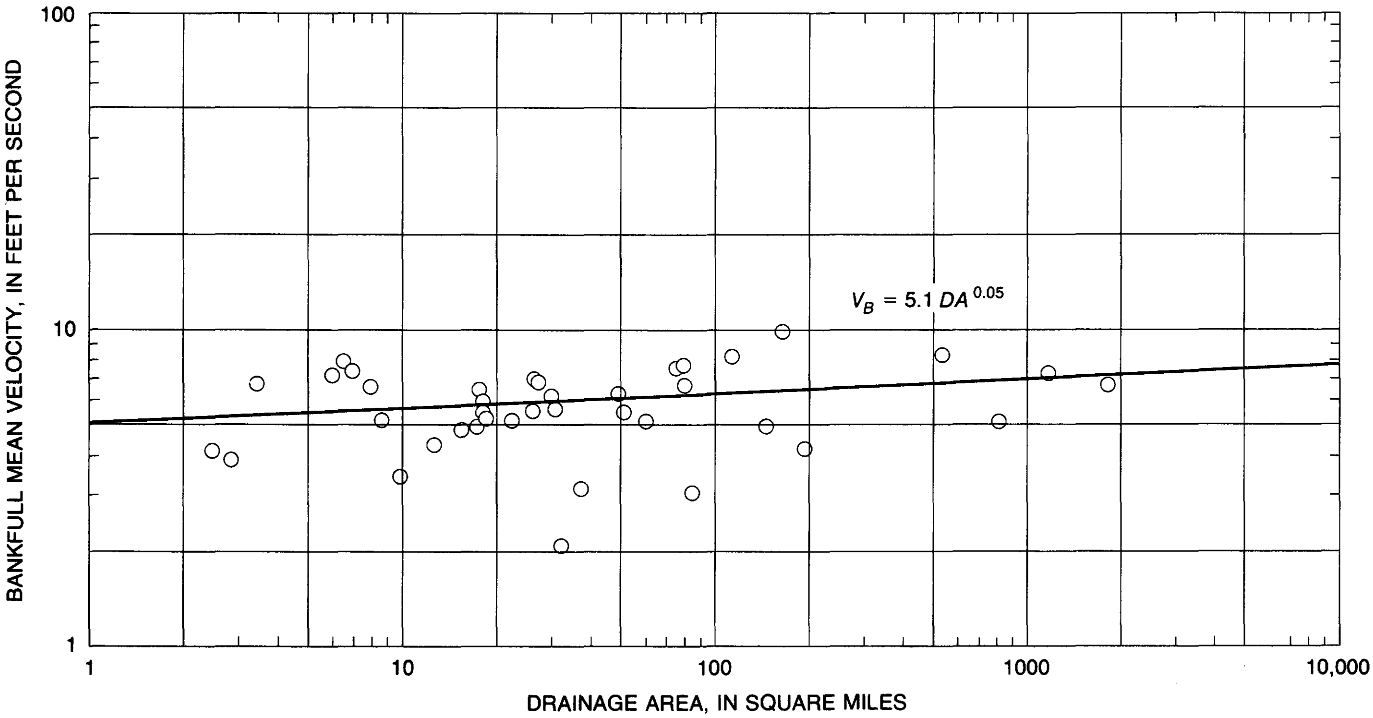

FIGURE 39.—Bankfull mean velocity as a function of drainage area.

expect 30 consecutive days with a mean discharge of about 8.2 percent or less of bankfull and 90 consecutive days with a mean discharge of about 9.0 percent or less of bankfull.

COLLECTION AND ANALYSIS OF WATER-QUALITY DATA

Water samples for the laboratory determination of

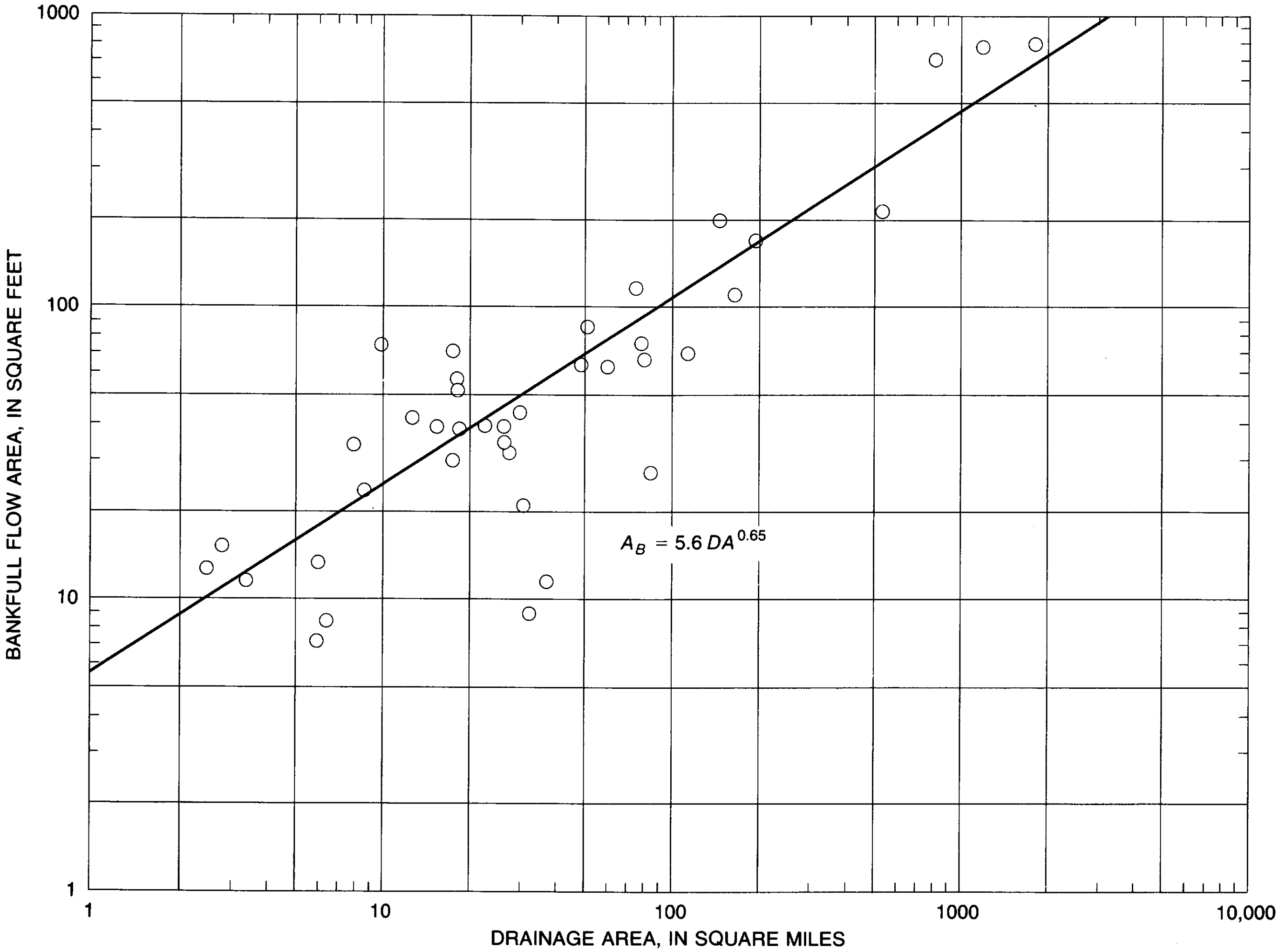

FIGURE 40.—Bankfull flow area as a function of drainage area.

the chemical composition of stream water were collected from the 39 principal water-data stations given in table 3 and at 16 additional sites. These additional sites are among the water-data stations given in table 22 as locations of biological studies.

The chemical-quality analyses were of two types. One type primarily includes determination of major-ion concentrations and is referred to and published by the U.S. Geological Survey as a standard analysis. Such analyses were performed on 250 water samples collected at 55 different locations. These analyses are included in table 40. The second type of analysis includes determination of concentrations of 21 selected trace elements chosen because of their suspected relevance to the stream-water composition. One hundred thirteen such analyses were performed on samples collected at 17 locations. These data are included in table 41.

Sediment characteristics were documented with 271 determinations of mean suspended-sediment concentrations for the 39 principal water-data stations. These mean values of suspended-sediment concentration represent only a fraction of the total number of samples obtained and analyzed. These data are included in table 42.

Other water-quality data collected include temperature, turbidity and bedload transport, and bacterial and biotic observations. These are presented in later sections of this report.

It should be noted that subsequent introductory paragraphs and brief definitions are not intended to be reviews of principles and methods of analysis, but to span the gaps between concepts, data collected, and interpretations. For more detailed discussions of principles and methods, the reader is referred to the bibliography, particularly standard references such as Hem (1970), Rainwater and Thatcher (1960), Fairbridge (1972), and McKee and Wolf (1963).

TABLE 22.—*Water-data stations for biological studies and for which water-quality data exist in addition to data for stations given in table 3*

U.S. Geological Survey station No.	Longitude	Latitude	Altitude (ft)	Drainage area (mi²)	Stream order	Name
13-2933.50	114°38′29″	44°02′53″	9,040	0.87	1	Fourth of July Creek below Fourth of July Lake near Obsidian, Idaho.
2973.84	114°33′15″	43°55′44″	7,110	18.05	5	South Fork of East Fork Salmon River near Clayton, Idaho.
2973.88	114°33′18″	43°55′46″	7,110	8.62	4	West Fork of East Fork Salmon River near Clayton, Idaho.
2973.94	114°30′32″	43°58′02″	6,850	41.22	5	East Fork Salmon River below Ibex Creek near Clayton, Idaho.
2974.00	114°28′42″	44°00′23″	6,570	75.56	6	East Fork Salmon River below Bowery Guard Station near Clayton, Idaho.
2974.02	114°38′33″	43°58′42″	7,900	4.10	3	Germania Creek above Galena Gulch near Clayton, Idaho.
2974.04	114°28′48″	44°02′21″	6,370	48.89	5	Germania Creek near Clayton, Idaho.
2974.34	114°36′08″	43°03′13″	9,840	.36	1	Little Boulder Creek above Avalanche Dam at Four Lakes Basin near Clayton, Idaho
2974.36	114°36′04″	44°03′15″	9,800	.38	1	Little Boulder Creek below Avalanche Dam at Four Lakes Basin near Clayton, Idaho.
2974.38	114°35′39″	44°03′06″	9,280	1.01	1	Little Boulder Creek above Quiet Lake near Clayton, Idaho.
2974.40	114°34′29″	44°03′30″	8,840	2.83	2	Little Boulder Creek above Baker Lake near Clayton, Idaho.
2974.45	114°32′18″	44°03′59″	8,[illegible]0	9.94	3	Little Boulder Creek below Boulder Chain Lake outlet near Clayton, Idaho
2974.50	114°36′44″	44°05′57″	6,[illegible]0	18.13	3	Little Boulder Creek near Clayton, Idaho.
2974.60	114°37′04″	44°06′43″	10,190	.16	1	Mountain Goat Basin Lake outlet above Walter Lake near Clayton, Idaho.
2974.62	114°37′00″	44°06′47″	10,040	.18	1	Snowbank tributary to Big Boulder Creek above Walter Lake near Clayton, Idaho.
2974.66	114°35′04″	44°07′03″	9,[illegible]20	1.65	2	Tin Cup Lake tributary to Big Boulder Creek near Clayton, Idaho.
2974.70	114°34′13″	44°06′39″	8,440	7.20	3	Big Boulder Creek below Tin Cup Lake Creek near Clayton, Idaho.
2974.74	114°31′56″	44°06′39″	8,200	.72	1	Slack Creek tributary to Big Boulder Creek above Little Redfish Lake Creek near Clayton, Idaho.
2974.80	114°31′16″	44°07′47″	7,230	12.77	3	Big Boulder Creek at Livingston Mill near Clayton, Idaho.
2974.85	114°32′07″	44°07′55″	7,300	3.32	3	Jim Creek at Livingston Mill near Clayton, Idaho.
2975.00	114°26′47″	44°07′03″	6,300	16.61	4	Big Boulder Creek near Clayton, Idaho.
2975.80	114°14′47″	44°06′01″	6,070	85.44	5	Herd Creek above Lake Creek near Clayton, Idaho.
2975.90	114°10′52″	44°05′45″	6,870	10.40	3	Lake Creek below Herd Lake near Clayton, Idaho.
2976.00	114°17′54″	44°09′11″	5,730	112.54	6	Herd Creek near Clayton, Idaho.
2976.70	114°02′03″	44°10′36″	6,140	37.86	4	Road Creek above Horse Basin Creek near Clayton, Idaho.
2976.80	114°12′07″	44°10′40″	6,140	32.59	4	Horse Basin Creek near Clayton, Idaho.
2977.00	114°17′09″	44°11′15″	5,630	84.98	5	Road Creek near Clayton, Idaho.
2978.80	114°16′09″	44°13′19″	5,710	34.00	4	Spar Canyon at Lower Spring near Clayton, Idaho.
2979.00	114°16′52″	44°13′31″	5,530	34.26	4	Spar Canyon near Clayton, Idaho.
2980.00	114°17′07″	44°13′29″	5,520	531.75	7	East Fork Salmon River near Clayton, Idaho.
2973.12[1]						Pat Hughes Creek above mine adit discharge.
2973.14[1]						Mine adit discharge.
2973.16[1]						Mine adit discharge below stilling pool.

[1]Miscellaneous water-quality data stations.

It should also be emphasized that any part of a water-quality study is only as valid as the water sample is characteristic of the stream from which it was collected and at best represents a single site on the stream at a moment in time—an at-the-site condition. Techniques of sample collection are detailed by Brown, Skougstad, and Fishman (1970). Elaboration of these techniques is not necessary, but it should be stated that all samples were carefully collected in clean bottles at a point in the stream representative of the entire flow in the stream at that instant. Samples collected for trace-element analysis were generally filtered immediately, and always within a few hours, through a 0.45-micrometer membrane filter, acidified with triple-distilled reagent-grade nitric acid to a pH value of less than 3.0, and shipped to the laboratory in acid-rinsed bottles. Samples for major-ion and nutrient analyses were collected in bottles prerinsed with stream water from the sampling locale. All samples were kept cool from time of collection to time of analysis. For preservation, especially of the nutrients, in 1972 the samples were shipped to the laboratory in insulated containers packed with ice. In 1970 and 1971, separate samples for nutrient analysis were collected, and these were preserved with mercuric chloride.

All chemical analyses except streamside determinations were made by the Central Laboratory, U.S. Geological Survey, Salt Lake City, Utah. Suspended-sediment concentrations in 1971 were determined by the Sediment Laboratory, California District, U.S. Geological Survey, Sacramento, Calif. Suspended-sediment concentrations in 1972 were determined by the Idaho District, U.S. Geological Survey, Boise, Idaho.

A BASIS FOR COMPARISON AND INTERPRETATION OF WATER QUALITY

A source of the chemical constituents of stream water is the chemical makeup of precipitation falling on the area, but the primary source is the composition of the earth's crust over and through which the waters of precipitation travel to reach the river channel.

No measurements of dissolved solids in precipitation were made in the study area, but analysis of data reported by Junge and Werby (1958) indicates the average mineral content of precipitation in the study area would be less than 10 milligrams per liter. This value is in good agreement with data collected or used in the Sierra Nevada mountains to the west (Feth and others, 1964), the Sangre de Cristo Mountains to the south (Miller, 1961), and the Wind River Mountains to the east (Hembree and Rainwater, 1961). Though no data are available, it is reasonable to assume that precipitation is responsible for only minor contributions to the dissolved-solids content of stream water.

Major rock types in the earth's crust are sufficiently consistent in their composition that one can use some average values of their composition. Table 23 gives the average composition of rock types in terms of oxides of the major elements. Data of table 23 do not imply the concentration of chemical constituents in stream waters, but only the relative composition of the constituents. Other factors controlling rates of solution

TABLE 23.—*Average composition in percentage by weight of various oxides in the earth's crust*

[From Ronov and Yaroshevsky (1972)]

	Granitic	Basaltic	Sedimentary
Silicon	63.9	58.2	49.9
Aluminum	15.2	15.5	13.0
Iron	4.9	7.6	5.8
Manganese	.1	.2	.1
Magnesium	2.2	3.9	3.1
Calcium	4.0	6.1	11.7
Sodium	3.1	3.1	1.7
Potassium	3.3	2.6	2.0
Phosphorus	.2	.3	.2
Carbon	.8	.5	8.2
Hydrogen	1.5	1.0	2.9
Titanium	.6	.9	.7
Total	99.8	99.9	99.3

are responsible for concentration of dissolved minerals in water. For example, the crystalline granites and basalts are more resistant to weathering than many sedimentary rocks, and other factors being equal, streams draining these areas of crystalline rock should be more dilute than streams draining the sedimentary areas.

Detailed studies of the area's mineral resources are currently under way in a major part of the area but have been completed for only a small part. These studies are being made by the U.S. Geological Survey in accordance with the provisions of the Wilderness Act (Public Law 88–577, September 3, 1964) and the Conference Report on Senate Bill 4, 88th Congress. These mineral surveys include reconnaissance geologic mapping and extensive sampling and mineral analysis of stream sediments, altered and unaltered rocks, and soil. One study (Killsgaard and others, 1970) includes only the extreme western fringe of the study area, and its data are pertinent to only two streams of the present study. Another study (Tschanz and others, 1974) encompasses most of the present study area south and east of the main-stem Salmon River. Data of this study will be extremely useful in interpretation of trace elements in stream waters; however, they were not available at the time of the present analyses. In lieu of these data, table 24 gives all elements for which analyses were made. This table includes the average weight percentage each element contributes to the composition of the earth's crust. Although table 24 includes only those elements analyzed in the present study, it includes all significant elements except titanium, which accounts for about 0.5 percent of the earth's crust. The chemical composition of stream-water data can be compared with the ranking of data in table 24.

TABLE 24.—*Weight percentages of the earth's crust for those elements analyzed in stream waters of this study*

[Data from Mason (1958), Parker (1967), Taylor (1964), and Fleisher (1953)]

Oxygen[1]	46.7
Silicon	27.7
Aluminum	8.15
Iron	5.00
Calcium	3.65
Sodium	2.85
Potassium	2.60
Magnesium	2.10
Hydrogen	.15
Phosphorus	.15
Total	99.05
Manganese	0.10
Fluorine	.05
Sulfur	.05
Barium	.03
Carbon	.03
Chlorine	.03
Strontium	.03
Chromium	.025
Vanadium	.015
Copper	.010
Zinc	.010
Nickel	.008
Lithium	.006
Nitrogen	.005
Cobalt	.002
Lead	.002
Molybdenum	.0015
Beryllium	.0010
Boron	.0010
Arsenic	.0005
Mercury	.00005
Cadmium	.00002
Selenium	.00001
Silver	.00001
Grand total	99.46

[1]Elemental oxygen not analyzed

STREAM-WATER TEMPERATURE

Stream-water temperature was measured at the time of each observation or collection of data; usually, this collection of data involved retention of a water sample for chemical analysis. The values of water temperature are presented in table 40 with data of the respective chemical analyses. Only one continuous-recording thermograph was operated in the area, and this was at the water-data station Little Boulder Creek near Clayton (13–2974.50). Data of this thermograph record are illustrated in figure 41 with traces of the daily minimum and maximum temperatures.

Figure 41 indicates water temperatures in winter (November to March) are generally less than 3°C and have diurnal fluctuations of 1°C or less. Stream temperature begins warming in April and generally peaks in early August. Summer diurnal fluctuations are as large as 5°C and reflect a combination of snowmelt source of stream water and warming of the stream water by solar radiation. The seasonal trends of temperatures are indicated by the mean monthly data in table 25.

Comparison of stream-temperature trends in figure 41 to stream-runoff trends in figure 20 indicates a partly inverse relation between the two parameters, especially in the spring months, and this probably indicates an

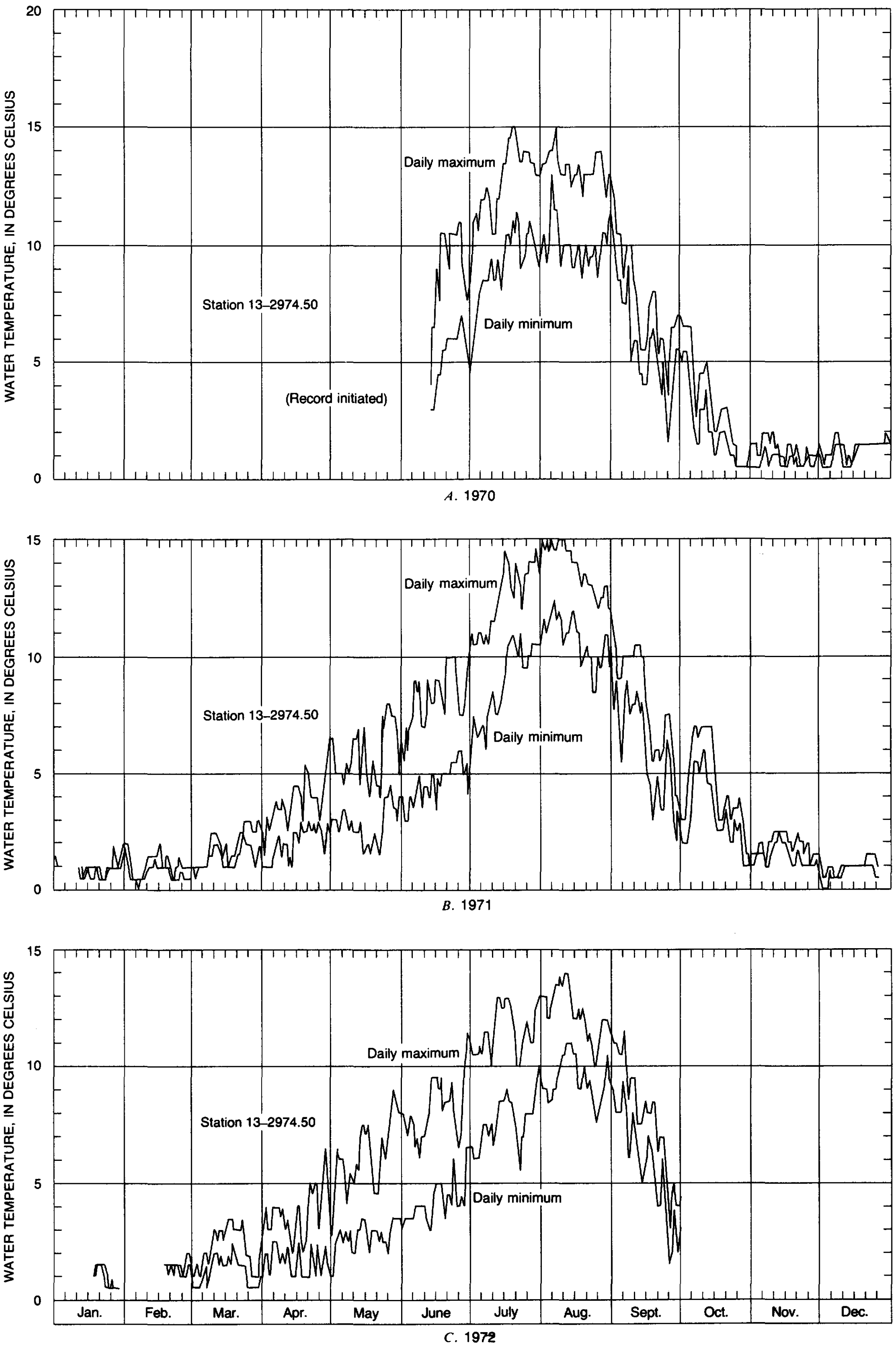

FIGURE 41.—Stream-water temperature, 1970–72, Little Boulder Creek near Clayton, Idaho. *A*. 1970. *B*. 1971. *C*. 1972.

TABLE 25.—*Mean monthly temperatures, in degrees Celsius, for Little Boulder Creek near Clayton (station 13–2974.50)*

Month	1970			1971			1972			Period of record, mean
	Mean high	Mean low	Mean	Mean high	Mean low	Mean	Mean high	Mean low	Mean	
January	----	----	----	1.1	0.9	1.0	1.0	1.0	1.0	1.0
February	----	----	----	1.4	.8	1.1	1.2	1.1	1.2	1.2
March	----	----	----	2.0	1.4	1.7	2.3	1.2	1.7	1.7
April	----	----	----	3.9	2.1	3.0	3.7	1.7	2.7	2.9
May	----	----	----	5.7	2.9	4.3	6.3	2.8	4.5	4.4
June	----	----	----	8.4	4.6	6.5	8.3	4.3	6.3	6.4
July	12.8	9.2	11.0	12.6	8.9	10.7	11.6	7.6	9.6	10.4
August	13.2	10.0	11.6	13.7	10.7	12.2	12.3	8.0	10.1	11.3
September	7.5	5.6	6.5	7.9	5.8	6.8	7.7	5.7	6.7	6.7
October	3.0	2.1	2.5	4.4	3.2	3.8	----	----	----	3.2
November	1.3	.7	1.0	1.9	1.4	1.6	----	----	----	1.3
December	1.3	1.1	1.2	1.0	.8	.9	----	----	----	1.0

inverse relation between water and air temperatures. That is, warm spring days cause snowmelt runoff to augment streamflow, but this snowmelt runoff is colder than water previously in the channel. Thus, spring rises in the runoff hydrograph are accompanied by colder water in the channel.

Although the temperature graphs in figure 41 are for a single tributary stream with a drainage area primarily in a mountainous area, both the general trend of temperature and values of temperature are considered to closely approximate the conditions at other locations. For example, comparison between Little Boulder Creek (13–2974.50) and Salmon River near Challis (13–2985.00) of individual temperatures in table 40 indicates that the Salmon River tended to be about 2°C warmer than Little Boulder Creek. Perhaps the biggest difference between stations is that streams in mountainous areas begin a fall cooling earlier than some of the downstream stations. The temperature data in table 40 also indicate the general cool temperatures of the area's stream water. Of the 250 observations in that table, which were generally collected over the spring and summer months, only 10 (4 percent) show temperatures greater than 15°C, and only one temperature is greater than 20°C.

STANDARD CHEMICAL ANALYSES

Data of standard chemical analyses include the date of measurement, stream discharge, water temperature, several physical characteristics of the water, concentration of major ions, and several computations based on these measurements, such as dissolved solids expressed in tons per day. All data of the standard analysis are tabulated in table 40.

Analytical techniques utilized in the chemical determinations were those standard to the Geological Survey at the time of analysis (see Brown and others, 1970) and are of sufficient accuracy to report at the significance level used in table 40.

At some stations, values of three water-quality parameters were determined in the field as well as later in the laboratory. For these three parameters, pH, specific conductance, and bicarbonate concentration, a delay in analysis influences the measurement such that a laboratory determination can be considered applicable only to the solution in the sample bottle. Values of field measurements are also included in table 40. Comparison of field and laboratory values indicates that usually the field values are higher for all three parameters, but the difference is not always consistent nor greatly significant. Accordingly, since laboratory values are available for all parameters at all locations, analysis of data in this section is based on the laboratory data.

The major cations constituting the dissolved-solids content include calcium, magnesium, potassium, and sodium; the major anions are bicarbonate, chloride, fluoride, and sulfate. Nitrite and nitrate concentrations are summed and reported as nitrogen, and orthophosphorus and total phosphorus are reported as phosphorus. Silicon present is reported in terms of an equivalent concentration of the oxide silica. Other elements are reported as trace elements even though some, such as iron and aluminum, occur with regularity in the analyses.

As emphasized by Hem (1970), the implication given in this report that discharge or flow measurements should be obtained at the sampling sites is intentional. Chemical analyses of river water generally require some sort of extrapolation, because the water sampled has long since passed on downstream by the time a laboratory analysis is completed. The discharge record provides a means of extrapolating the chemical record if the two are closely enough related. The discharge data also serve as a means of averaging the water analyses and give an idea of total solute discharges.

pH AND SPECIFIC CONDUCTANCE

The concentration (activity) of hydrogen ions in water solutions is very low when expressed in terms of milligrams per litre or moles per litre. The abbreviation pH was adopted to represent the negative base-10 logarithm of the hydrogen-ion activity in moles per litre. At 25°C, pure water has a neutral pH value of 7.00. As temperature increases, the neutral value of pH becomes slightly smaller.

River waters in areas not affected by pollution generally have a pH between about 6.5 and 8.5, and this is the range of values for streams in the study area. Values of pH seemingly do not correlate significantly to values of other water-quality parameters. In fact, the range in values of pH is no greater than might be expected in the normal diurnal cyclic fluctuation of pH that has been observed in near-surface water of rivers (Livingston, 1963). For the individual water-data stations, the mean or median value of pH at each station ranges from about 7.0 to 7.9 and indicates that generally within the study area, stream waters are about neutral.

The specific electrical conductance, or conductivity, is the ability of a substance to conduct an electrical current and is expressed as the reciprocal of the resistance in ohms (mhos) per centimetre at a temperature of 25°C. Common usage omits the inclusion of the length unit, multiplies the value by 10^6, and expresses values as micromhos. Pure water has a very low specific conductance, but as ionic concentrations increase, conductance of the solution increases. Therefore, the conductance measurement provides an indication of ionic concentration.

The relation between specific conductance and simple solutions is nearly linear over a moderately dilute range in concentration, but as concentrations increase, the relation becomes more curvilinear. The relation is not quite as simple for natural waters containing a variety of ionic species, but a plot of specific conductance versus dissolved solids on log-log graph paper generally gives a straight-line relation over the usually encountered range of concentration. The specific-conductance and dissolved-solids data in table 40 were analyzed using log-transformed regression techniques. The relation

$$DS = 1.039\ SC^{\ 0.914}$$

was determined for the 250 pairs of data and has a correlation coefficient of 0.985. Dissolved solids, DS, is in milligrams per litre, and specific conductance, SC, is in micromhos. Often the ratio of dissolved solids to specific conductance is considered a constant value of about two-thirds, but the preceding equation shows the dependence on concentration. For various values of dissolved solids and specific conductance, stream water in the study area has the following values of the ratio DS/SC:

SC	DS	DS/SC
10	8.5	0.85
25	19.7	.79
50	37.1	.74
100	69.9	.70
200	131.8	.66
500	304.4	.61

Because regression relations exist for the dominant ions and specific conductance, a recent trend in water-quality analysis has been the application of such statistical analyses to the synthesis and regionalization of data (Steele, 1971; Blakey and others, 1972). That is, on the basis of measurements of conductivity, reliable predictions of the component amounts of dissolved solids may be made, and these predictions are general for an entire area of moderate homogeneity. The high degree of correlation for the area-wide relation of dissolved solids and conductivity in the present study indicates that such techniques would be applicable here. But in keeping with the earlier thesis in this report of relating streamflow characteristics to hydraulic and channel geometry at bankfull stage, the water-quality data will be analyzed in the same manner. A combination of both concepts allows such predictions as the mean annual discharge of dissolved solids from ungaged streams.

DEPENDENCY OF IONIC CONCENTRATION ON SOLUBILITY OF ROCK AND MAGNITUDE OF DISCHARGE

Under natural conditions, dissolved-solids concentrations are usually highest during periods of low flow. At times of low flow, water reaches a stream only after a slow subsurface journey which often spans a considerable distance. During its underground passage, the water dissolves a large variety of chemical constituents from the soil and rocks. During high-flow periods, water movement, either overland or through the upper soil layers, is much more rapid than at low flow, and high-flow runoff is much more dilute than low flow because its contact with the soil and rocks is for a shorter period of time.

To illustrate the dilution effect of high flow on the concentration of dissolved solids, the specific-conductance data in table 40 were log-transformed and regressed against values of discharge. To provide a dimensionless abscissa scale, the discharge ratio, Q/Q_B, was used rather than the absolute values of discharge, and the regression-equation technique was applied individually to each water-data station set of measurements. The results of these regressions yield a set of equations, one for each water-data station, of the form

$$SC = b\ (Q/Q_B)^s,$$

where SC is the specific conductance in micromhos, b is a coefficient (to be discussed later), Q/Q_B is the discharge ratio, and s is an exponent indicating the rate of change in values of specific conductance as values of the discharge ratio change. Table 26 gives the station numbers, correlation coefficients, values of the exponent s (slope of the specific conductance versus discharge ratio relation), and computed values of specific conductance at a bankfull discharge ($Q/Q_B=1.0$) and at mean annual discharge ($Q/Q_B=0.25$). It should be noted that values of specific conductance at $Q/Q_B=1.0$ are equal to values of the coefficient b. Figure 42 is a graph of the relations in table 26; the end points of each line in figure 42 indicate the range in values of the discharge ratio observed at each location.

Negative values of the exponent s in table 26 and the downward-to-the-right slope of the lines in figure 42 illustrate the dilution effects of increased streamflow on values of dissolved solids (specific conductance). The lines in figure 42 indicate that the relation is not 1 to 1. That is, even though discharges were measured over a 20-fold range in magnitude, values of specific conductance varied only over about a 2-fold range in magnitude.

The rather high values of correlation coefficient in table 26 indicate well-defined relations between specific conductance and discharge at the individual water-data station locations, and this can be verified graphically by plotting the actual data of specific conductance as a function of discharge. Further, considerable parallelism exists in the lines of the graph in figure 42—there is no trend of convergence or divergence of the lines. These factors indicate that an average value of the exponent s would provide a reasonable approximation for all streams in the study area. Analysis of standard deviations indicates that two-thirds of the values of s range between values of −0.13 to −0.33. Mean and median values of s are shown in table 26 and indicate that an average value of $s=-0.23$ is suggested for the area. This leads to an equation of the form

$$SC=b(Q/Q_B)^{-0.23}.$$

Absolute values of specific conductance at each water-data station location, or in reality the individual values of the coefficient b, are determined largely by the chemical composition of the different rock types and their solubility and to a lesser degree by the length of time water is in contact with them.

Chemical composition, solution, and solute concentration in waters draining a single rock type have been documented elsewhere. For example, Miller (1961) has shown that solute concentrations of waters draining quartzite, granite, and sandstone are in the proportion 1:2.5:10. The importance of solubility was shown by Miller in that most of the solute content of water draining the sandstone is derived from the easily soluble carbonate cement and the limestone which

TABLE 26.—*Summary of log-transformed regression data of specific conductance as a function of discharge*

Graph plotting number	U.S. Geological Survey station No.	Correlation coefficient, r	Slope, S, of specific conductance and Q/Q_B relation	Value of specific conductance: Bankfull ($Q/Q_B=1.0$)	Value of specific conductance: Mean annual ($Q/Q_B=0.25$)
1	13–2922.00	−0.933	−0.223	79	107
2	2924.00	−.915	−.214	33	45
3	2932.00	−.955	−.159	112	140
4	2934.00	−.927	−.261	74	106
5	2950.00	−.842	−.077	51	57
6	2956.50	−.814	−.126	58	69
7	2960.00	−.909	−.204	58	77
8	2965.00	−.950	−.424	56	100
9	2970.00	−.988	−.456	64	120
10	2971.00	−.883	−.340	72	115
11	2972.50	−.535	−.117	239	281
12	2973.00	−.732	−.101	154	177
13	2973.10	−.874	−.177	56	72
14	2973.20	−.996	−.620	24	57
15	2973.30	−.669	−.252	63	89
16	2973.40	−.970	−.219	76	103
17	2973.50	−.988	−.313	90	139
18	2973.60	−.988	−.235	82	113
19	2973.80	−.973	−.371	74	123
20	2973.84	−.988	−.266	43	62
21	2973.88	−.954	−.227	76	104
22	2973.96	−.944	−.244	100	137
23	2974.00	−.949	−.281	82	121
24	2974.04	−.984	−.224	96	131
25	2974.18	−.873	−.136	66	80
26	2974.25	−.942	−.253	97	137
27	2974.40	−.754	−.069	17	18
28	2974.45	−.977	−.261	32	46
29	2974.50	−.822	−.243	43	60
30	2974.80	−.972	−.309	36	55
31	2974.85	−.986	−.187	87	112
32	2975.00	−.967	−.297	60	90
33	2975.30	−.478	−.052	122	131
34	2976.00	−.942	−.140	126	153
35	2976.70	−.957	−.214	139	187
36	2976.80	−.592	−.081	367	410
37	2977.00	−.833	−.158	213	265
38	2980.00	−.962	−.229	118	162
39	2985.00	−.930	−.281	96	142
Mean			−.232		
Median		−.944	−.229		

together constituted less than 1 percent of the rock. Thus, it may be expected that the concentration of dissolved solids, as expressed by the value of specific conductance, is dependent on the rock type through which its contributory waters drain.

Within the study area, the diversity of rock types is such that water-data stations do not represent single-rock-type drainages. Compositing rock types tend to average results, but the effect is still visible. For example, Little Boulder Creek (13–2974.50) drains primarily crystalline rocks of the Idaho batholith and Challis Volcanics and has a specific conductance at bankfull discharge of 29 micromhos (table 26); Slate Creek (13–2972.50) drains an area primarily in the Milligan Shale and has a specific conductance at bankfull discharge of 150 micromhos; and the Salmon River at Challis (13–2985.00) composites the lithology of the entire study area and has a specific conductance at bankfull discharge of 78 micromhos.

Values of specific conductance at bankfull and mean annual discharge are given in table 26. It can be inferred that the highest values of specific conductance are associated with rock types of the highest solubility and that the reverse is true for the lowest values.

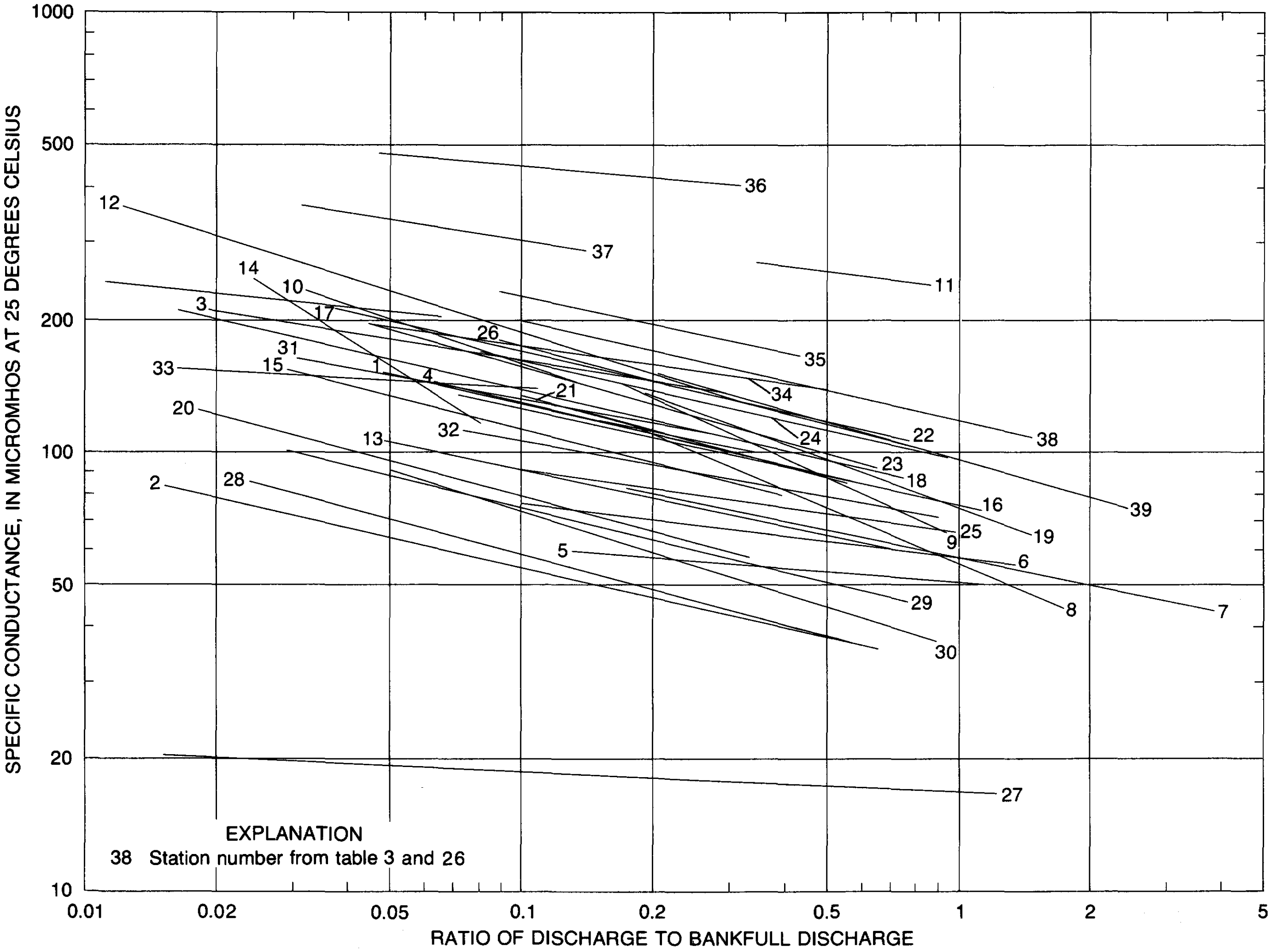

FIGURE 42.—Specific conductance as a function of discharge ratio.

Intermediate values of specific conductance may have that value because the rock type is of intermediate solubility, but most likely such values indicate that the upstream drainage is a composite of highly and poorly soluble rock types. The important item to note is that in areas other than those composed of single rock types, the solute content of stream waters is variable and dependent on rock type. Thus, determination of an average coefficient for the area is not possible.

In an effort to document rock type or composite of rock types for each water-data station, lithologic counts were conducted at those sites with channel-geometry surveys (table 3). The technique consisted of randomly selecting 20 rocks from the streambed and identifying their lithologies. The results are summarized in table 27. These data are not particularly definitive because some results are partly concealed. For example, the great extent of sedimentary rock in Slate Creek drainage (13–2972.50) is masked because of the abundance of quartzite found in the streambeds. However, rocks in the streambed of Slate Creek are orthoquartzite and imply a sedimentary origin.

One useful aspect of table 27 is the relative abundance of the rock types found on the streambeds, which in order of the most abundant are andesite, quartzite, basalt, quartz monzonite, and shale. These five rock types account for more than 70 percent of all types, and all five are considered to be relatively resistant to weathering. Their relative resistance to weathering is a dominant reason for their abundance in the streambeds, but the presence of these resistant rocks in a given streambed is not necessarily indicative of low solute content.

Next to rock type, the largest factor in determining solute concentration of stream water appears to be the trend of decreasing precipitation toward the northeast corner of the study area. In this region as detected by the Road Creek stations (13–2976.70 to 13–2977.00),

TABLE 27.—*Summary of streambed lithology (percentage of each rock type on streambed)*

U.S. Geological Survey station No.	Igneous											Metamorphic			Sedimentary	
	Quartz	Granite	Rhyolite	Quartz monzonite	Grandiorite	Rhyodacite	Trachyte	Latite	Andesite	Basalt	Tuff	Primarily hornfels	Primarily slate	Primarily quartzite	Primarily siltstone	Primarily sandstone
13–2922.00	----	----	----	----	----	----	----	----	15	10	20	----	----	40	15	----
2924.00	----	30	5	60	----	----	----	----	5	----	----	----	----	----	----	----
2932.00	----	5	----	----	----	----	5	----	----	30	----	20	----	35	5	----
2934.00	----	5	----	15	----	----	----	----	5	5	----	----	25	25	15	5
2950.00	5	10	----	40	----	----	----	5	20	15	----	----	----	5	----	----
2956.50	----	10	5	35	5	----	----	5	30	----	----	----	----	10	5	----
2960.00	----	----	10	25	5	5	----	15	5	10	----	5	----	20	----	----
2965.00	----	25	----	10	----	----	----	5	20	10	----	----	5	20	----	5
2970.00	----	5	----	10	----	----	----	----	----	15	----	----	25	30	15	----
2971.00	----	10	----	5	----	5	----	5	25	10	5	----	10	25	----	----
2972.50	----	----	----	----	----	----	----	----	----	15	----	25	15	45	----	----
2973.00	5	----	5	----	5	5	----	5	20	40	10	----	----	----	5	----
2973.10	----	----	5	----	----	5	----	10	40	15	----	----	20	5	----	----
2973.20	----	----	----	15	----	25	----	10	35	----	----	----	10	5	----	----
2973.30	----	----	----	5	----	----	----	5	25	----	----	10	40	15	----	----
2973.40	----	----	----	----	----	----	----	5		5	----	20	20	35	15	----
2973.50	----	----	----	----	----	----	----	----	15	25	----	----	35	----	25	----
2973.60	5	----	----	----	----	10	5	----	25	40	5	----	----	10	----	----
2973.80	----	----	----	5	5	5	----	5	30	25	----	----	----	10	15	----
2973.84	----	5	5	5	----	5	5	5	65	5	----	----	----	----	----	----
2973.88	----	----	----	----	----	5	----	----	65	15	----	----	----	5	----	10
2973.96	5	5	----	5	5	----	----	15	30	----	----	----	----	30	----	5
2974.00	----	----	----	10	----	5	----	5	40	5	----	----	----	25	----	10
2974.04	----	----	----	----	----	10	----	10	65	10	----	----	----	5	----	----
2974.18	----	----	5	----	5	10	----	10	45	25	----	----	----	----	----	----
2974.25	----	----	----	----	5	10	----	10	50	----	----	----	5	20	----	----
2974.40	----	35	----	50	5	----	5	----	----	----	----	----	----	5	----	----
2974.45	5	5	----	5	----	----	----	----	30	----	----	----	----	50	5	----
2974.50	----	----	5	5	----	10	----	----	60	15	----	----	----	----	5	----
2974.80	----	5	----	25	5	----	----	----	35	5	5	10	----	----	5	----
2974.85	----	----	----	----	----	10	----	----	60	----	5	10	----	5	10	----
2975.00	----	----	----	10	5	----	----	----	45	20	----	10	----	10	----	----
2975.30	----	----	10	----	----	10	----	5	50	15	10	----	----	----	----	----
2976.00	----	----	----	----	5	5	----	----	75	15	----	----	----	----	----	----
2976.70	----	----	----	----	----	----	----	----	25	75	----	----	----	----	----	----
2976.80	----	----	5	----	----	15	----	25	15	5	----	----	----	30	----	5
2977.00	----	----	----	----	----	----	5	----	45	5	5	----	----	15	20	----
2980.00	----	----	10	----	20	5	10	5	40	----	5	5	5	----	----	----
2985.00	5	----	----	----	----	5	----	5	5	15	----	----	35	15	10	5
Average	.8	4.0	1.8	8.7	1.9	4.2	.9	4.2	29.7	12.8	1.8	2.9	6.4	14.1	4.2	1.2

stream waters are high in solute concentration. It is reasoned that precipitation in this region is sufficiently low that dilution comparable with that in other regions of the study area never occurs. But also because of the low precipitation, water runoff in the northeast region is some 10-fold less than the average for the study area. (See fig. 36.) Thus, even though solute concentrations are highest in this region, the dissolved-solids yield in tons per year is among the lowest of any in the study area.

It should be noted that some within-channel factors may also influence stream-water composition. These factors include reaction of water with minerals in the streambed and in solution, evaporation and transpiration losses, and effects of the stream biota. Within the study area, these effects are considered minimal. Although the influences of man are superimposed on all natural conditions, the effects of minor flow diversions and augmentation and any subsequent stream pollution are considered minimal in the upper Salmon River area.

CONTENT OF MAJOR IONS

Concentration values of major cations and anions for each water sample collected are among the data included in table 40. The major cations include calcium (Ca), sodium (Na), magnesium (Mg), and potassium (K). If the data of the Salmon River near Challis (13—2985.00) are used as a composite of the upstream waters, the relative abundance of these cations expressed in milligrams per litre and in the ratio Ca:Na:Mg:K is about 1.0:0.22:0.12:0.04. The major anions include bicarbonate (HCO_3), sulfate (SO_4), chloride (Cl), and fluoride (Fl). Nitrogen and phosphorus components will be discussed later under "Nutrients." The relative abundance of the anions expressed in milligrams per litre and in the ratio HCO_3:SO_4:Cl:Fl is about 1.0:0.06:0.01:0.005. Stream waters are clearly typed as calcium bicarbonate.

The more significant of the major cations and anions have characteristics very similar to those shown by specific conductance and noted by the data of table 26 and the graphs of figure 42. For ions which occur in less significant amounts, for example, potassium, chloride, and fluoride, the characteristics become more erratic, and the resemblance of data to figure 42 becomes more remote. In the manner of preparing table 26, table 43 gives details of log-transformed regression equations fitted to the more significant ion concentrations and dissolved solids for each station. Table 44 gives similar details for the less significant ion concentrations and some of the computed data, but for only the 15 stations with the largest amount of data. Figures 43–48 are graphs of the regression equations available from the data in table 43.

For the major cations, figures 43–45 indicate similarity to the relation of specific conductance to discharge (fig. 42), but the similarity decreases as ionic concentration decreases. Values of concentration for each of the cations are dependent on individual locations, but an average value for the slope of the relation of calcium, sodium, and magnesium as a function of discharge is −0.22 for each of the three parameters. A median value of the correlation coefficient, however, decreases from 0.95 for calcium to 0.81 for magnesium. Potassium, a cation occurring in much more dilute quantities, has a relation slope of −0.08 and a median correlation coefficient of only 0.35.

The relations of concentration of the major anions to discharge are shown in figures 46–48. The trend is much the same as for the major cations; the average slope of the relation to discharge is −0.21 for bicarbonate, −0.27 for sulfate, and −0.15 for chloride. Median values of the correlation coefficient for the relations range from 0.91 for bicarbonate to 0.55 for chloride. Fluoride, the least significant of the anions in terms of concentration, has a slope to discharge relation of −0.35.

Generally, the relations of the major ions as functions of discharge indicate that ionic concentrations decrease as discharge increases. Figures 43–48 indicate, however, that some individual locations show reversals to this trend. For example, the station Little Boulder Creek above Baker Lake (13–2974.40, graph plotting number 27) shows slight, but positive, increases in concentration of magnesium and sulfate with increases in discharge. The data indicate that generally these exceptions occur for concentrations so dilute that the analyses are borderline with analytical accuracy or for streamflows so low ($Q/Q_B<0.05$) that the results are not correlative with the majority of streamflows presented in this report. An exception to this explanation appears to be values of chloride concentration for the majority of the water-data stations in Stanley Basin. Stanley Basin is the only area within the study area with extensive surfaces of near-level topography, and these surfaces are often boggy after spring runoff and later irrigation. It appears likely that evaporation from these surfaces increases the ionic concentrations of standing water and at times leaves behind residual deposits. The following spring's runoff collects these mineral concentrates and delivers them to the river channels at time of high flow. For most major ions, an influx of ionic concentrate is insufficient to reverse or even alter the normal relations of concentration to discharge, but for the normal ionic concentrations of chloride (<0.5 mg/l), the percentage increases could easily alter the relations.

The dissolved-solids graph of figure 49 illustrates a compositing of individual constituents, primaily the six major constituents illustrated in figures 43–48. As expected, the appearance of figure 49 is similar to the

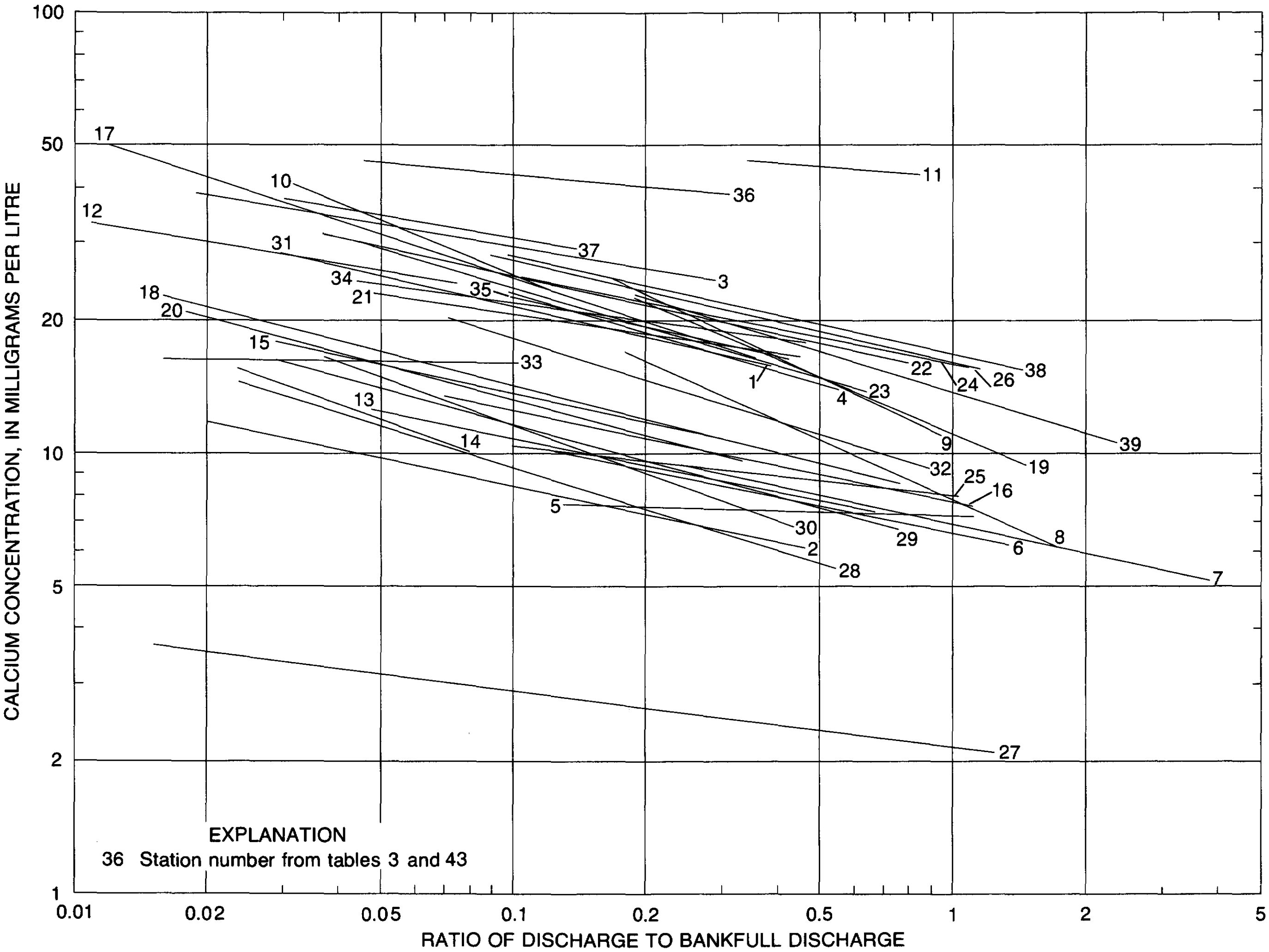

FIGURE 43.—Calcium concentration as a function of discharge ratio.

graphs of the major constituents and is nearly identical to the graph for specific conductance (fig. 42). The slope of the relation to discharge is −0.20 for dissolved solids compared with −0.23 for specific conductance. The difference in value of the two exponents relates to the previously established relation indicating that dissolved solids do not decrease in concentration as rapidly as values of specific conductance. Furthermore, increasing amounts of suspended solids at high flow give some decreased measure of electrical conductivity but do not alter amounts of dissolved solids. In this respect, values of dissolved solids used in this report are computed values obtained by summing the concentrations reported for the various dissolved constituents. This summation actually includes the sum of constituents in their solid phase rather than the ions in solution. For example, the bicarbonate ions in solution are converted to carbonate in the solid phase by the factor HCO_3 (mg/l)×0.49=CO_3 (mg/l). Thus, values of dissolved solids in milligrams per litre given in table 40 are always less than the straight arithmetic sum of the various constituents.

SILICA

Silicon, as noted in table 24, is second only to oxygen in abundance in the earth's crust. Oxides of silicon are an important constituent of all igneous and metamorphic rock, and thus one would expect significant quantities of silicon in stream water if that were the only factor involved. The term silica for SiO_2 is commonly used in referring to silicon in water, and dissolved silica is the term used in this report.

In reality, the range of concentrations of silica most commonly observed in stream waters is from about 2 to 40 milligrams per litre. The higher concentrations are related to the temperature of the water, the mineralogy and relative solubility of the rock type, and the mode of flow conveyance to the channel whether it be overland flow or ground-water inflow.

Because of the abundance of silicon in the rock

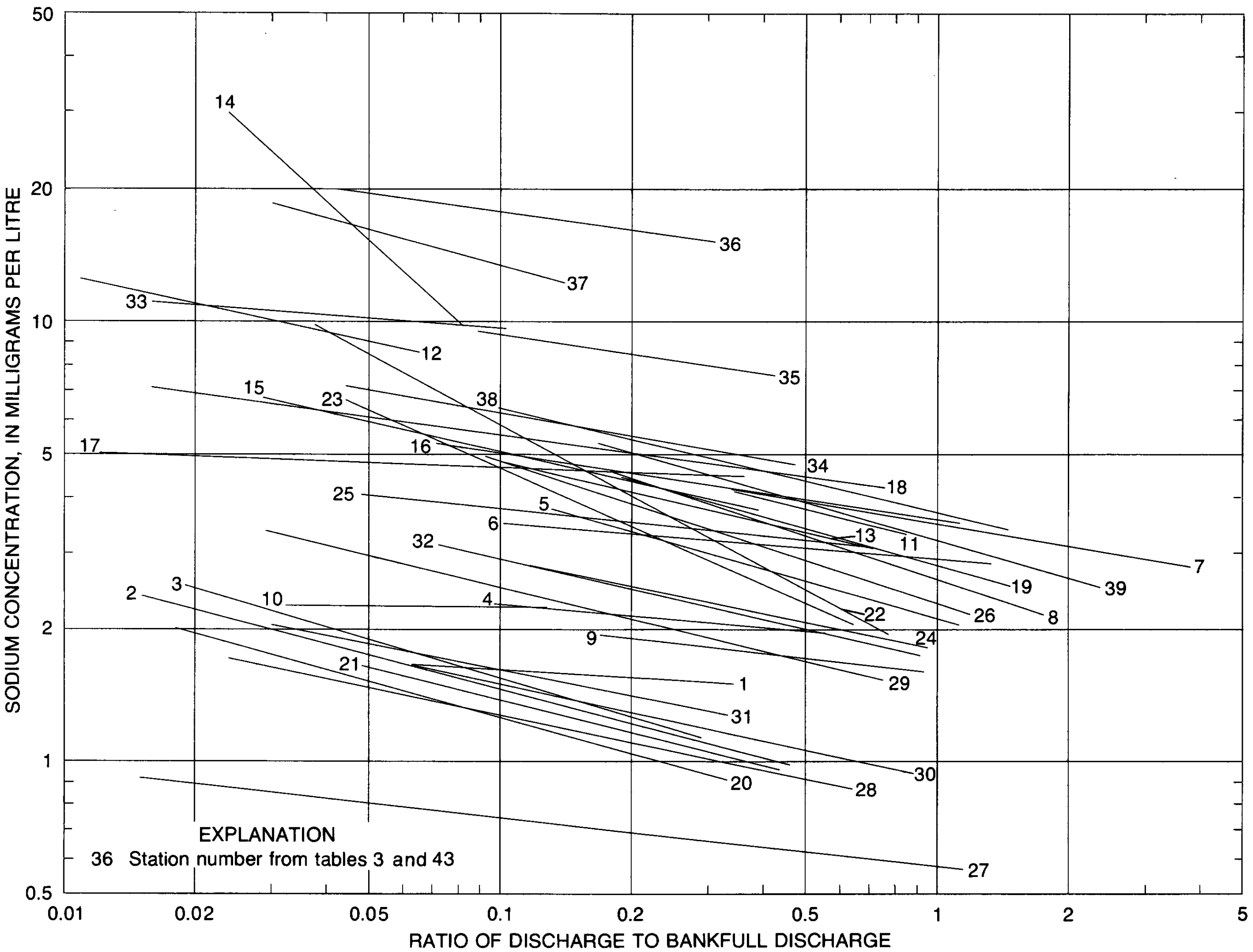

FIGURE 44.—Sodium concentration as a function of discharge ratio.

minerals and its ready release from mineral surfaces in the presence of water, dissolved silica concentrations in stream waters do not decrease with increases in streamflow as rapidly as the major ion concentrations. Thus, stream waters are likely to have near constant values of silica concentration regardless of discharge.

Table 28 is a summary of regression equation data for silica as a function of discharge. A number of the individual water-data stations show a very slight increase in silica concentration with increases in streamflow, but the majority show slight decreases. An average value for the slope of the silica-discharge relation is -0.05, and the median value of correlation coefficient is 0.78. The data of table 28 are graphically represented in figure 50 and show the nearly constant value of silica content as a function of discharge.

The variation of silica content in stream water just mentioned has been observed before. Kennedy (1971) showed in an analysis of water from several stream channels that as streamflow increased, some of the streams increased in silica concentration, others decreased, and in still others the trend was uncertain. His explanation is that silica concentrations are higher in water that seeps through the soils (subsurface flow) than in either overland flow or in ground water. During a stream rise, silica decreases initially, while overland flow comprises much of the streamflow and then increases as subsurface flow becomes the major component of streamflow. With decreasing discharge, ground water becomes an increasing proportion of streamflow, and silica concentration slowly decreases. Thus, correlation between silica and stream discharge is poor during storm runoff.

In the present study area, however, storm runoff is secondary to spring snowmelt as the source of increases in discharge. Snowmelt is relatively gradual, and it can be assumed that during the spring rise in the runoff hydrograph, water is reaching the stream channels in a

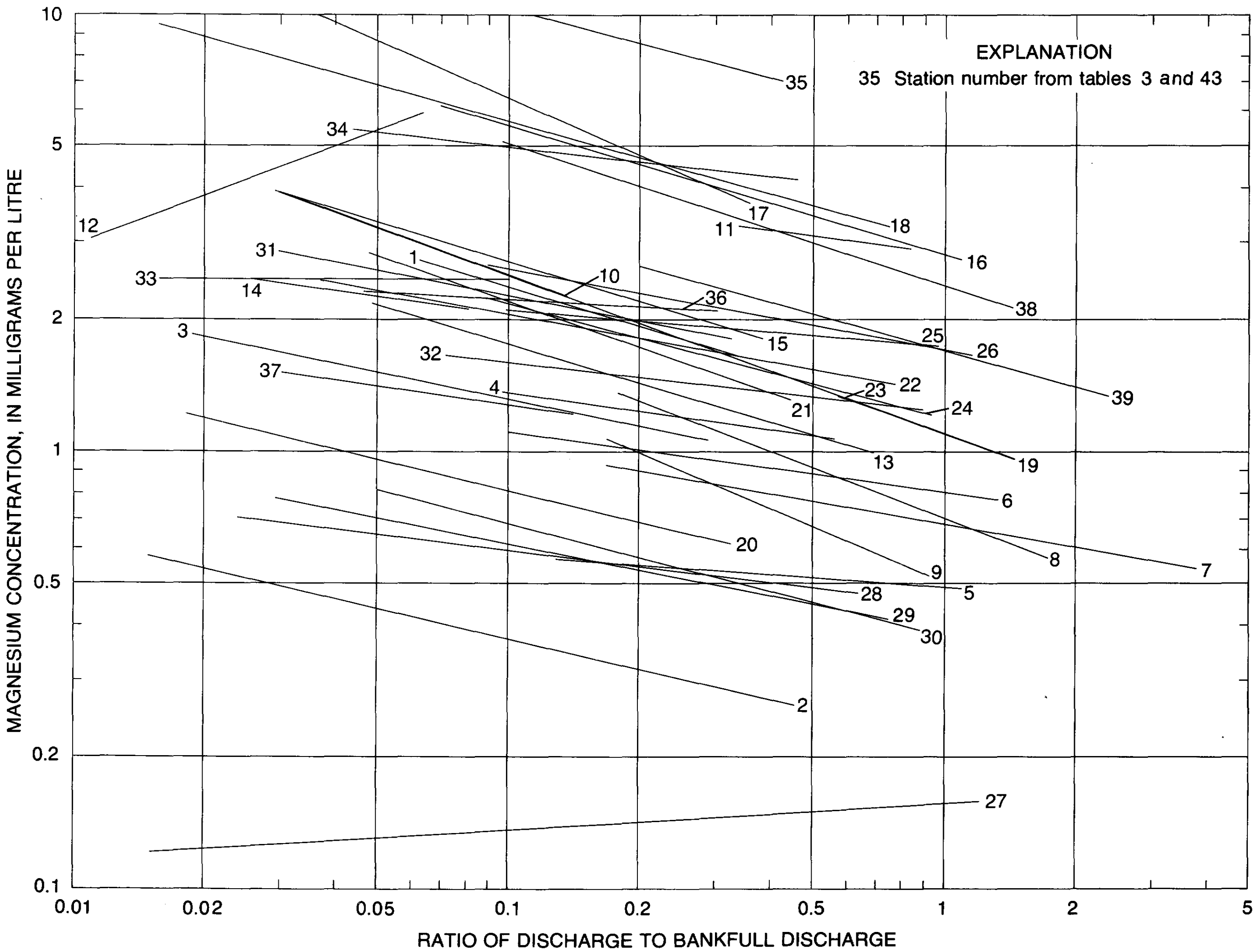

FIGURE 45.—Magnesium concentration as a function of discharge ratio.

TABLE 28.—*Summary of log-transformed regression data of silica as a function of discharge*

Graph plotting No.	U.S. Geological Survey station No.	Correlation coefficient, *r*	Slope of silica and Q/Q_B relation	Value of silica	
				Bankfull (Q/Q_B=1.0)	Mean annual (Q/Q_B=0.25)
1	13–2922.00	−0.827	−0.058	9.2	10
2	2924.00	−.966	−.127	5.4	6.5
3	2932.00	−.991	−.090	19	21
4	2934.00	−.784	−.111	12	14
5	2950.00	−.368	−.078	10	11
6	2960.00	−.917	−.063	18	19
7	2960.00	−.917	−.063	18	19
8	2965.00	−.777	−.210	12	15
9	2970.00	−.950	−.189	11	14
10	2971.00	.732	.028	22	22
11	2972.50	.102	.009	14	14
12	2973.00	.454	.021	29	28
13	2973.10	−.240	−.016	18	19
14	2973.20	.736	.138	33	27
15	2973.30	.322	.008	19	19
16	2973.40	−.566	−.032	26	27
17	2973.50	.906	.069	24	22
18	2973.60	−.649	−.017	24	25
19	2973.80	−.764	−.106	12	14
20	2973.84	−.809	−.096	3.8	4.3
21	2973.88	−.778	−.081	5.2	5.8
22	2973.96	−.923	−.153	6.2	7.7
23	2974.00	−.872	−.173	5.6	7.1
24	2974.04	−.878	−.076	11	12
25	2974.18	−.716	−.026	18	19
26	2974.25	−.453	−.043	9.7	10
27	2974.40	.396	.080	3.3	3.0

TABLE 28.—*Summary of log-transformed regression data of silica as a function of discharge* —Continued

Graph plotting No.	U.S. Geological Survey station No.	Correlation coefficient, *r*	Slope of silica and Q/Q_B relation	Value of silica	
				Bankfull (Q/Q_B=1.0)	Mean annual (Q/Q_B=0.25)
28	2974.45	−.839	−.130	6.8	8.1
29	2974.50	−.632	−.121	9.1	11
30	2974.80	−.795	−.136	6.7	8.1
31	2974.85	−.804	−.112	11	13
32	2975.00	−.486	−.084	11	13
33	2975.50	.930	.078	30	27
34	2976.00	.325	.017	14	14
35	2976.70	−.925	−.123	31	37
36	2976.80	−.420	−.047	39	41
37	2977.00	.096	.005	38	38
38	2980.00	−.840	−.101	11	12
39	2985.00	−.712	−.073	13	14
Mean			−.056	----	----
Median		−.778	−.076	----	----

consistent manner. This manner provides for an almost constant value of silica which may be in near equilibrium with the rock type and water temperature. Low values of silica content, such as data line 17 in

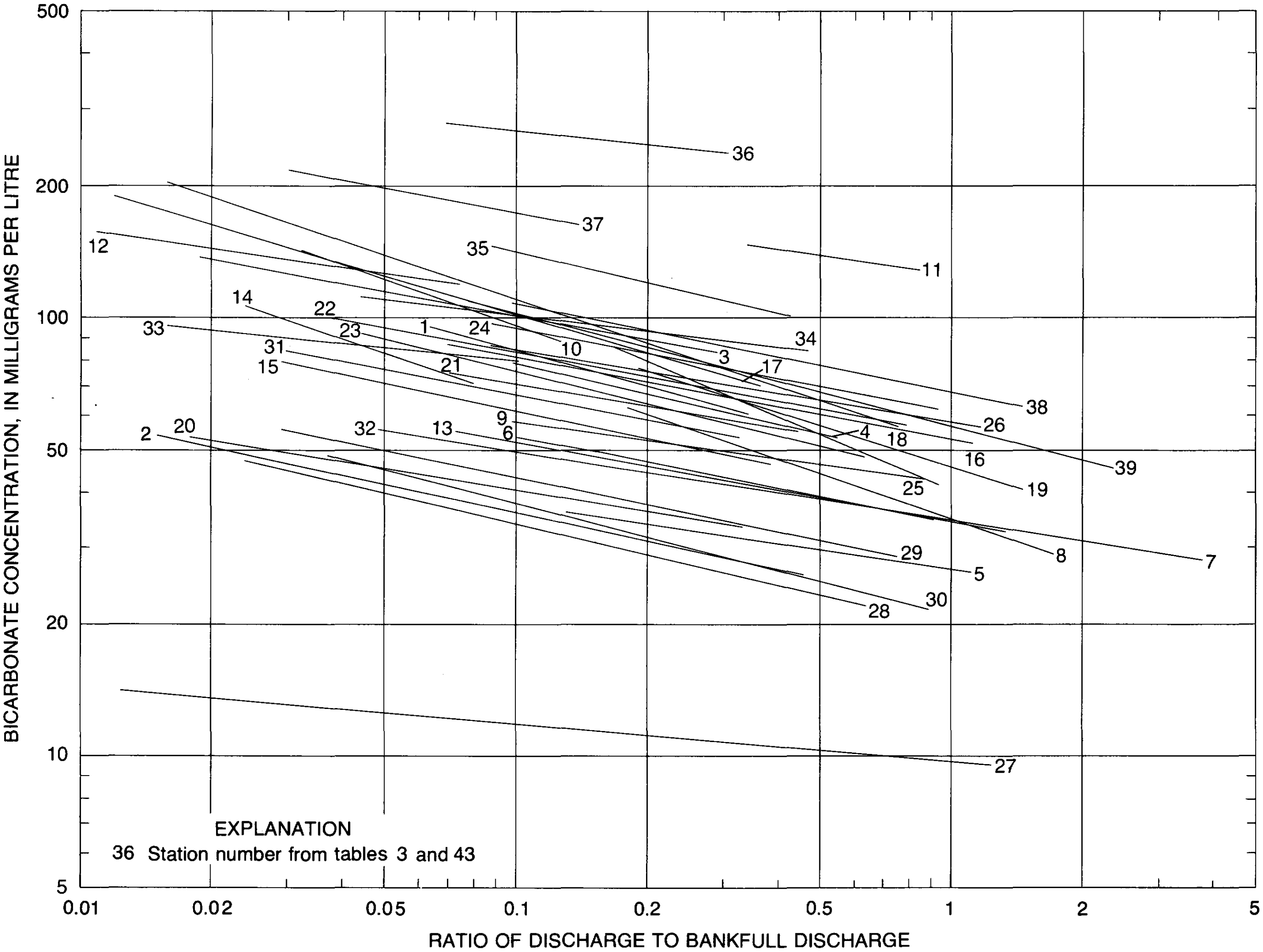

FIGURE 46.—Bicarbonate concentration as a function of discharge ratio.

figure 50, indicate a less soluble silica source in the quartz-rich environment in upper Little Boulder Creek. High values of silica content, such as data lines 35–37, indicate a more soluble silica source in the amorphous silica environment of Road Creek drainage. In both of these examples and for intermediate values of silica content, concentrations of silica are nearly constant with changes in discharge.

NUTRIENTS

Although nitrogen and phosphorus may be found in rocks, a significant source of their presence in stream waters is due to byproducts of biological processes. Further, both nitrogen and phosphorus are essential nutrients for plant growth. For these reasons, nitrogen and phosphorus are frequently labeled as nutrient constituents rather than major or trace ions, though certainly they would fall in one of the latter categories also.

Nitrogen is usually present in soil or biological matter, and oxidation of nitrogenous materials generally produces nitrite and nitrate. Nitrite is seldom present in amounts large enough to influence the ionic balance, and in the present study nitrite and nitrate ions are combined in terms of an equivalent concentration of elemental nitrogen. Nitrogen concentrations are included in table 40, and for 15 selected water-data stations, details of regression-equation analyses of nitrogen concentration as a function of discharge are presented in table 44.

Phosphorus is more common in rock than nitrogen, but like nitrogen the most important sources for the element in stream water are animal metabolic waste, decaying vegetation, and cultural application by man, especially fertilizer application where irrigation is practiced. The more common phosphorus ion is the orthophosphate anion. Orthophosphate ions in terms of equivalent concentrations of elemental phosphorus and

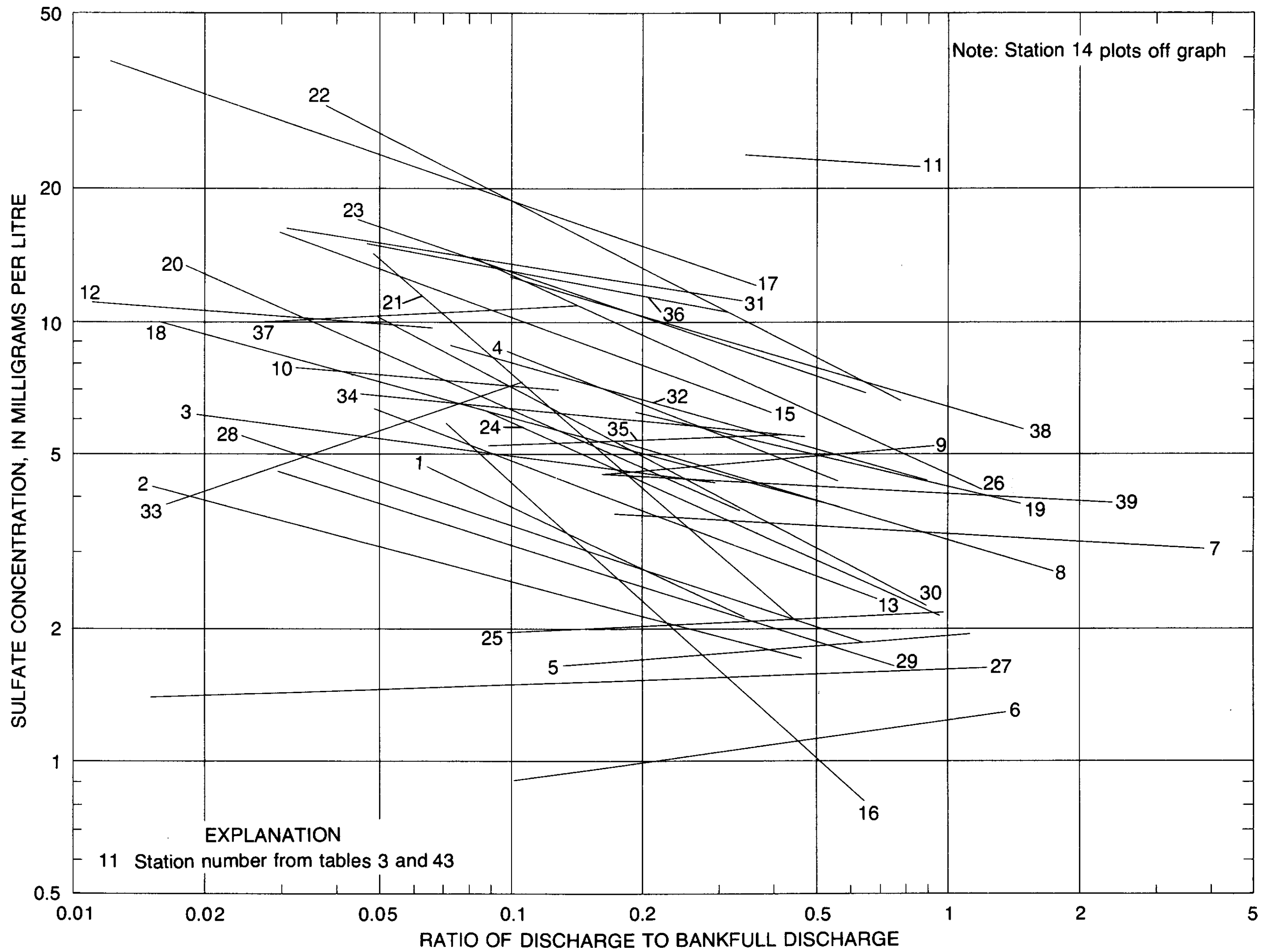

FIGURE 47.—Sulfate concentration as a function of discharge ratio.

concentrations of total phosphorus are presented in the same "Summary of Data" as for nitrogen.

Because nitrogen and phosphorus in stream waters are more dependent on what may be considered mobile sources (biological and man-related activity) rather than stationary sources (rock types), concentrations of these nutrients in stream waters are somewhat erratic. Water samples from a given water-data station may show a range from zero to significant levels of nutrients. Regression relations to discharge are less meaningful for nutrients than other ionic concentrations. For examples, a spring application of fertilizer may give highest phosphate concentrations in stream water during spring floods; likewise, low flows of late fall may show higher concentrations of nitrate than low flows of early fall because of the nitrogen input from decay of seasonal organic matter. For these reasons, regression analysis data in table 44 indicate some streams have positive relations of nutrient contents to discharge and others have negative relations. For nitrite and nitrate expressed as nitrogen, the average concentration varies with discharge to the 0.14 power. For orthophosphates as phosphorus, the value of this exponent is 0.19, and for total phosphorus, the exponent is 0.13. All these average values indicate a positive relation of nutrients to discharge, but the relation is reversed at a number of streams.

As noted by Hem (1970), aquatic vegetation of the free-floating types, such as algae, depends on dissolved nitrogen and phosphorus compounds for its nutrient supply. Growth of these species may also be influenced by the availability of other required elements. Dense, rapidly multiplying algal growths or blooms sometimes occur in water bodies that periodically receive increased concentrations of nitrogen or phosphorus. These dense growths are generally undesirable to water users and may interfere with other forms of aquatic life, especially if the water body becomes overloaded with oxidizable debris as a result of the sudden dieback of an algal bloom.

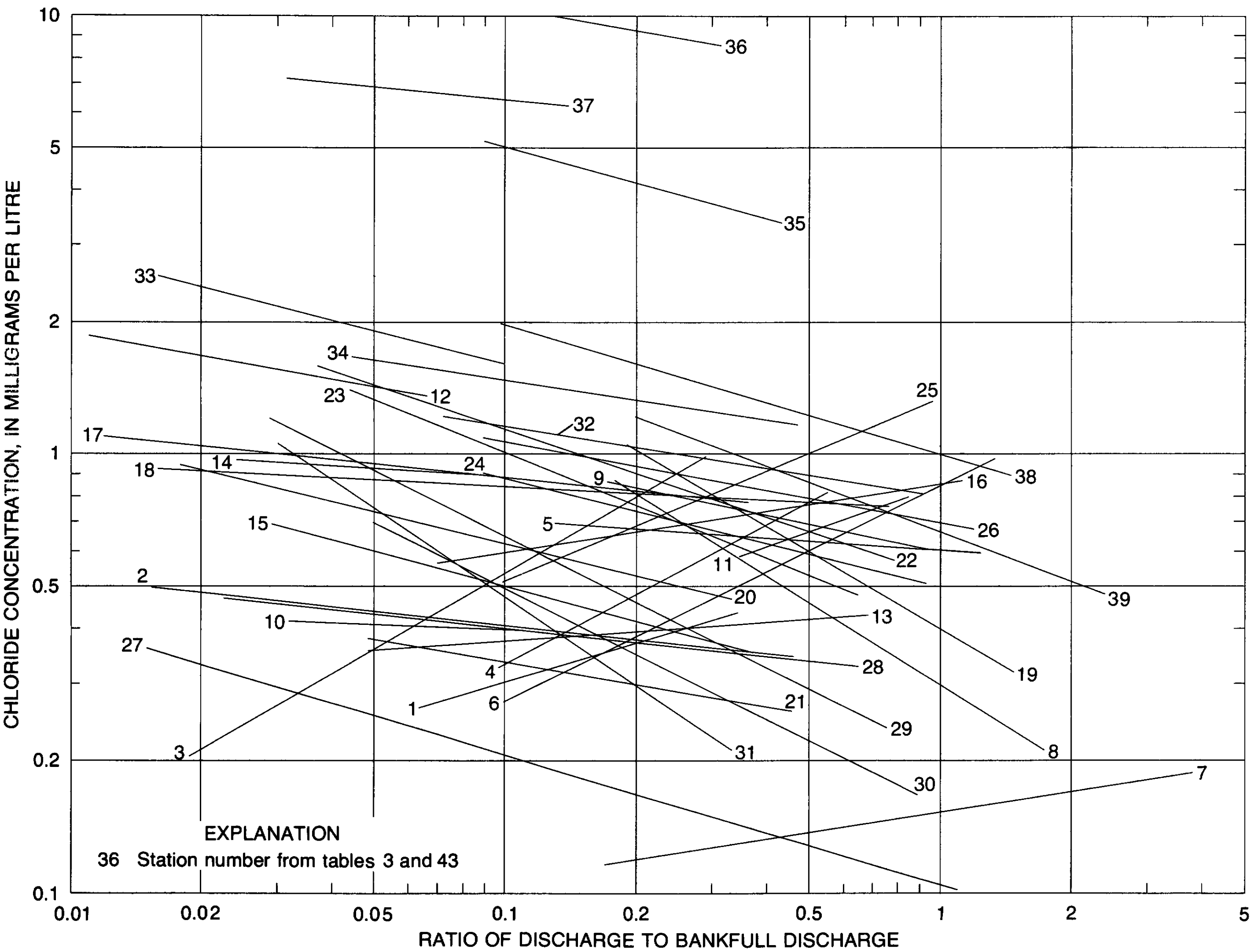

FIGURE 48.—Chloride concentration as a function of discharge ratio.

The enrichment of a water body with nutrients is termed "eutrophication" by limnologists and is accompanied by a high rate of production of plant material in the water. Troublesome algal production within the study area occurred only along Pat Hughes Creek, tributary to Thompson Creek, in the period of February to April 1972. High flows occurring in late May flushed the stream not only of any causative constituents, but also of most evidence of the algal growth itself. This flushing action occurred before water samples were collected for analysis, but not before local residents documented the algal growth with a photographic record. However, the data in table 40 for the four water-data stations 13–2973.12 to 13–2973.20 provide some information for determining the cause. Station 13–2973.12 is located on Pat Hughes Creek at a headwater location. Station 13–2973.14 records discharge water from a mine adit being blasted into a hard-rock slope adjacent to Pat Hughes Creek, and station 13–2973.16 records runoff water from a stilling pool to which the adit water is directed. The algal growth was observed only downstream of these stations. Station 13–2973.20 is on Pat Hughes Creek about 1 mile downstream from the influx of the stilling-pool water. Data of June 11, 1971, for station 13–2973.20 indicate water-quality characteristics of Pat Hughes Creek before mine blasting operations; nutrient and other chemical-characteristic values may be considered normal. The later data of 1971 show increasing concentration of chemical constituents, but allowing for normal low-flow concentrating, only the increased values for nitrogen and sulfate are significant. The June 29, 1972, data show normal quality characteristics on Pat Hughes Creek upstream of the mine blasting but for the adit and stilling-pool waters, show high concentrations of nitrogen and sulfate. Although the downstream Pat Hughes Creek station indicates dilution of the sulfate and nitrogen, it can be inferred that the mine adit waters were responsible for the algal growth. The sudden influx of nitrite- and nitrate- concentrated

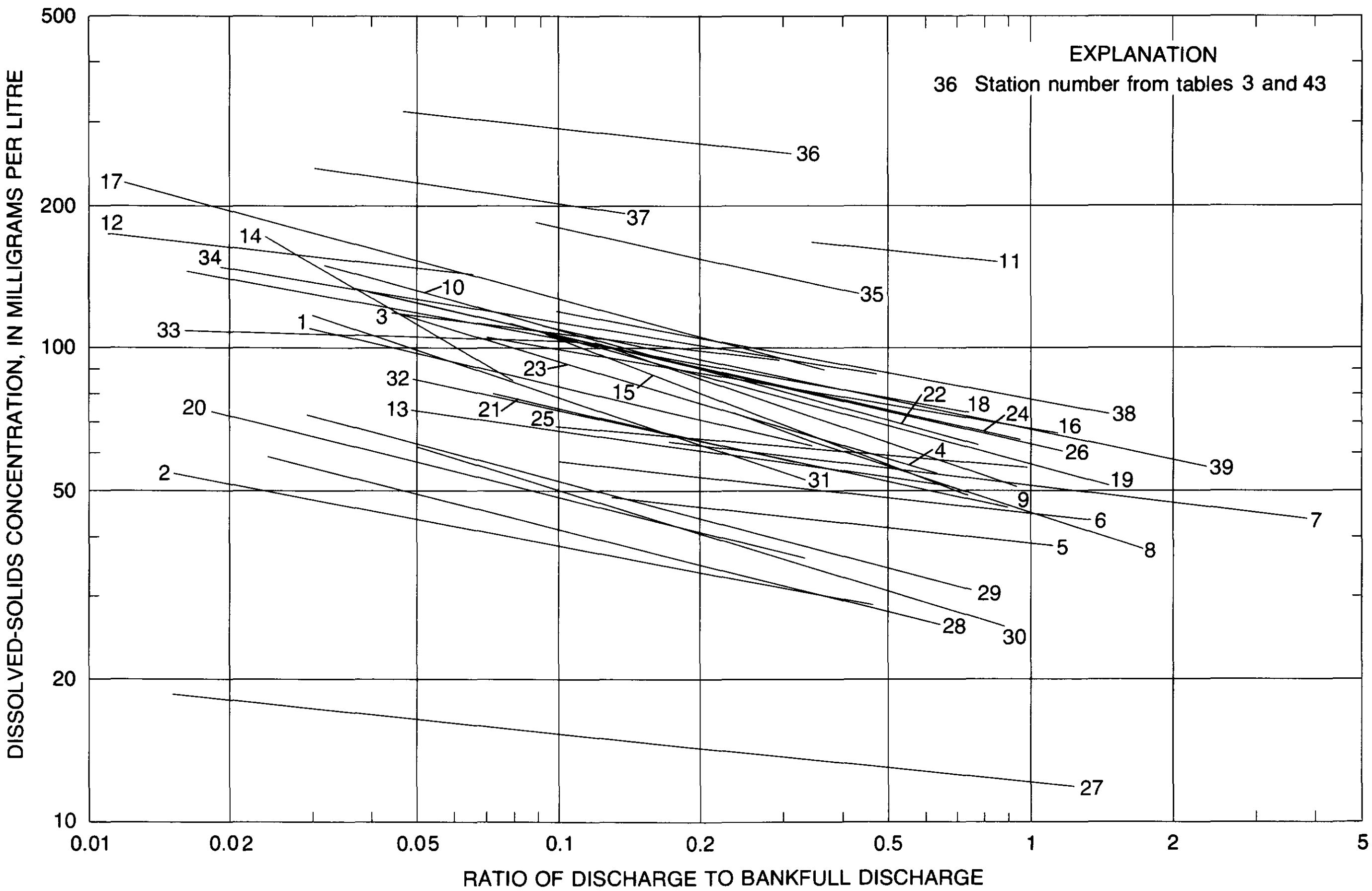

FIGURE 49.—Dissolved solids as a function of discharge ratio.

water, the higher pH and temperature of the adit water, and the primary algal growth season of early spring are all factors contributing to the healthy growth of algae. The nitrogen source for the adit waters was not identified, but suspected sources would include nitrate content of explosives used in blasting.

ALKALINITY AND HARDNESS

Chemical analyses commonly include the concentration of those anions contributing to alkalinity, and these are most generally assumed to be bicarbonate and carbonate. In the stream waters of the study area, bicarbonate is the primary ion contributing to alkalinity, which is most often expressed as milligrams per litre of calcium carbonate. Bicarbonate can be converted to equivalent concentration of calcium carbonate by multiplying the former by 0.82. Thus, within the study area, values of alkalinity are 0.82 values of bicarbonate. Accordingly, alkalinity varies as the −0.21 power of discharge, the same as for bicarbonate.

Hardness is a chemical property of water to which many people refer. Most often it is related to the effects of sudsing (or lack of sudsing) observed in the use of water with soap. Most of these effects are associated with the presence of calcium and magnesium. It is conventional to consider hardness as calcium plus magnesium hardness and to express the results as total hardness in terms of an equivalent concentration of calcium carbonate. Values of total hardness are included in table 40, and details of the regression-equation analyses are included in table 44. Total hardness varies with discharge to the −0.28 power for the 15 stations included in table 44, and this value, along with the high values of correlation coefficient, reflect the predictable amounts of calcium ions found in the water.

A scale for evaluating hardness is a relative matter. Persons living in areas of water with low dissolved-solids content might consider waters found elsewhere hard, while residents of the other location might consider the same waters soft based on their experience. Hardness in water used for ordinary domestic purposes does not become particularly objectionable until it reaches a level of about 100 milligrams per litre. Waters within the study area generally are softer than this level.

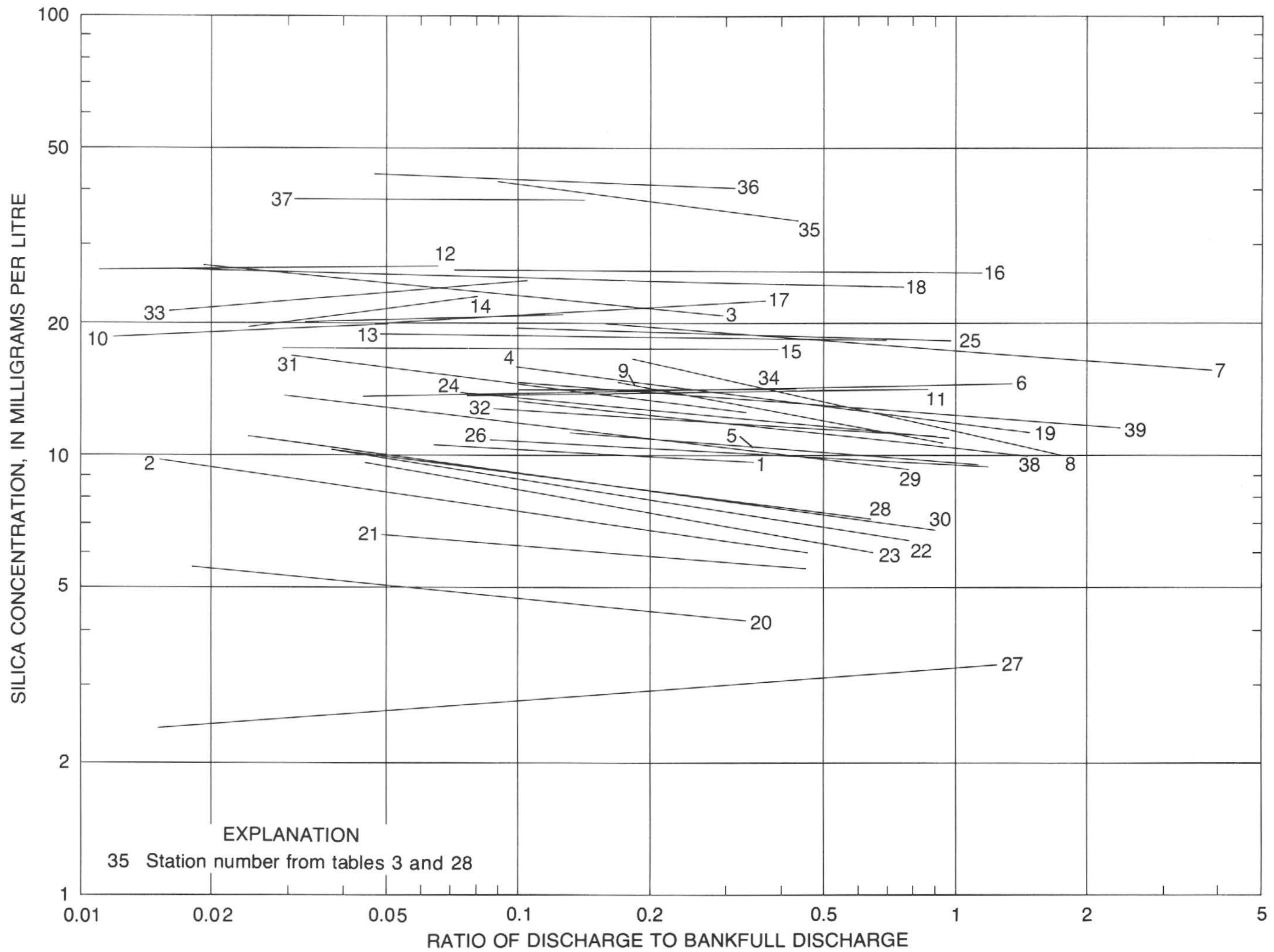

FIGURE 50.—Silica concentration as a function of discharge ratio.

AREAL COMPOSITION OF STREAM WATER

The analysis of the principal constituents of stream water, especially the regression analyses of each chemical parameter as a function of discharge, lends itself to a regional portrayal of the composition of the stream water. For example, from the graphs in figure 42, for values of specific conductance as a function of discharge, values of specific conductance at any given value of the discharge ratio may be determined for each of the water-data stations. These values can then be plotted on an area map at the respective station locations, and equal-value lines of water quality can be assigned to the map on the basis of the value of the plotted data points.

The author (Emmett, 1972b) has prepared an atlas with a series of 19 such maps, each portraying one of the parameters of a standard chemical analysis and also including suspended-sediment and turbidity data. This atlas includes only data collected in 1971, but the data of 1972 reinforce the validity of the 1971 data rather than conflict with it.

The preparation of such maps involves (1) the selection of a discharge ratio for which water-quality parameter values are to be selected and (2) following the laws of contouring in assigning equal-value lines to the data. It was decided that mean annual discharge (approximated by a value of discharge ratio equal to 0.25) would be as meaningful a value of discharge as could be selected. Higher values of the discharge ratio would typically provide overly dilute concentrations for the parameters, and lower values of the discharge ratio would typically be the reverse. It should be noted that this technique for selecting representative values of the water-quality parameters has inherent advantages over the widely used system of presenting data for low flow or high flow. Inspection in figures 42–50 of the end points of the range in discharge indicates that if the

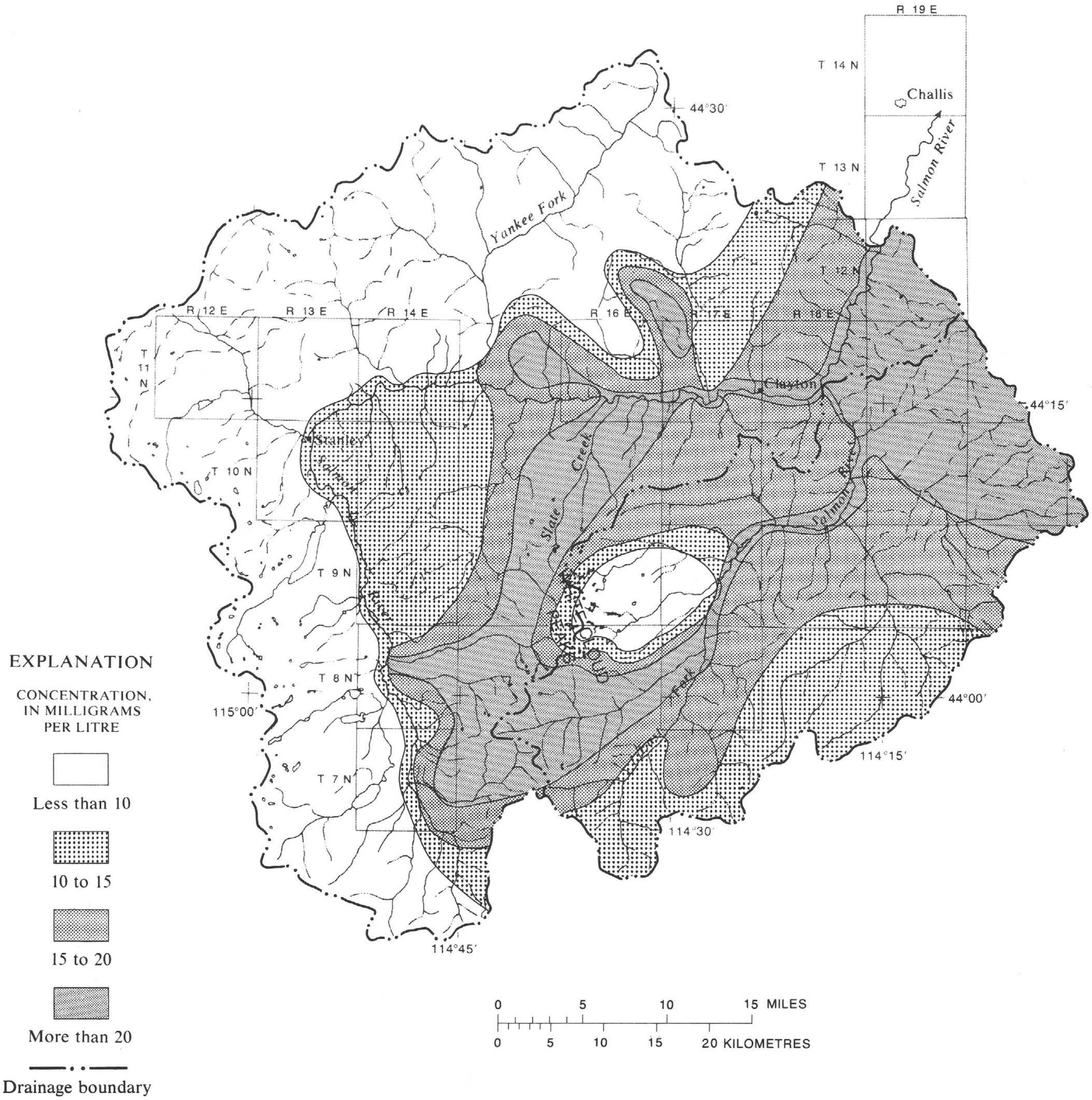

FIGURE 51.—Areal concentration of calcium in streams at mean annual discharge.

latter method had been chosen, low-flow data would actually cover a range of the discharge ratio from 0.01 to 0.34 and the high-flow data would cover a range of discharge ratio from 0.06 to 3.8. Such ranges in the discharge ratio provide for a greater range in water-quality values at a given station than among stations at a given discharge. Thus, equal-value lines of water quality were assigned to the maps on the basis of the values of the water-quality parameters representative of mean annual discharge. As the equal-value lines trend away from the data positions, the accuracy in locating the lines decreases; however, the relations established between the equal-value lines and geology, especially in the better defined areas, allowed reasonable extrapolation of data.

Figures 51–56 are water-quality maps of the type presented in the atlas (Emmett, 1972b). Maps selected for inclusion here include the major cations of calcium

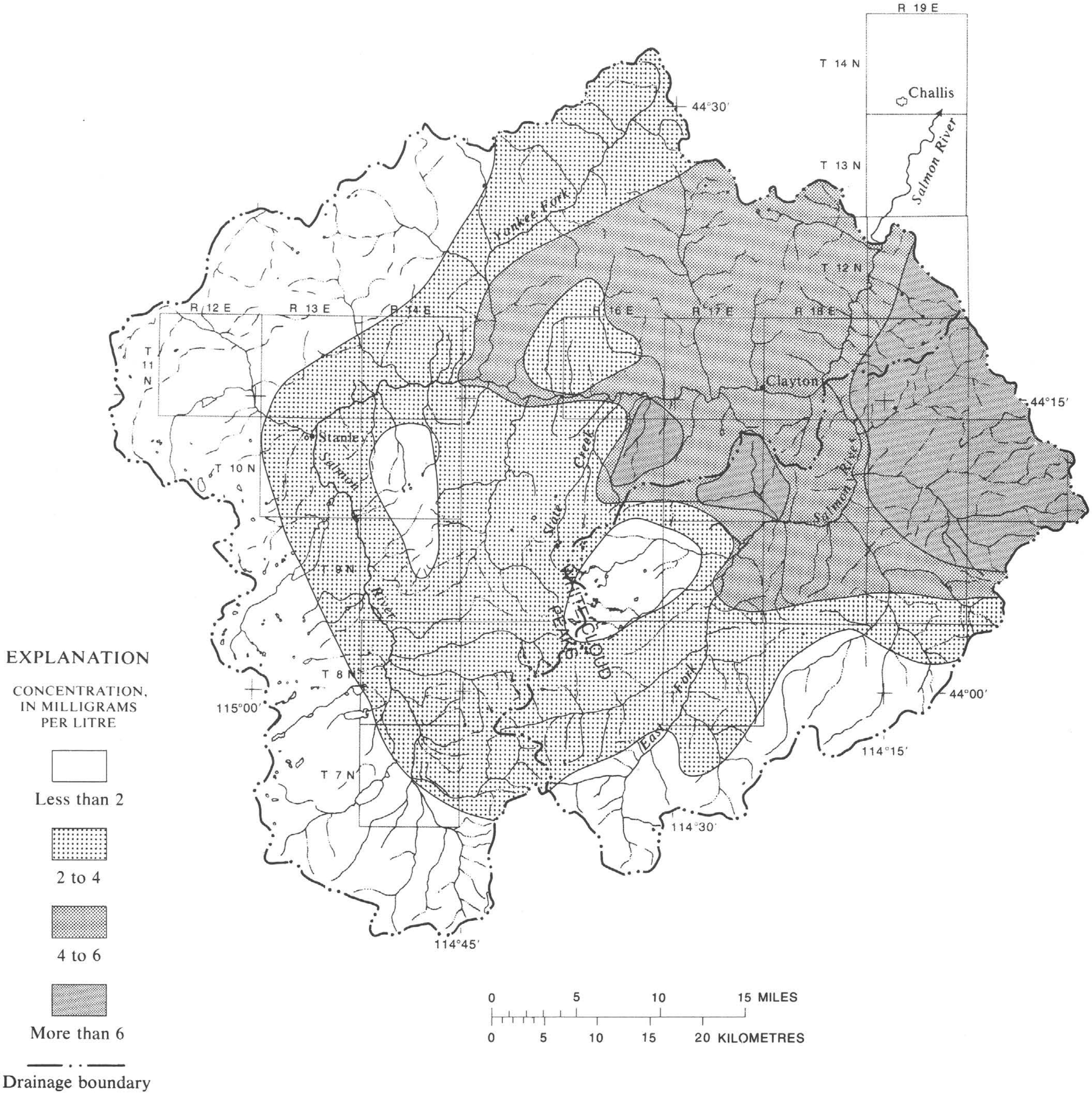

FIGURE 52.—Areal concentration of sodium in streams at mean annual discharge.

and sodium, the major anions of bicarbonate and sulfate, dissolved silica, and dissolved solids. Figures such as figures 43–47 show a strong tendency toward parallelism of the individual major ionic parameters versus discharge relations. If the parallelism were exact, the equal-value lines of water quality on maps such as figures 51–56 would, for any value of the discharge ratio, be identically located on the map but have different absolute values for the water-quality parameters, such as sodium or calcium. For the present data, as exemplified by the slight nonparallelism shown in figures 43–47, the configuration of maps of water quality for any discharge would be similar, but not identical, to the configuration as presented for mean annual discharge.

Maps showing equal-value lines for the chemical parameters occurring in less significant amounts than the major ions would not necessarily bear any re-

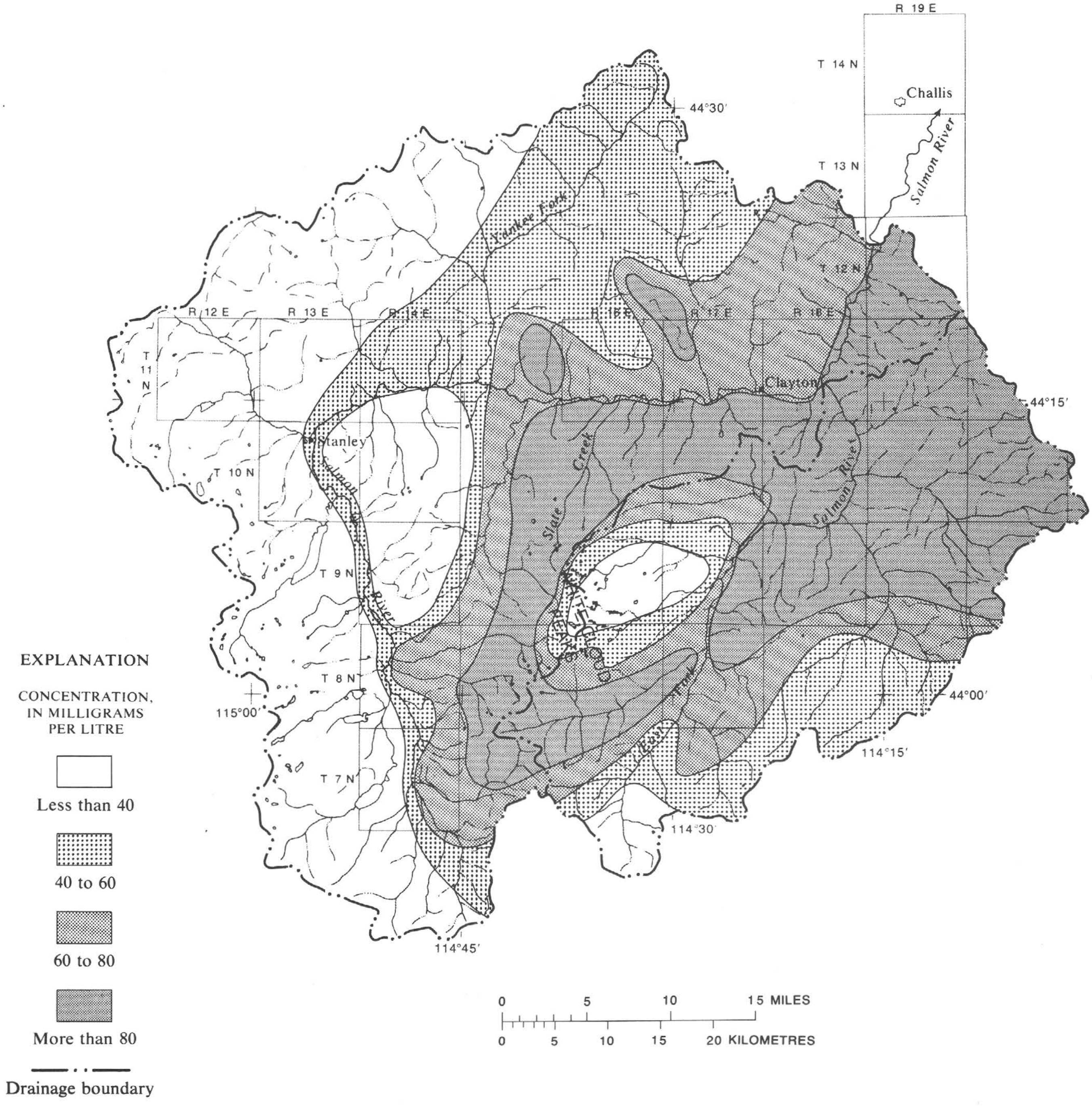

FIGURE 53.—Areal concentration of bicarbonate in streams at mean annual discharge.

semblance to the trend established in figures 51–56. For example, a map of phosphate values might bear more resemblance to a map illustrative of fertilizer use than to a geologic map. Further, a map of phosphate at small values of the discharge ratio might bear no resemblance to a map prepared for large values of the discharge ratio because parallelism of the phosphate versus discharge relation for individual stations is nonexistent. Still, in the manner described, it is physically possible to prepare maps for any of the parameters, but because of the vagaries involved, maps for the lesser constituents are less physically significant. For details of these lesser constituents, the reader is referred to the original publication (Emmett, 1972b).

The maps of figures 51–56 indicate at a glance some of the characteristics of the major components of water quality in the upper Salmon River. Deviations in the quality can be related to the geology, topography, and,

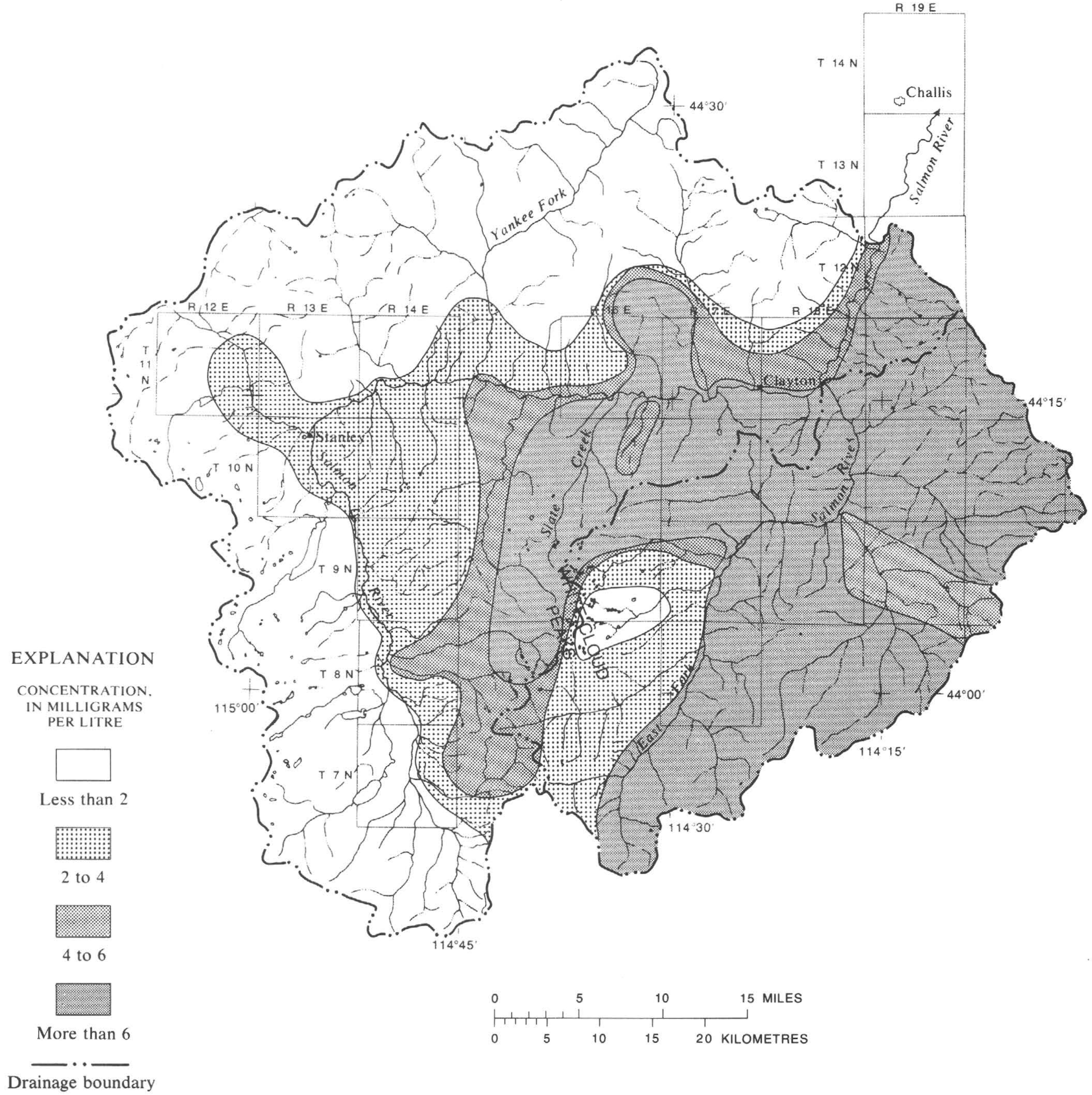

FIGURE 54.—Areal concentration of sulfate in streams at mean annual discharge.

to a certain extent, man-induced environmental impacts. The effect of geology is noted by the generally more dilute waters in areas of more resistant rock. Thus, areas of the Idaho batholith show lower mineral concentrations than areas of sedimentary rock. Topography has its greatest importance on the orographic effect of precipitation and, thus, on runoff and the dilution factor. Most striking is the eastward increase in mineral concentration as mean annual precipitation decreases. Man's impacts are most often very localized and are difficult to include on generalized maps such as figures 51–56.

TRACE-ELEMENT ANALYSES

No exact definition exists for trace element as it relates to constituents of stream water. Some investigators prefer to include only the eight most abundant elements (see table 24) as major elements, but these

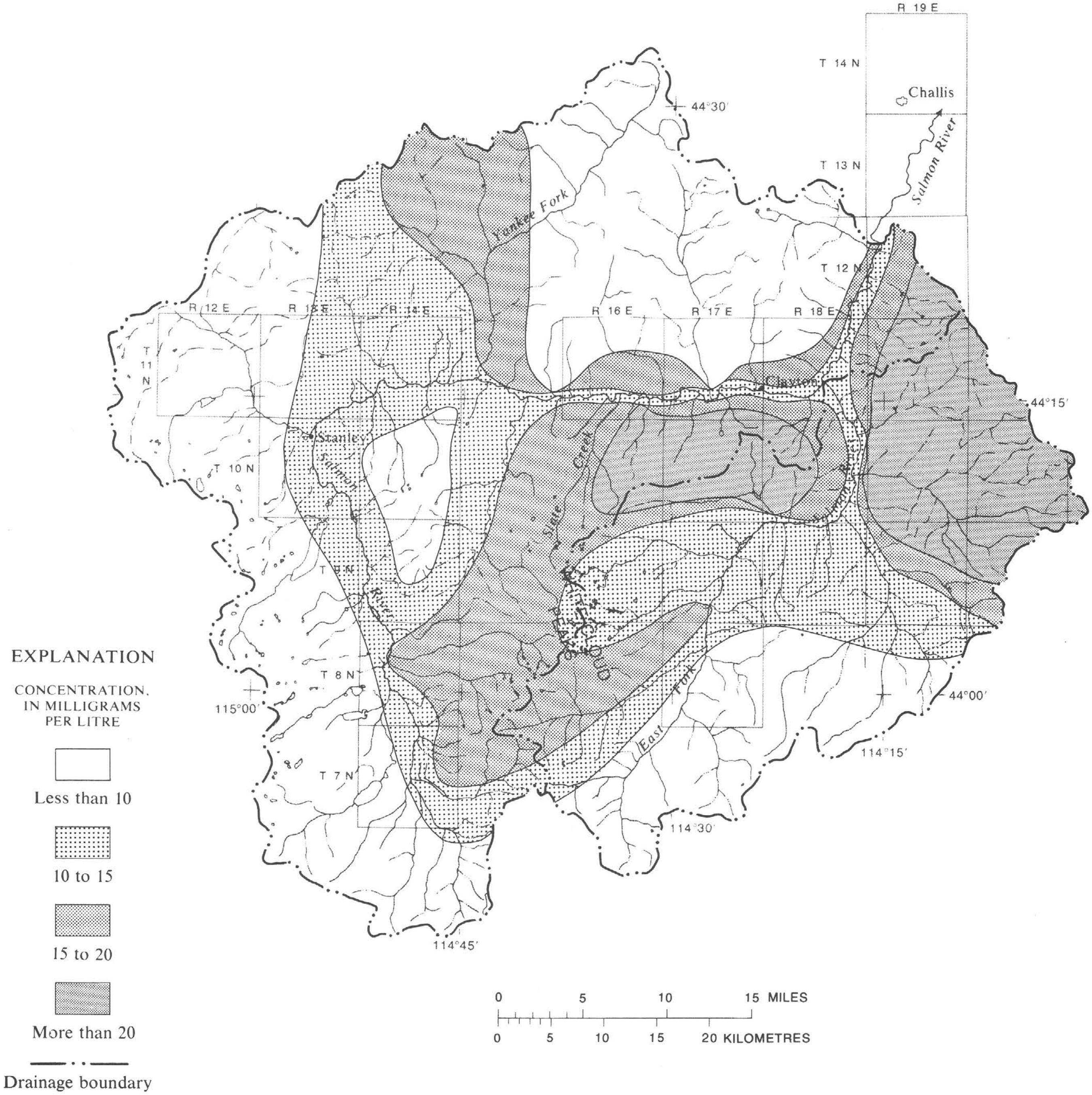

FIGURE 55.—Areal concentration of silica in streams at mean annual discharge.

include aluminum and iron, which are seldom found in greater than trace amounts in stream waters. Others prefer to include as trace elements those substances typically occurring in stream waters in concentrations of 1.0 milligram per litre or less, but these include chloride, fluoride, potassium, and other constituents which are commonly determined and considered major ions. In this study, those elements not routinely analyzed in the standard analyses (table 40) are considered trace elements. Concentrations of these trace elements, except in isolated and singular instances, were less than 1.0 milligram per litre; in fact, as will be shown later, the sum of the trace metals totals less than 1.0 milligram per litre in most samples.

No part of a water-quality study is more singularly time consuming and expensive, both in the field and the laboratory, than the analyses for trace elements. Yet, these are the data which indicate relations between

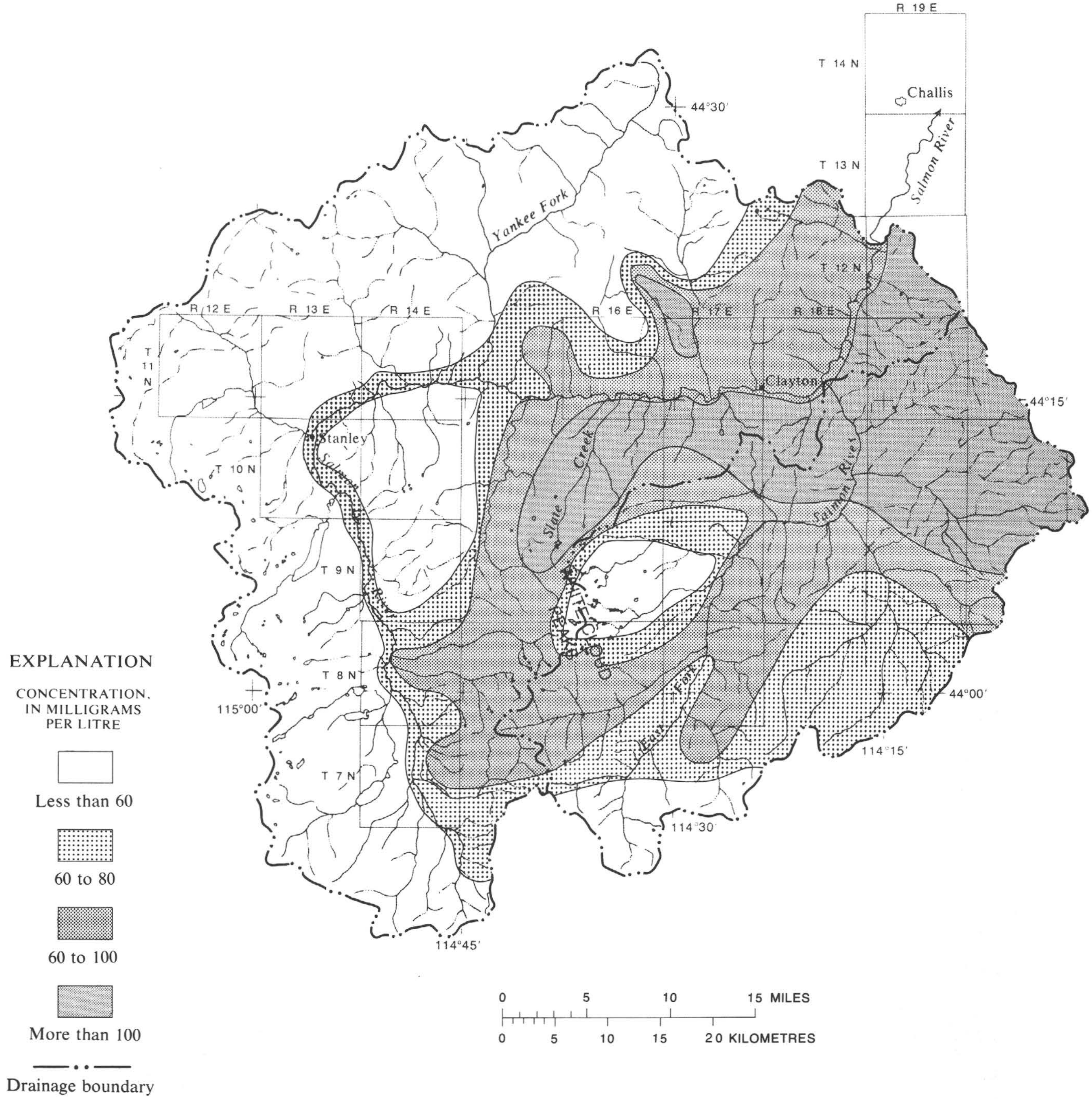

FIGURE 56.—Areal concentration of dissolved solids in streams at mean annual discharge.

water composition and environmental degradation, either through water pollution or natural conditions. A summary of the trace-element determinations from the present study is included as table 41. It should be noted that the concentrations of trace elements are reported in micrograms per litre, or 1,000-fold smaller units than used for the major-ion data.

The occurrence of trace elements in surface water is considerably more random in time, space, and concentration than that of the major ions. The frequency of reported occurrence of the trace elements is given in table 29. Of the 21 elements for which analyses were made, all were detected in one sample or another. The elements found in the fewest number of samples were chromium, beryllium, and silver in 9, 10, and 12 percent of the samples, respectively. Though one could not predict that these elements would be found least frequently, the results are not surprising considering the posi-

TABLE 29.—*Frequency of reported occurrence of trace elements*

Element	Number of analyses	Analyses showing detectable occurrence		Locations showing detectable occurrence
		Number	Percentage	(Percentage)
Aluminum	113	70	61.9	100
Arsenic	103	53	51.5	100
Barium	111	28	25.2	83
Beryllium	111	11	9.9	75
Boron	106	64	60.4	100
Cadmium	112	49	43.8	100
Chromium	103	9	8.7	67
Cobalt	112	45	40.2	100
Copper	112	84	75.0	100
Iron	113	111	98.2	100
Lead	112	77	68.8	100
Lithium	103	46	44.7	100
Manganese	113	57	50.4	100
Mercury	99	72	72.7	100
Molybdenum	109	85	78.0	100
Nickel	112	89	79.5	100
Selenium	112	60	53.6	100
Silver	112	14	12.5	83
Strontium	113	112	99.1	100
Vanadium	110	84	76.4	100
Zinc	113	79	69.9	100
Total or average	2,304	1,300	56.4	96

tion of these elements in the earth's crustal abundance ranking in table 24. The trace elements most frequently found in the stream waters were strontium, iron, nickel, and molybdenum in 99, 98, 80, and 78 percent of the samples, respectively. The inclusion of molybdenum in this ranking might normally be surprising except for the known low-grade but widespread molybdenum deposits in the area. The exclusion of aluminum from the most-found element list is misleading, but the laboratory detection limits for aluminum is 10 micrograms per litre and for many of the other elements is 1 microgram per litre or less. Had values for aluminum concentrations of 1–10 micrograms per litre been reported, aluminum would have been one of the most frequently reported trace elements.

Of the 2,304 individual analyses summarized in table 29, 1,300, or 56 percent, indicated the presence of the element being sought. Alternative to such a statistical breakdown, the last column of table 29 shows the percentage of locations where at least two samples were collected and at least one of the samples included the sought element. There are 12 such locations. These data are somewhat surprising in that they indicate the elements are significantly more widespread in occurrence than they are consistent in occurrence. For example, chromium was the least found element and occurred in only 9 out of 103 samples. But the 9 samples in which it was found were collected at 8 of the 12 locations. Of the 21 trace elements analyzed, 17 were found at least once at all locations sampled. As a sort of average, data of table 29 indicate that about 96 percent of all locations would, at one time or another and to the level of the detection limits, indicate the presence of the 21 trace elements in stream water.

The range of concentration for each occurring trace element is summarized in table 30. The smallest values of concentrations of trace elements in table 30 generally imply the laboratory detection limit for each of the trace elements. For each 10 percentile of the samples analyzed for each element, the concentration for that element is given. At 0 percentile, the concentration for each element is 0 because analyses for each element included at least one sample for which the element was not detected (table 29). At 50 percentile, the concentration is the median concentration for the number of samples analyzed. Since 14 of the 21 elements have a nonzero concentration as the median concentration, two-thirds of the elements occur in over 50 percent of the samples. Values of concentration at 100 percentile are maximum values recorded for each element. It may be noticed that there is considerable difference in concentrations at the 90 percentile level and the maximum observed concentration. Since the 100 percentile column makes no allowance for a contaminated sample or an analytical error, values of concentration at the 90 percentile level may be considered more reasonable values of normally occurring maximum concentrations. Data at the 90 percentile level indicate that even if maximum concentrations for each element occurred in the same sample, and this is highly unlikely, the sum of the trace elements totals only about 1.0 milligram per litre. In most instances, therefore, this sum is well below 1.0 milligram per litre.

The preceding data indicate that the trace elements are not necessarily consistent in their occurrence. A further analysis can show the existence of any variation in concentration with discharge. In the manner of analysis for the major ions, table 31 is a summary of regression-equation data for iron concentration as a function of discharge. Iron was selected for the analysis because of its relative abundance in the earth's crust and the reported frequency of occurrence in stream waters. Data of table 31 do not show such a correlation; values of the slope exponent relating iron to discharge varied from +1.04 to −0.20, and the correlation coefficients are only moderate in value. Further, the value of iron concentrations at mean annual discharge is relatively consistent among stations and indicates the normal range of iron concentration in the study area.

On the advice of V. C. Kennedy (1973, written commun.), a similar analysis was conducted for dissolved strontium. Kennedy reasoned that although iron appeared useful for such analysis, it was a poor choice because its solubility in natural stream waters is very low. A significant amount of the iron variation would probably be due to clays passing the filters during field preservation of the water samples. Similar problems would arise with aluminum. The regression data for the

TABLE 30.—*Trace-element concentration, in micrograms per litre, at selected percentiles of samples analyzed*

[0 = a concentration less than that detectable]

Element	Inclusive percentage of samples analyzed										
	0	10	20	30	40	50	60	70	80	90	100
Aluminum	0	0	0	0	10	10	100	100	200	400	1,500
Arsenic	0	0	0	0	0	1	2	2	4	6	106
Barium	0	0	0	0	0	0	0	0	100	200	4,500
Beryllium	0	0	0	0	0	0	0	0	0	0	30
Boron	0	0	0	0	10	10	10	20	20	30	80
Cadmium	0	0	0	0	0	0	1	1	1	1	4
Chromium	0	0	0	0	0	0	0	0	0	0	6
Cobalt	0	0	0	0	0	0	1	1	2	3	4
Copper	0	0	0	1	1	1	2	3	3	5	24
Iron	0	10	10	20	20	20	30	30	40	60	1,100
Lead	0	0	0	0	1	1	3	3	4	7	11
Lithium	0	0	0	0	0	0	7	10	12	17	70
Manganese	0	0	0	0	0	1	10	10	20	75	570
Mercury	0	0	0	.1	.1	.1	.1	.2	.2	.3	1.0
Molybdenum	0	0	0	1	2	2	3	4	5	8	34
Nickel	0	0	0	2	2	3	3	4	4	6	16
Selenium	0	0	0	0	0	1	2	4	6	10	66
Silver	0	0	0	0	0	0	0	0	0	1	1
Strontium	0	40	50	50	78	90	120	150	180	270	380
Vanadium	0	0	0	.2	.4	.8	.9	1.1	1.3	2.2	7.2
Zinc	0	0	0	0	10	10	10	20	20	40	170

TABLE 31.—*Summary of log-transformed regression data for iron concentration as a function of discharge*

U.S. Geological Survey station No.	Correlation coefficient, r	Slope of iron and Q/Q_B relation	Iron concentration in micrograms per litre	
			Bankfull (Q/Q_B = 1.0)	Mean annual (Q/Q_B = 0.25)
13–2950.00	0.576	0.557	85.9	40.0
2965.00	.538	.402	48.2	27.6
2975.50	.684	.516	98.1	48.0
2973.80	.916	.897	50.6	14.6
2974.25	.123	.065	14.5	13.3
2974.40	− .398	− .171	11.1	14.1
2974.45	− .559	− .199	16.2	21.3
2974.50	− .097	− .037	23.0	24.2
2974.80	− .213	− .131	13.7	16.4
2974.85	.478	.229	30.4	22.1
2980.00	.682	1.04	96.9	22.9
2985.00	.351	.378	58.2	34.5
Mean	----	.296	----	----
Median	.538	.229	----	----

TABLE 32.—*Summary of log-transformed regression data for strontium concentration as a function of discharge*

U.S. Geological Survey station No.	Correlation coefficient, r	Slope of strontium and Q/Q_B relation	Strontium concentration in micrograms per litre	
			Bankfull (Q/Q_B = 1.0)	Mean annual (Q/Q_B = 0.25)
13–2950.00	−0.427	−0.580	43	96
2965.00	− .554	− .698	29	76
2973.50	− .494	− .263	69	99
2973.80	− .258	− .139	74	90
2974.25	− .407	− .226	128	175
2974.40	− .260	− .222	38	52
2974.45	− .732	− .375	45	76
2974.50	− .367	− .134	88	106
2974.80	− .067	− .036	54	57
2974.85	− .443	− .272	31	46
2980.00	− .111	− .063	161	175
2985.00	− .625	− .541	52	110
Mean		− .296	----	----
Median	− .427	− .263	----	----

strontium analysis are presented in table 32. The results are considerably more consistent than the iron analysis, although the relations still show only moderate correlation. Values of the slope exponent relating strontium concentration to the discharge ratio are all negative and range in value from −0.04 to −0.70. The correlation coefficients range from nearly 0 to about 0.7. Values of the strontium concentration at mean annual discharge are consistent with the exception of the two East Fork Salmon River Stations (13–2974.25 and 13—2980.00). Data for these stations show a concentration of strontium about twice that of average and indicate that somewhere upstream of station 13– 2974.25, one or more tributary streams contained amounts of strontium that were unusual for the area.

In a similar analysis, the station Jim Creek above Livingston Mill (13–2974.85) indicated significantly higher levels of zinc than other locations (see table 41). Further study indicated that past mining in the area involved a zinc-enriched ore. The zinc was not removed as part of the milling operation, and zinc-enriched tailings, as well as the original zinc ore body, became sources of extraordinary amounts of zinc in the surface waters. To a considerable extent, this zinc content in the waters can be traced through the remaining three downstream water-data stations.

STREAM BIOTA

Biological observations and sample collections of freshwater life were made at 30 locations. These locations and a brief description of each site are given in table 20. The biological surveys were started in 1972, and during the period of July to October, as many as three visits were made to each site. These studies are continuing; because the field studies are incomplete and laboratory identification and analyses of samples already collected are even more incomplete, the following is only a brief discussion of the nature and techniques of the study and a tentative indication of stream quality based on the aquatic biota observed.

The purpose of the biological survey was to determine the types of aquatic life at selected stream locations and to note any condition in the aquatic life that reflected a change in water quality. A measure of the water quality or healthiness of the stream is indicated by the relative population sizes of the three major groups of organisms; namely, algae, invertebrates, and insects. In natural, healthy streams a large number of species is present, and generally total populations are large. Conclusions relative to stream healthiness are drawn from the kinds and numbers of species which form the majority of the biota.

As described by Patrick and Grant (1971), in healthy conditions where nutrient levels are low, the algae population is primarily diatoms; there is an assortment of insects with the larger population being mayflies, caddisflies, and stoneflies, and there are several invertebrate species including some worms, although their number is small. As streams become overenriched with nutrients, patches of blue-green algae appear along with some filamentous green algae. Snails may also become more plentiful. With organic pollution of the stream water, the diatoms become less common, and flatworms may become very common. If toxic conditions exist in the stream, flatworms disappear, mayflies become rare, and the species of caddisflies shift. As toxicity increases, the total number and diversity of species decrease.

The moving waters of streams offer a variety of aquatic environments as discharge increases in the downstream direction. This variation includes temperature, types of substratum and soils over and through which the water flows, areas of sunshine and shade, and successions of riffles, falls, and pools. To provide a representative sampling of the environments, the sampling locations in table 20 include all slope aspects or directions of stream drainage. Within this division of locations, further division by stream order assures all sizes of streams being sampled. Further, first-order stream locations include sites above and below lakes as well as several sites just below snowpack origins of first-order streams.

To assure representative sampling at each stream location, several techniques were employed. The most comprehensive was dip-net sampling of the biota from rocks, logs, plants, and debris as well as sifting mud, sand, and gravel from the stream-bottom material. A drift net placed in a representative reach of streams collected floating organisms. Seston sampling collected even microscopic living and nonliving bodies of plants or animals floating in the water. Rocks selected from the stream bottoms were cleaned of organisms, and plankton and algae samples were collected. Several types of artificial substrates were left in the streams to be collected on each succeeding visit. These visits were timed to coincide with seasonal variations in stream biota. Complete details of the sampling procedures are discussed by Slack, Averett, Greeson, Lipscomb (1973).

Data thus far indicate that stream waters in the area are generally healthy. As indicated by the data in table 40, nutrient levels in stream waters are low to only slightly enriched. Algal growths and blooms present few problems. The total number and diversity of aquatic biota species indicates general stability in the chemical constituency of the stream water and near-ideal concentrations of the chemical contents. Preliminary identification of organisms indicate that stonefly, mayfly, and caddisfly dominate, and these groups are indicative of healthy conditions. Likewise, preliminary identification indicates that predominant organisms at some locations deviate somewhat from the dominant types just mentioned. For example, at Big Boulder Creek near Clayton (station 13–2975.00), a generally smaller diversity and population of species indicated some imbalance in stream habitat. Initially, it was supposed that upstream ore-processing activities—the zinc enrichment previously noted—were responsible. Subsequent investigations showed healthy stream conditions only a short distance upstream in the same channel, and a more reasonable explanation appears to be that unnatural bank sloughing associated with road construction was responsible. As another example, the west-flowing streams of Road Creek and Herd Creek drainages indicate a higher, though still low, level of organic content than the east-flowing streams of Big and Little Boulder Creek drainages. Though not definitive, the higher levels of organic content are probably related to more intense grazing activity in Road Creek and Herd Creek drainages than elsewhere. Both of these examples of stream waters deviating from generally healthy characteristics should be considered tentative until further laboratory analyses and field data verify the results. They are included here as examples of the usefulness of biological observations in water-quality studies. It is apparent that when the full results of the biological studies become available they will amplify the validity of water-quality determinations based on the chemical quality alone.

OTHER BIOLOGICAL OBSERVATIONS

Several other types of biological measurement add to the overall evaluation of water quality. Table 33 gives data for dissolved oxygen, total organic carbon, and fecal and total coliform bacteria. Data are available for five water-data stations, and these stations coincide

TABLE 33.—*Summary of microbiological, dissolved oxygen, and organic carbon parameters for five water-data stations*

U.S. Geological Survey station No.	Date	Discharge, Q (ft³/sec)	Temperature, T (°C)	Coliform (colonies per 100 ml)	Fecal coliform (colonies per 100 ml)	Field dissolved oxygen (mg/l)	Percent saturation	Total organic carbon (mg/l)
13–2974.40	6–23–70	73	1.5	11	0	10.6	105	----
	8–27–70	3.2	11.0	40	1	7.8	98	----
	10–13–70	2.2	.0	0	0	10.6	101	----
	6–29–71	18	1.0	0	0	10.5	103	----
	8–31–71	4.3	11.0	220	0	----	----	----
	10– 5–71	.89	5.5	14	0	9.8	109	----
	6–20–72	27	1.5	0	0	9.5	95	0.0
	7–18–72	18	9.5	1	0	8.0	97	1.0
	8–29–72	3.8	10.0	0	0	7.7	96	.0
	10– 3–72	1.5	2.0	0	0	9.7	98	----
13–2974.45	6–23–70	172	3.5	152	0	10.4	107	----
	8–27–70	13	9.5	22	3	8.6	101	----
	10–13–70	7.0	.0	4	0	10.6	98	----
	6–29–71	82	2.5	3	0	10.6	106	----
	8–31–71	17	9.5	55	6	----	----	----
	10– 5–71	8.1	5.5	18	0	10.0	107	----
	6–20–72	104	2.5	1	0	9.7	96	.0
	7–18–72	61	9.5	11	0	9.0	106	.0
	8–29–72	13	10.0	12	5	8.0	95	.0
	10– 3–72	6.5	2.5	0	0	9.9	98	.0
13–2974.50	6–24–70	198	7.0	----	36	10.2	104	----
	8–28–70	14	10.5	37	37	9.3	104	----
	10–12–70	9.4	5.0	4	1	10.3	101	----
	6–28–71	120	7.0	30	0	9.9	103	----
	8–30–71	19	11.0	72	3	8.7	99	----
	10– 6–71	12	5.5	9	2	9.8	98	----
	6–20–72	107	6.5	8	1	9.1	92	.5
	7–17–72	66	10.5	3	0	8.0	91	.0
	8–30–72	16	10.0	8	1	8.8	96	1.0
	10– 2–72	9.0	5.0	1	0	10.0	98	1.5
13–2974.80	6–22–70	164	7.0	----	1	9.5	103	----
	8–26–70	13	11.5	----	154	8.5	102	----
	10–12–70	9.3	3.5	0	0	10.4	102	----
	6–28–71	82	3.5	5	0	10.3	101	----
	8–31–71	21	11.0	25	3	----	----	----
	10– 6–71	6.9	2.0	8	1	10.7	103	----
	6–19–72	71	5.5	0	0	9.4	97	.0
	7–18–72	46	11.5	1	0	7.8	120	1.0
	8–29–72	16	11.0	0	0	8.2	96	.0
	10– 3–72	11	5.0	0	0	10.0	102	.0
13–2974.85	6–22–70	26	8.5	----	2	9.2	104	----
	8–26–70	3.1	10.0	545	111	8.6	100	----
	10–12–70	2.4	3.0	0	0	10.5	102	----
	6–28–71	17	3.0	5	1	10.3	101	----
	8–31–71	3.7	8.5	160	2	----	----	----
	10– 6–71	3.6	2.0	16	4	10.5	100	----
	6–19–72	17	5.0	1	0	9.4	96	.0
	7–18–72	9.9	9.5	22	0	8.7	135	.0
	8–29–72	4.4	10.0	6	1	8.5	96	1.0
	10– 3–72	3.5	3.5	0	1	9.9	98	1.5

with stations for which major-ion and trace-element analyses are available and at which stream-biota observations were made.

The source of most oxygen in stream water is the atmosphere, but some is contributed as a byproduct of photosynthesis. Streams in which there is considerable organic productivity often have wide fluctuations of dissolved oxygen in response to biological activity. The dissolved-oxygen content of stream water is an indication of the biochemical condition of the water, and desirable stream biota require high dissolved-oxygen levels at all times. Owing to the rapidly changing input and consumption rates, the oxygen content of a stream is highly variable and meaningful only for the location and time of sampling. Values of dissolved oxygen in table 33 expressed as concentration in milligrams per litre are variable; however, the solubility of oxygen in water is primarily a function of temperature and pressure. In terms of percentage of saturation, values of dissolved oxygen in table 33 indicate all data are centered around 100 percent saturation. Because the data are consistent at near-saturation values, they are considered to be transferable to most other locations in the study area. Thus, dissolved oxygen does not appear to be deficient in the studied streams.

Recent developments indicate that measurements of total organic carbon provide a more comprehensive indication of organic pollution in streams than measurements of dissolved oxygen. The few measurements of total organic carbon in table 33 show concentrations ranging from 0.0 to 1.5 milligrams per litre. These concentrations are not excessive and like the dissolved-oxygen data indicate that organic pollution is not a problem in the streams sampled.

One of the dangers in considering stream water as safe for drinking is that it may have been recently contaminated by waste of human or animal fecal origin. The danger is that water so contaminated contains pathogenic organisms which are carriers of such infectious diseases as dysentery. The organisms most commonly used as indicators of pathogenic pollution are fecal coliform bacteria and the coliform bacteria group as a whole. Fecal coliform bacteria are superior to total coliform as indicators of pathogenic contamination of water because the latter group includes organisms not necessarily of fecal origin. They have no sanitary significance as they can come from soils and vegetation.

Fecal- and total-coliform data, expressed as colonies per 100 millilitres of water sampled, are included in table 33. With few exceptions, fecal-coliform colonies per 100 millilitres were either 0 or very small. It is not possible to tell if the fecal coliform colonies present are of human or animal origin. Although the number of fecal-coliform colonies counted is very small, waters with fecal bacteria cannot be recommended for drinking without some purification. In reality, the water is much purer than most natural water swimming areas frequented by millions of recreationists every year. As mentioned, the total-coliform count is not as significant as the fecal-coliform count. Although total-coliform colonies are considerably higher than fecal-coliform colonies, the number of colonies is few enough to indicate no serious problems. Most likely, the coliform data could be extrapolated to indicate that pathogenic quality may improve in the upstream direction and degrade in the downstream direction. The first three stations in table 33 are in downstream order and tend to verify this trend, but the data are so few that this trend should be considered as speculative.

SUSPENDED SEDIMENT

Unlike dissolved solids, which tend to have only a severalfold range in values of concentration over a wide range in discharge, suspended sediment commonly has more than a 1,000-fold range in concentration. Also, unlike dissolved-solids concentrations, sediment concentrations are generally higher during high flow than during low flow. For a given value of the discharge ratio, differences in values of suspended-sediment concentration between locations are largely dependent on the rock and soil types and such factors as erodibility. At high values of discharge, the increased competence of a stream to transport sediment is important only to the extent that sediment is available for transport. Owing to extremes of erodibility rates among soil types and man-induced impacts on natural erosion rates, concentrations of suspended sediment for a given value of the discharge ratio are highly variable among locations.

Table 42 presents all suspended-sediment data collected during the study. Because suspended-sediment concentrations within the stream commonly are variable both laterally and vertically, the values of suspended-sediment concentration in table 42 are actually composite values obtained from at least three verticals in each section. Thus, the composite values may be considered representative for the discharge. Because suspended-sediment concentrations are also extremely variable with discharge, the composite values should be further considered instantaneous values and representative only of the respective discharge. For a given discharge, many streams show a difference in suspended-sediment concentration depending on whether the water stage is rising or falling. Data of this report are too few to define a hysteresis for suspended-sediment concentrations, and values of the concentration may be considered intermediate of any hysteresis effect.

Suspended-sediment samplers utilized were the DH–48 for wading measurements and the D–49 for cable measurements. Details of these samplers and sampling techniques have been described by Guy and Norman (1970).

Commonly, values of instantaneous suspended-sediment concentrations are plotted as a function of discharge to obtain a type of sediment rating curve. Although only two data points are required to develop such a curve, the data are usually so variable that reliance can be placed only where several data points describe the same curve. Of the 39 water-data stations in table 42, 20 stations have at least six values of suspended sediment. For these 20 stations, table 34 includes details of log-transformed regression-equation analyses for the suspended-sediment concentration as a function of the discharge ratio. The curves described by these regression-equation data are shown in figure 57. This illustration shows at a glance which of the data stations have the highest suspended-sediment concentrations for a given value of the discharge ratio. For the 20 stations in figure 57, water-data stations 11, 31, and

TABLE 34.—*Summary of log-transformed regression equation data for suspended-sediment concentration as a function of discharge*

Graph plotting No.	U.S. Geological Survey station No.	Correlation coefficient, *r*	Slope of suspended-sediment concentration and Q/Q_B relation	Value of suspended sediment (mg/l)	
				Q/Q_B=1.0	Q/Q_B=0.25
5	13-2950.00	−0.069	−0.045	4.3	4.6
8	2965.00	.938	1.352	18.1	2.8
9	2970.00	.933	1.872	74.4	5.6
11	2972.50	.934	4.926	2,770	3.0
17	2973.50	.724	1.127	107	22.5
19	2973.80	.858	1.507	34.9	4.3
22	2973.96	.878	1.220	93.8	17.3
23	2974.00	.895	.985	75.5	19.3
24	2974.04	.960	2.038	262	15.5
25	2974.18	.953	2.239	320	14.4
26	2974.25	.912	1.501	50.7	6.3
27	2974.40	−.246	−.173	1.3	1.6
28	2974.45	.407	.229	4.2	3.1
29	2974.50	.923	1.089	89.6	19.8
30	2974.80	.761	.700	17.9	6.8
31	2974.85	.819	1.631	742	77.3
32	2975.00	.780	2.449	1,511	50.7
34	2976.00	.661	1.127	175	36.7
38	2980.00	.948	1.863	223	16.8
39	2985.00	.946	2.020	80.9	4.9

32 have the "dirtiest" water. Stations 31 and 32 are in Big Boulder Creek drainage area, and high values of suspended sediment are associated with road construction and maintenance practices, minor mining activity, and natural instability of soils on steep slopes of glacial origin. Station 11 is in Slate Creek drainage area, and high values are associated with channel instability resulting from an extremely rare flood in 1963, natural instability of the Milligan Formation within the area, and to a minor extent some mining-related activities.

Stations 5 and 27 in figure 57 indicate slightly negative slopes for the relation of suspended-sediment concentration to discharge. Both of these streams have a naturally low content of suspended sediment with concentrations borderline with analytical accuracy and large percentage errors. The statistical regression of data for stations 5 and 27 is misleading in indicating "cleaner" water at high discharges, and the data should be interpreted that for any discharge these stations have insignificant concentrations of suspended sediment.

Maps showing the areal concentration of suspended sediment were prepared by the author in the same manner described for the parameters of chemical composition (Emmett, 1972b). Figure 57 indicates that considerable differences would appear between maps prepared for concentration at mean annual discharge (Q/Q_B=0.25) and bankfull discharge. Because most suspended sediment is transported at high stages, the map prepared for bankfull stage would be the more appropriate to illustrate the presence of suspended sediment. Such a map is not presented here because extremely variable concentrations of suspended sediment create many difficulties in extrapolating between water-data station locations. However, the original map (Emmett, 1972b) isolated with a series of equal-value lines the areas of high suspended-sediment concentrations discussed.

Perhaps of more interest than the relation of suspended-sediment concentration to discharge is the relation of suspended-sediment load, *G*, to discharge. Table 35 provides the details of regression-equation techniques applied to the same data of table 34, with the results expressed as suspended-sediment load in tons per day. These relations are plotted in figure 58. In terms of Leopold and Maddock (1953), hydraulic-geometry values of the slopes of the lines in figure 58 are designated as the exponent *j*. Values of *j* range from 0.6 to 5.9, but an average value is 2.5. This value is the same as the average value determined for a number of streams in the midwest United States (Leopold and others, 1964). For further comparison, values of suspended-sediment load for each water-data station may be regressed against values of bankfull discharge to determine the downstream hydraulic geometry characteristics of suspended sediment. Such an analysis yields

$$G=0.89{Q_B}^{0.75} \quad (r=0.500).$$

Although the moderate value of the correlation coefficient indicates considerable scatter to the data, the downstream exponent of j=0.75 compares with an average value of j=0.8 for streams in the midwest United States (Leopold and others, 1964).

In figure 58, each successive downstream station must indicate a greater sediment load for a given ratio of Q/Q_B; otherwise, the inference is of sediment deposition in the channel. As an example, the curve (39) for the Salmon River at Challis (13–2985.00) envelopes the curve (19) for the Salmon River upstream of the East Fork (13–2973.80) which in turn envelopes the curve (8) for the Salmon River below the Yankee Fork (13–2965.00). Some minor irregularities to this pattern do exist and probably indicate that, locally, during the short period of sediment record (1971–72) some reaches of channel were aggrading and others were degrading. Such irregularities do not indicate that the Salmon River drainage is not in equilibrium (neither aggrading nor degrading), for equilibrium is thought of in terms of at least several years and of the channel's response to flows of a variety of magnitude and frequency.

One observation of suspended-sediment concentration is of unusual interest but alone provides information of uncertain usefulness. The data are for Malm Gulch (13–2983.00), an ephemeral tributary with a drainage area of 9.4 square miles and located in the semiarid extreme northeast of the study area. A flash

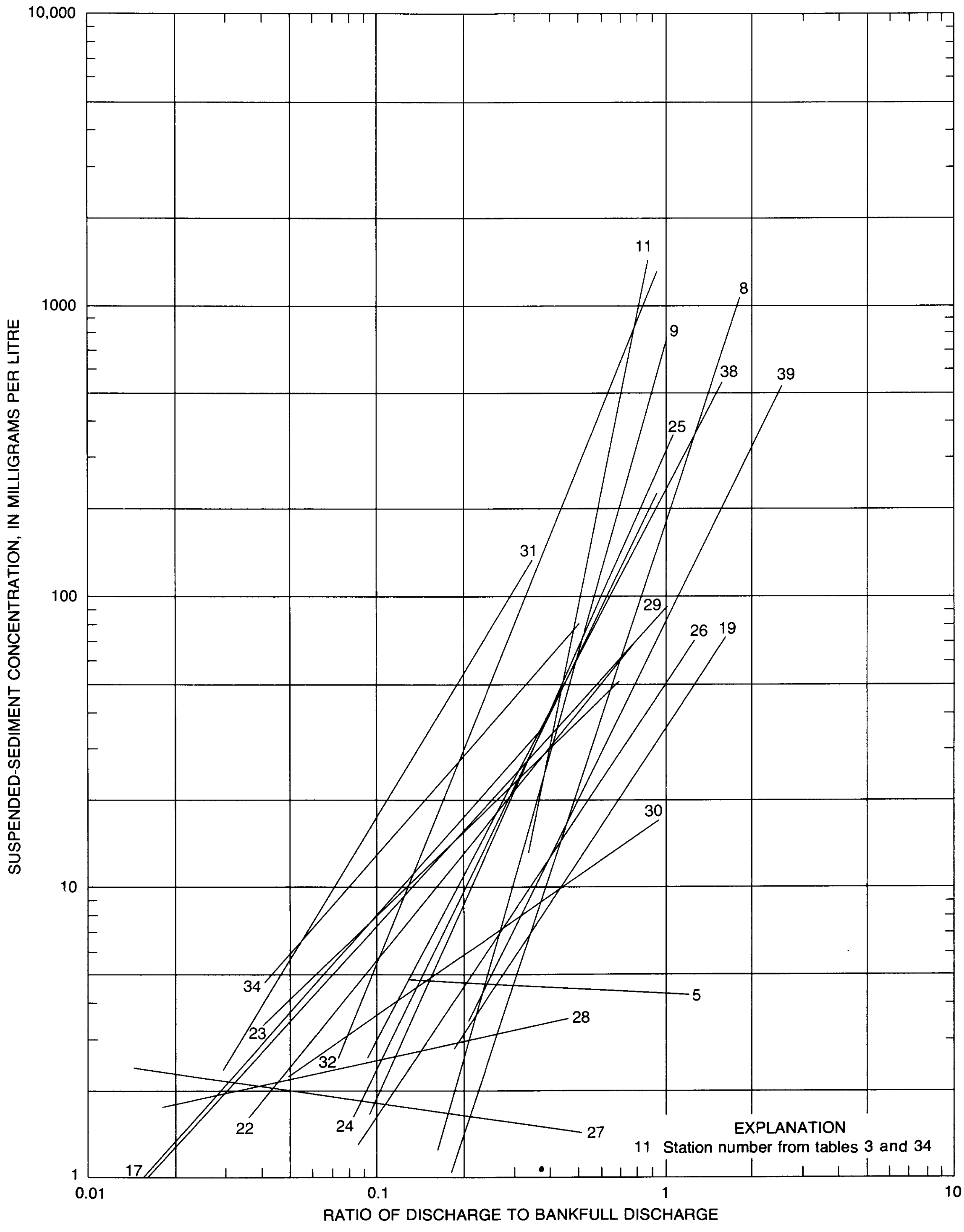

FIGURE 57.—Suspended-sediment concentration as a function of discharge ratio.

TABLE 35.—*Summary of log-transformed regression equation data for suspended-sediment load as a function of discharge*

Graph plotting No.	U.S. Geological Survey Station No.	Correlation coefficient, *r*	Slope, *j*, of suspended-sediment load and Q/Q_B relation	Value of suspended sediment (tons/day) Q/Q_B=1.0	Value of suspended sediment (tons/day) Q/Q_B=0.25
5	13–2950.00	0.829	0.955	11.6	3.1
8	2965.00	.979	2.353	1.83	7.0
9	2970.00	.970	2.864	121	3.5
11	2972.50	.953	5.924	892	.24
17	2973.50	.781	2.249	18.7	.83
19	2973.80	.941	2.506	482	14.9
22	2973.96	.962	2.230	55.7	2.5
23	2974.00	.969	1.956	180	11.9
24	2974.04	.982	2.669	182	4.5
25	2974.18	.978	3.267	58.4	.63
26	2974.25	.966	2.502	150	4.7
27	2974.40	.685	.620	.2	.06
28	2974.45	.901	1.208	2.9	.83
29	2974.50	.976	2.053	72.8	4.2
30	2974.80	.942	1.699	8.98	.85
31	2974.85	.911	2.651	167	4.2
32	2975.00	.869	3.433	891	7.6
34	2976.00	.802	1.967	222	14.5
38	2980.00	.977	2.868	1,116	20.9
39	2985.00	.977	3.079	1.169	16.4
Mean			2.452		
Median		.962	2.506		

flow resulting from a thunderstorm was measured indirectly to have a peak flow of 450 cubic feet per second. This corresponds to about the 10-year flood. Two measurements at about 4 cubic feet per second on the receding hydrograph indicated a suspended-sediment concentration ranging from about 112,000 to 245,000 milligrams per litre, or an average of about 180,000 milligrams per litre (table 42). The two samples were collected "simultaneously," and each represents a composite average across the channel. Prior to concentration analysis, the two samples appeared similar in the amount of settled solids. On the basis of estimated porosity and the volume percentage of sample settled, the smaller of the two concentrations is probably in error, but even if this smaller concentration of sediment persisted during the estimated four hours duration of flow, several tens of thousands of tons of sediment were supplied to the main-stem Salmon River. This amount of sediment is more than half the estimated average annual sediment yield from the entire East. Fork Salmon River tributary.

Ten of the analyses for suspended-sediment concentration included determination of particle-size distribution. Data of these particle-size distributions are included in table 36. Nominally, the median particle size is at about 0.06 millimetre, or at the break between silt- and sand-size particles. The median particle size, however, appears to be somewhat variable with discharge, and as discharge increases, the percentage of fine particles increases and the median particle size decreases.

In contrast to the silt-sand size distribution of suspended sediment included in table 36, the particle-size distribution for the samples from Malm Gulch indicate 90 percent of the sediment is silt size or finer and more than 50 percent is in the clay-size range.

TURBIDITY

Turbidity is an expression of the optical property of water that causes light rays to be scattered and absorbed rather than transmitted in straight lines and is caused by a variety of suspended particulate matter. Such matter may be living or dead plant and animal cells, silt, clay, or many other inorganic and organic waste materials. The resulting effect is to give a cloudy or opaque appearance to water.

Fine particulate materials in suspension limit the penetration of sunlight and thus restrict the growth of bottom and suspended plant life. The solids may also flocculate plant and animal life resulting in stream-bottom deposits of settleable solids and in a smothering and crushing action deleterious to benthic organisms. Food chains are interrupted, and all animal life becomes

TABLE 36.—*Particle-size distribution of suspended sediment*

Sieve size (mm)	Percentage finer than sieve size									
Station No.	13–29 72.50	13–29 75.00	13–29 80.00	13–29 80.00	13–29 80.00	13–29 80.00	13–29 85.00	13–29 85.00	13–29 85.00	13–29 85.00
Date	6–15–72	5–31–71	5–29–72	5–31–72	6–1–72	6–2–72	5–29–72	5–31–72	6–1–72	6–2–72
Discharge (ft³/sec)	109	63	1,380	2,250	2,700	3,170	7,200	10,500	12,300	13,600
Concentration (mg/l)	1,390	2,120	237	330	403	415	213	506	641	583
2.0	100									
1.0	99						100	100	100	100
.50	77		100	100	100	100	90	81	77	93
.25	60	100	90	92	92	94	58	61	65	73
.125	40	99	67	74	73	80	41	52	57	62
.0625	34	96	56	65	63	76	33	46	53	55
.0442	22	----				56			41	41
.0312	20	88				55			39	39
.0221	18	----				54			38	38
.0156	14	68				50			34	35
.0110	11	----				45			31	33
.0078	11	51				40			27	28
.0055	10	----				35			24	24
.0039	8	34				32			21	22
.0028	6	----				25			17	18
.0019	5	34				20			14	15

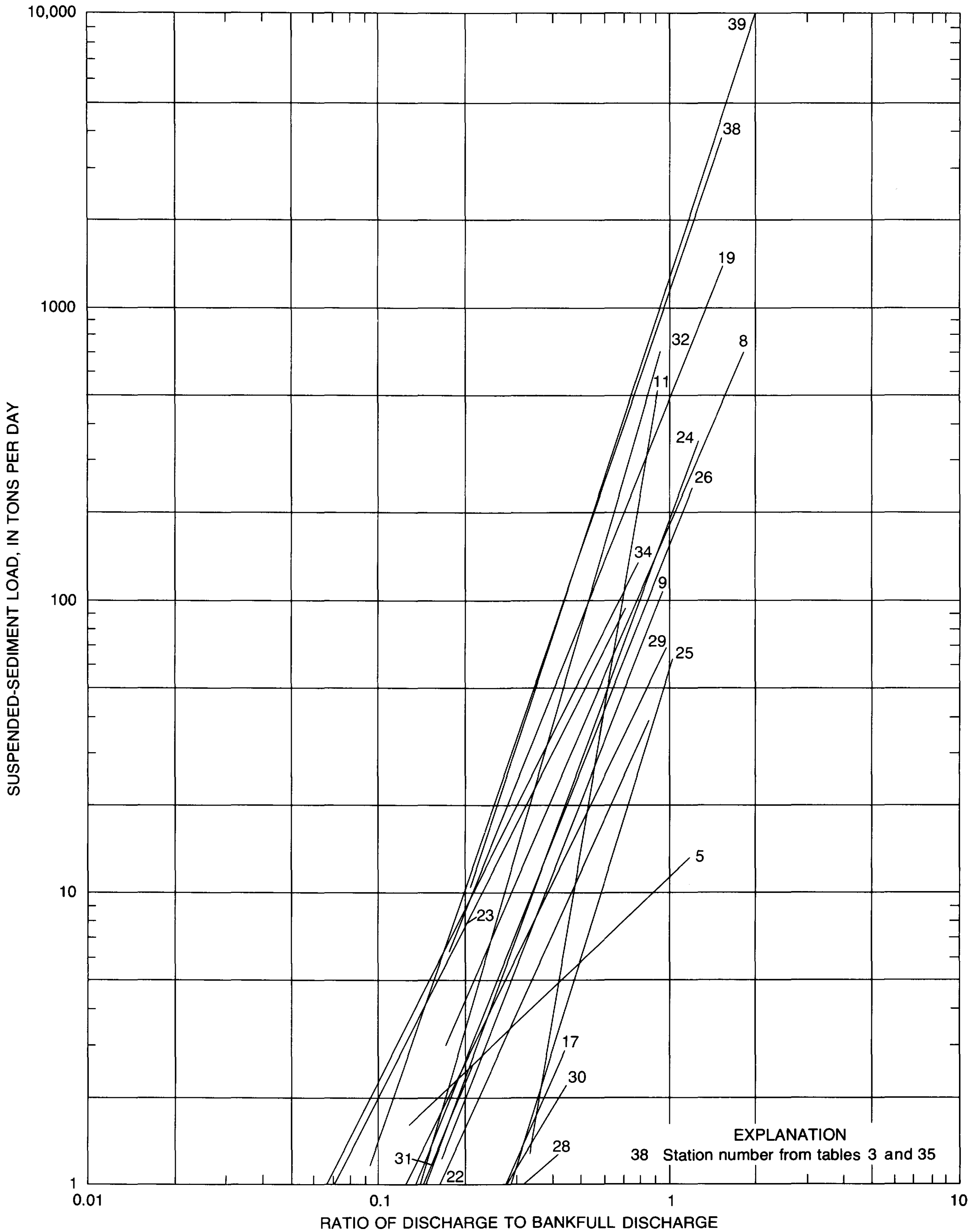

FIGURE 58.—Suspended-sediment load as a function of discharge ratio.

sparse or stunted. Thus excessively high values of turbidity may be extremely detrimental to stream biota as well as esthetically displeasing.

Turbidity in the present study was measured in most water samples retained for suspended-sediment analysis. Values of turbidity are included in table 42 and are expressed in Jackson Turbidity Units. The sediment suspended in the streams contains large quantities of silt- and clay-size particles, and it is this size fraction of the suspended sediment that is primarily responsible for high values of turbidity. Values of turbidity should correlate with values of suspended-sediment concentration, and further, because suspended sediment correlates with discharge, turbidity should also correlate with discharge. By using data from table 42 for the two stations with the most turbidity data, the following typical relations and correlation coefficients were determined:

Station 13–2980.00,

$$t=1.33G_c^{0.61} \quad (r=0.933)$$

and

$$t=36.2\,(Q/Q_B)^{1.13} \quad (r=0.933);$$

station 13–2985.00,

$$t=0.73\,G_c^{0.70} \quad (r=0.938)$$

and

$$t=17.2\,(Q/Q_B)^{1.26} \quad (r=0.816),$$

where t is turbidity in Jackson Turbidity Units and G_c is suspended-sediment concentration.

The foregoing equations indicate that when turbidity is primarily caused by suspended sediment, values of turbidity are roughly proportional to the two-thirds power of suspended-sediment concentration. Suspended sediment is not the only contributor to turbidity, however, and at discharges below about mean annual ($Q/Q_B=0.25$) and as suspended sediment continues to decrease, turbidity begins to increase as very fine particulate matter remains in suspension (but contributes little to values of suspended sediment) and concentrates as the flow decreases.

Generally, values of turbidity are reasonable for the aquatic population. However, even within the range of the yearly variation, out-of-season changes could be detrimental. For example, values of turbidity normally occurring during spring high water could be extremely harmful if they occurred during the fall fish-spawning season. Few unusually high values of turbidity other than those occurring in association with high values of suspended-sediment concentration were observed during the study, and these are probably insignificant in the overall evaluation of the area's water quality.

BEDLOAD TRANSPORT

Several sets of bedload-transport measurements were made in 1972. These measurements were preliminary to continuing studies of bedload transport in the area. A brief discussion of the preliminary data follows to indicate the magnitude of bedload-transport rates.

The bedload sampler used was the Helley-Smith modification of the original Arnhem sampler design (Helley and Smith, 1971). The sampler was adapted to be weighted by lead and lowered by cable or hand held and carried to position in streams that were wadeable. Two types of bedload observations were made. One series consisted of repetitive cross-sectional measurements to define spatial variations in transport rate and also to determine average bedload-transport rate for the stream. A second series consisted of repetitive measurements at a single vertical in the stream cross section to determine temporal variations in bedload rate and also to interrelate some aspects of the hydraulics of flow to the transport rate.

Table 37 summarizes most of the preliminary

TABLE 37.—*Summary of bedload-transport measurements obtained with Helley-Smith bedload sampler*

U.S. Geological Survey Station No.	Bed material size, d_{50}, by pebble count (mm)	Date of observation (1972)	Discharge, Q (ft³/sec)	Average maximum-section bedload transport (tons/day/ft)	Average channel-wide bedload transport (tons/day/ft)	Total bedload transport (tons/day)	Suspended-sediment transport (tons/day)
13–2972.50	43.0	5–29	42.8	----	0	0	5.22
		6– 1	81.2	----	.19	4.18	53.9
		6– 2	80.0	----	.61	13.49	97.2
		6–15	108.3	18.42	1.40	30.79	290
		6–16	97.6	16.68	8.27	181.91	242
		6–17	108.4	19.29	----	----	238
2974.18	34.0	5–31	50.8	----	.49	5.42	52.0
		6– 1	60.0	----	.78	8.60	66.0
2980.00	41.0	5–29	1,374	----	.22	11.15	1,020

NOTE.—All transport rates expressed in terms of dry weight of sediment.

measurements of bedload transport. Bed-material sizes included in table 37 are by pebble count (see table 13), and suspended-sediment data are from table 42. The average channel-wide transport rates were determined from the cross-sectional series of measurements and multiplied by the channel width to obtain total bedload transport. The few data available from table 37 suggest bedload transport rates are correlative with discharge and, at least up to some high value of discharge, increase with increases in discharge at a somewhat greater rate than suspended-sediment transport. Below some nominal but high stage of flow (unpublished data collected elsewhere by the author suggest this stage to be about minimum annual peak discharge), bedload transport is about 0. For most moderately high flows, bedload transport is about 1–50 percent of suspended-load transport. Over the course of a year, bedload transported by a stream, at least by the gravel-bed streams of the present study, is probably on the order of 1–10 percent of the suspended-load transported.

The data are insufficient to provide an understanding of the mechanics of bedload transport, and a comparison with theoretical or empirical formulas is not necessarily valid because adequate field data do not exist to test the reliability of empirical equations of bedload transport. However, L. B. Leopold (1972, written commun.), in compiling all known bedload data and plotting them in the manner of the Bagnold (1966) approach, used the data of the present study, and they were corroborative with extrapolation of other data.

The average maximum-section transport rates in table 37 were obtained from the series of repetitive measurements at a single vertical in the section. The location of this vertical was selected on the basis of maximum observed rates of bedload transport from the cross-sectional set of measurements. The data are consistent in that they show about the same rate of average transport for each of 3 days with about the same discharge; however, individual measurements composing the average rate of transport show large variation. Figure 59 illustrates temporal variations in bedload-transport rates along with hydraulic measurements made at the same location.

Temporal variations in bedload-transport rate are about tenfold; however, the variations tend to correlate with some of the hydraulics measurements. A change from moderate to high bedload-transport rates was accompanied by a surge in velocity, the scouring and then filling of the channel bed, and an initial increase and then decrease in depth of flow. Data of figure 59 are from the June 17 data at station 13–2972.50 (table 37). They are unique in that they are some of the few, perhaps only, such data in existence. However, in themselves, they are insufficient to separate cause from effect.

A particle-size analysis of the composite of all transported bedload sediment indicated in the graph of figure 59 is presented in figure 60. The median particle size of bedload material is 22 millimetres (by sieve analysis), and this compares with a median bed-material size of 43 millimetres (by pebble count).

ANNUAL RUNOFF OF SOLIDS

Data collected and presented in this report are sufficient to allow approximate computations of annual runoff of suspended sediment and dissolved solids. By using a technique described by Johnson (1971), duration curves and instantaneous ratings of suspended sediment and dissolved solids are combined to provide the discharge of solids at each representative flow. These values are multiplied by the duration of each representative flow and totaled to obtain annual discharge of solids.

Table 38 includes the computation for the annual suspended-sediment yield for the water-data station Salmon River near Challis (13–2985.00). In this table, columns 1 and 2 are the duration-curve data based on the entire length of station record. Column 3 shows values of the instantaneous suspended-sediment concentration in milligrams per litre associated with water discharges of column 2. Column 4 is the multiplication of column 2, column 3, and a constant to express suspended-sediment discharge in tons per day. Column 5 is the average suspended-sediment discharge during the time increment of column 1. Column 6 is the annual runoff of suspended sediment contributed by each representative value of discharge from column 2. It is obtained by multiplying column 5 by the increment of time from column 1 and the number of days in the year. Column 7 is a cumulative summation of the percentage of annual runoff of suspended sediment contributed by each entry in column 6. The summation of column 6 is the average annual discharge of suspended sediment. From the 1,800-square-mile study area, the average annual discharge of suspended sediment is about 70,000 tons, or 38.6 tons per square mile.

Cumulative values of suspended sediment in tons per year may be plotted as a function of percentage of time to indicate the importance of a few days of high flows on the magnitude of annual sediment load. Such a plot is illustrated by the average-year plot in figure 61. Alternative illustration is provided in figure 62 by plotting the cumulative percentage of annual sediment yield as a function of cumulative percentage of flow duration. These data and graphs indicate that more than 90 percent of the average annual sediment yield is

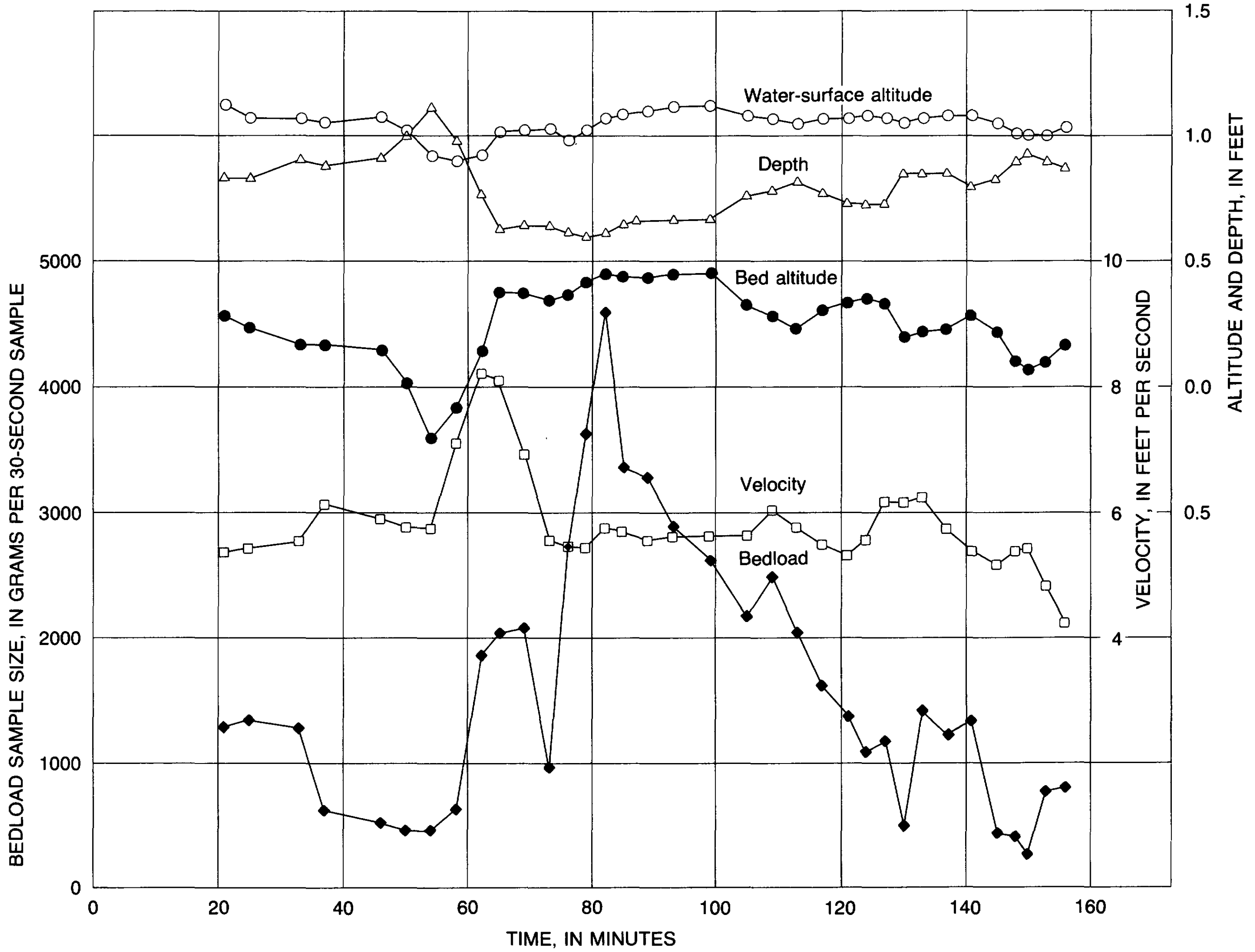

FIGURE 59.— Measurements of bedload transport and concurrent hydraulic and channel data, Slate Creek near Clayton, Idaho.

contributed in less than 10 percent of the time (high-flow runoff). Bankfull stage has an associated water discharge of about 5,500 cubic feet per second and occurs about 4 percent of the time. About three-quarters of the average annual discharge of suspended sediment occurs during this 4 percent of the time.

In much the same manner, annual suspended-sediment yield for the particular study years of 1971 and 1972 were also computed. For these years, values of mean daily discharge were tabulated by rank, and each discharge was given a duration of 1 day in 365 days per year. Other computations are the same as for the average-year data. Results of these computations are shown as the 1971 and 1972 curves in figures 61 and 62. From figure 61, suspended-sediment yield in 1971 was about 195,000 tons and in 1972 was about 322,000 tons, or about 275 and 450 percent, respectively, of suspended-sediment yield for the average year. The influence of peak flows on the amount of suspended-sediment yield is apparent. The year 1972 had a 29 percent greater peak flow than the year 1971, but the suspended-sediment yield was 65 percent greater. Both years 1971 and 1972 had greater annual runoff of water than average, and even though 1972 experienced the greater peak discharge, 1971 had the greater annual runoff of water. Bankfull stage was exceeded 11.5 percent of the time in 1971 and 8.5 percent of the time in 1972. From figure 62, discharges greater than bankfull were responsible for 93 percent of the suspended-sediment yield in 1971 and 89 percent in 1972.

Similar analyses may be conducted for dissolved solids, and table 39 shows the computations for dissolved-solids discharge based on average-year data. The average annual dissolved-solids load is about 122,000 tons, or about 75 percent greater than the discharge of suspended sediment. The dissolved-solids

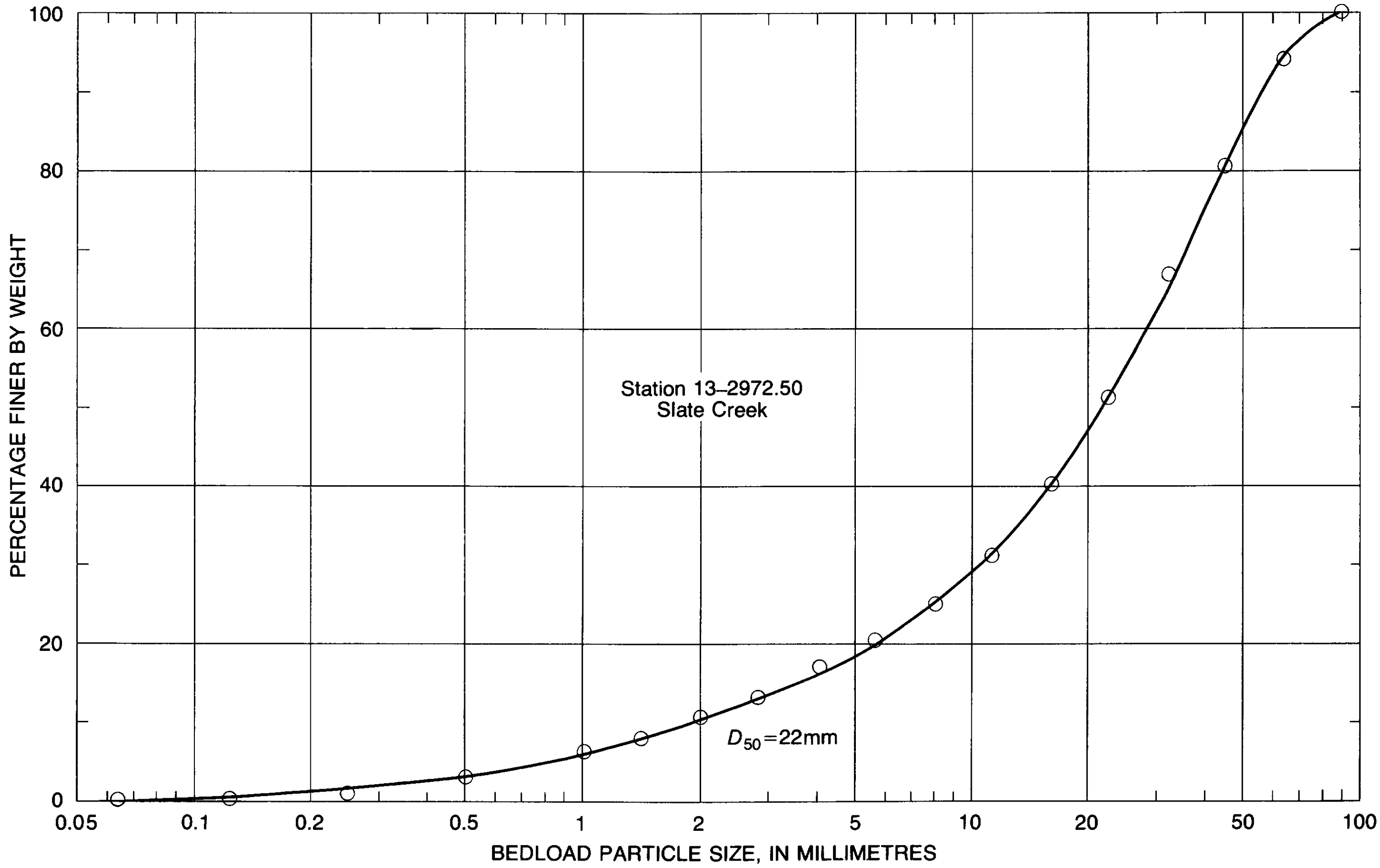

FIGURE 60.— Particle-size distribution of bedload material.

data are illustrated in figures 63 and 64, and the average-year curves for suspended-sediment data are included for comparison. The most striking difference in the two curves is the more uniform contribution of dissolved solids throughout the year. Unlike suspended sediment, dissolved solids increase in concentration as discharge decreases, and these compensating factors provide for more temporal uniformity in dissolved-solids yield. Whereas 20 percent of the time (high flows) accounts for virtually all the suspended-sediment yield, the same time accounts for less than half the dissolved-solids yield.

The total average annual solids yield of suspended sediment and dissolved solids is about 191,370 tons. Bedload transport might increase this value to about 200,000 tons. On the basis of a weight of about 150 pounds per cubic foot, approximately 2.5 million cubic feet of material leaves the area during an average year. Distributed over the entire drainage area, this represents a lowering of the ground surface of about 0.06 inch per century. Obviously, average erosion rates in the area are very low.

SYNOPTIC APPROACH TO WATER QUALITY

An alternative approach to the areal determination of water quality for a given stage of flow regardless of the simultaneity of data collection between locations is a synoptic or simultaneous analysis. Both approaches have their merits, but in reality the synoptic approach is impossible for small study teams, for at a given instant an individual can be at only one location. Also, because a large range of discharges was desired for the present study, the primary approach chosen was the sampling of high-, medium-, and low-water characteristics and the interpolation of data to flows of a common frequency among stations.

To supplement these nonsimultaneous data, several synoptic runs were made to document water temperature and specific conductance and to estimate discharge at as many locations as could be sampled in a single day. An example of such data is illustrated in figure 65 for a run conducted on June 28, 1972. Data of figure 65 are generally consistent in that main-stem values respond to tributary inputs, but without precise discharge

TABLE 38.—*Computations of annual suspended-sediment yield, Salmon River near Challis (13–2985.00)*

Percentage of time	Discharge equaled or exceeded, Q (ft³/sec)	Suspended-sediment concentration (mg/l)	Suspended-sediment discharge (tons/day)		Annual sediment yield (tons)	Percentage of annual sediment yield
			Instantaneous	Average		
0.0	15,400	770	32,017			
.1	11,000	360	10,692	21,355	7,802	11.23
.3	10,000	295	7,965	9,329	6,816	21.04
.5	9,000	230	5,589	6,777	4,949	28.17
1.1	7,900	170	3,626	4,608	10,099	42.71
1.8	7,000	130	2,457	3,042	7,776	53.90
2.8	6,200	96	1,607	2,032	7,422	64.59
4.0	5,500	74	1,099	1,353	5,932	73.13
5.6	4,900	57	754	927	5,417	80.93
7.5	4,300	42	488	621	4,310	87.13
9.3	3,800	32	328	408	2,681	90.99
11.0	3,400	25	230	279	1,731	93.48
13.0	3,000	18.5	150	190	1,388	95.48
15.4	2,600	13.5	94.8	122	1,070	97.02
17.5	2,300	10.3	64.0	79.4	610	97.90
18.9	2,100	8.3	47.1	55.6	285	98.31
21.5	1,800	5.8	28.2	37.7	358	98.83
23.5	1,600	4.5	19.4	23.8	146	99.04
25.2	1,400	3.3	12.5	16.0	117	99.20
26.5	1,300	2.8	9.8	11.4	55	99.28
30.4	1,100	1.9	5.6	7.7	110	99.44
33.5	1,000	1.5	4.1	4.9	55	99.52
39.7	880	1.2	2.9	3.5	80	99.64
48.6	780	.9	1.9	2.4	77	99.75
60.1	690	.7	1.3	1.6	66	99.84
74.8	610	.5	.8	1.1	58	99.93
87.9	540	.4	.6	.7	33	99.97
95.3	480	.3	.4	.5	15	99.99
100.0	290	.2	.2	.3	4	100.00
Total					69,462	

measurements and greater frequency of sampling, little additional quantitative interpretation can be provided. The synoptic data do provide an especially useful technique for isolating contributions of unusual quality. The stream water with the highest conductivity presented in figure 65 is from Slate Creek (specific conductance equals 242 micromhos). Stream water in the main-stem Salmon River responds by an increase in conductance from 69 micromhos upstream of Slate Creek to 82 micromhos downstream. Thus, even though the synoptic data were not of particular usefulness in themselves, they were a valuable aid in the interpretation of other data.

SUMMARY DISCUSSION OF WATER-QUALITY DATA

A large number of water samples analyzed for their chemical and other properties indicate that stream waters in the upper Salmon River area may generally be classified as of very good quality. The primary composition of the stream water is calcium bicarbonate. Secondary common cations include sodium, magnesium, and potassium; secondary common anions include sulfate, chloride, and fluoride. Little or no carbonate is present. Silica contents are moderate, and nutrients expressed as nitrogen or phosphorus are not excessive. The average pH value is mildly basic, ideal for most uses of water.

Analyses for 21 selected trace elements, including many of those considered as toxic to man, indicate that none are present in troublesome amounts. Generally the chemical composition of the surface water is within the recommended limits for public water supplies (U.S. Public Health Service, 1962; World Health Organization, 1971). Except for the Road Creek drainage area (the northeast quadrant of the East Fork Salmon River region), dissolved solids were less than 200 milligrams per litre, and even the Road Creek area had dissolved solids less than the recommended limit of 500 milligrams per litre. A few widely scattered trace-element analyses showed concentrations exceeding recommended limits, but these were so few that the detrimental aspects appear minimal. Generally, the sum of the trace-element concentrations totaled less than 1.0 milligram per litre and thus is within conservative limits established by some resource agencies (McKee and Wolf, 1963).

Other observations of stream biota and bacterial content also indicate a general healthiness of stream

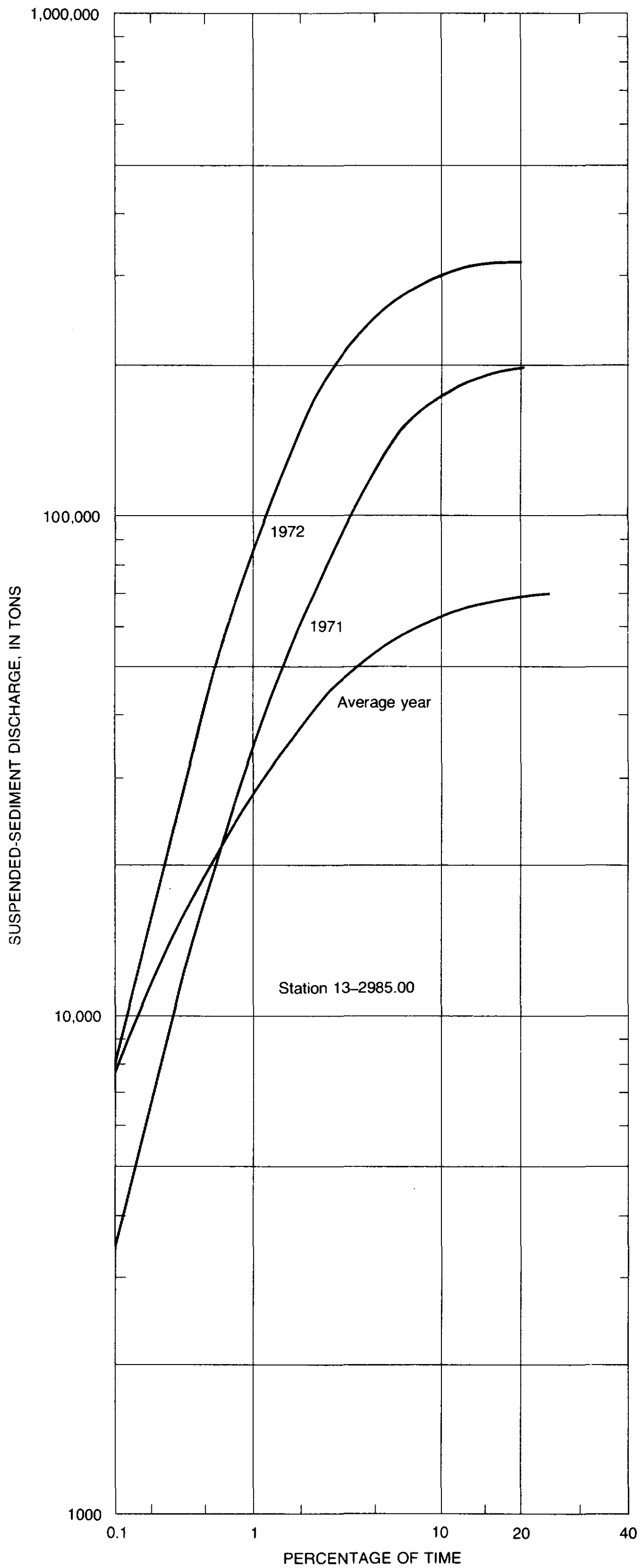

FIGURE 61.—Discharge of suspended sediment as a function of percentage of time.

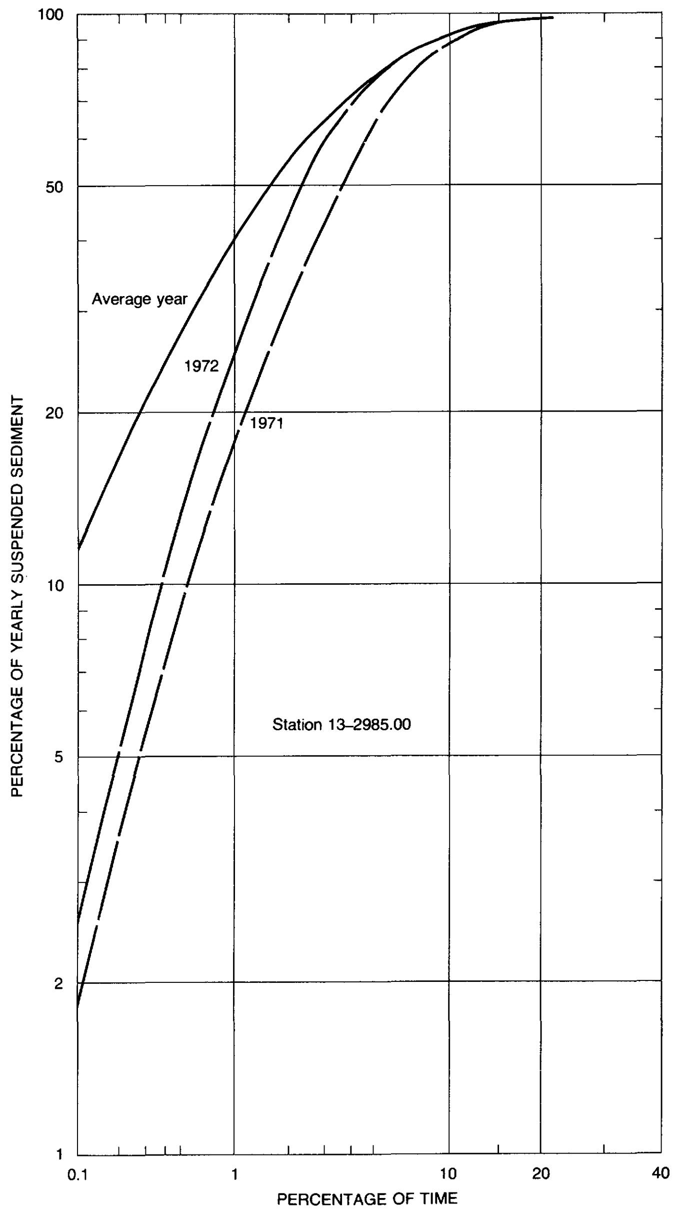

FIGURE 62.—Percentage of annual discharge of suspended sediment as a function of percentage of time.

waters, although these studies show that no single set of criteria is sufficient to define water-quality standards. For example, maximum concentration of dissolved zinc in public water supplies is set at 5 milligrams per litre (U.S. Public Health Service, 1962); however, except for taste, concentrations as much as 700 milligrams per litre are probably not harmful to humans. At the same time, concentrations of zinc in excess of 0.1–1.0 milligram per litre are fatal to many fish.

In terms of the popularly used concepts of alkalinity and hardness, the water quality is rated very good.

TABLE 39.—*Computation of annual dissolved load, Salmon River near Challis (13–2985.00)*

Percentage of time	Discharge equaled or exceeded (ft³/sec)	Dissolved solids concentration (mg/l)	Dissolved-solids discharge (tons/day) Instantaneous	Dissolved-solids discharge (tons/day) Average	Annual dissolved solids yield (tons)	Percentage of annual dissolved solids yield
0.0	15,400	57	2,376			
.1	11,000	57	1,693	2,032	742	0.61
.2	10,000	58	1,566	1,630	1,191	1.59
.5	9,000	58	1,409	1,488	1,087	2.48
1.1	7,900	59	1,258	1,334	2,923	4.87
1.8	7,000	60	1,134	1,198	3,063	7,39
2.8	6,200	61	1,021	1,078	3,940	10.62
4.0	5,500	62	921	971	4,256	14.11
5.6	4,900	63	833	877	5,125	18,31
7.5	4,300	64	743	788	5,469	22.80
9.3	3,800	66	677	710	4,668	26.63
11.0	3,400	68	624	650	4,036	29.94
13.0	3,000	70	567	596	4,354	33.51
15.4	2,600	73	512	540	4,734	37.40
17.5	2,300	76	472	492	3,774	40.40
18.9	2,100	78	442	457	2,337	42.41
21.5	1,800	82	399	420	3,989	45,68
23.2	1,600	85	367	383	2,378	47.63
25.2	1,400	89	336	352	3,302	50.34
26.5	1,300	92	323	330	1,567	51.62
30.4	1,100	97	288	306	4,359	55.20
33.5	1,000	101	273	280	3,170	57.80
39.7	880	106	252	262	5,933	62.67
48.6	780	111	234	243	7,899	69.15
60.1	690	117	218	226	9,493	76.93
74.8	610	122	201	210	11,275	86.18
87.9	540	129	188	194	9,282	93.80
95.3	480	136	176	182	4,912	97.83
100.0	290	168	132	154	2,644	100.00
Total					121,908	

The sediment quality of water is also good, with only moderate amounts of suspended sediment except in times of high flow and at a few locations where man's impact accelerates sediment contributions to stream channels. Proper land use can minimize man's impact, but in any event the high-flow concentrations of suspended sediment are not excessive for natural rivers.

Relations were established between stream discharge and the concentration of dissolved and suspended solids. Generally, dissolved solids become more dilute with increases in streamflow, and the relation with discharge is a power equation with an exponent of −0.20. Major ion concentrations vary with discharge about as dissolved solids vary with discharge, but the relations of trace elements to discharge become erratic as their concentrations decrease. The suspended-sediment concentration increases with increases in streamflow, and the relation with discharge is somewhat variable but generally follows a power law with an exponent of 2.5.

By using the concept of average duration of flow for flows of various frequencies, the total annual runoff of solids from the study area is about 200,000 tons, and the ratio of dissolved-solids runoff to suspended-sediment runoff is about 1.75 to 1.0.

The behavioral characteristics of the chemical and sediment properties of stream water are generally similar between water-data stations of different locations. That is, the dilution or concentration rate of change with discharge and the general composition of the chemical constituents were about the same at most locations. This indicates some uniformity in both the chemical composition of crustal rocks and the runoff rate of water available for dilution of chemical constituents and transport of suspended solids. The expression of these relations in terms of the ratio of discharge to bankfull discharge provides a basis for comparison of the quality parameters between stations. For a given value of the discharge ratio, individual stations have concentrations of dissolved and suspended solids that primarily reflect solubility and erodibility of upstream rock types. Annual yields of total solids further depend on annual runoff of water, but because of general consistency in data, considerable extrapolation of data is possible. For example, a single measurement of specific conductance will allow determination of dissolved solids and the proportionate amount of each constituent, especially of the common ions. Further, the concentration change with discharge is predictable.

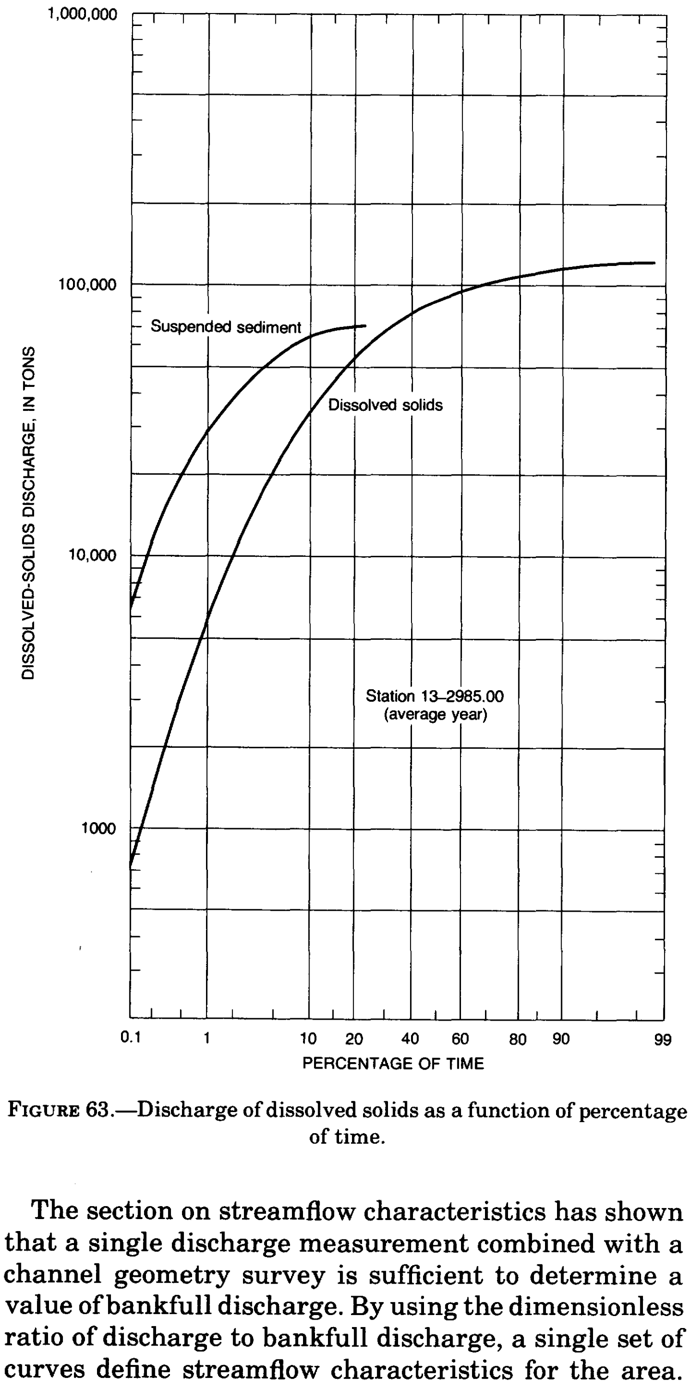

FIGURE 63.—Discharge of dissolved solids as a function of percentage of time.

The section on streamflow characteristics has shown that a single discharge measurement combined with a channel geometry survey is sufficient to determine a value of bankfull discharge. By using the dimensionless ratio of discharge to bankfull discharge, a single set of curves define streamflow characteristics for the area. Combination of streamflow characteristics and water-quality characteristics as a function of the dimensionless discharge ratio allow further computations. For example, conversion of the specific conductance measurement to dissolved-solids concentrations, the distribution of dissolved-solids concentration over a range in values of the discharge ratio, and use of the duration curve of the discharge ratio allow the computation of annual yield of dissolved solids from an otherwise ungaged and unmeasured stream. It should be emphasized that such extrapolation of data is only incidental to the primary purpose of the present study which is to document the baseline hydrologic characteristics at measured locations. But the masses of data allowing extrapolation serve to confirm that the baseline characteristics have been adequately described.

SUMMARY OF FINDINGS

The upper 1,800 square miles of the Salmon River drainage area in south-central Idaho has a little disturbed, natural environment, where for the most part the surface waters are in a pristine state. Geology within the area is relatively simple and consists of extensive areas of Idaho batholith and Challis Volcanics and smaller areas of sedimentary rock. The area is rather highly mineralized, and this fact has promoted areawide mineral exploration and mining, which today is less intense than in the past. The topography is mountainous, and main-stem rivers flow in canyonlike gorges except in Stanley Basin, where there is a fairly wide alluvium-filled depression. The ruggedness of the terrain allows little land use except grazing of stock, and thus the area is little populated. However, this ruggedness and the remoteness of the terrain have fostered increasing recreational use, which promises to be the largest economic use of the land in the future. In 1972, the Congress of the United States set aside a large part of the area as the Sawtooth National Recreation Area, and parts of the recreational and other areas are under study for inclusion in wilderness, primitive area, or national park classification.

The area is drained by the main-stem Salmon River and a principal tributary, the East Fork Salmon River, which drains about 30 percent of the total area of study. On the basis of a Horton analysis conducted for the entire drainage of the East Fork Salmon River, the drainage density is about 2.61 miles of stream per square mile of area and indicates about 4,700 miles of stream channel in the study area. There are about 2.66 stream channels per square mile, or about 4,800 streams in the area. About 76 percent of the streams are first-order streams, the East Fork Salmon River is a seventh-order stream, and the main-stem Salmon River within the study area is inferred to be an eighth-order stream. The stream bifurcation ratio is about 4.0.

Climate in the area is typically characterized by long, cold winters and short summers. Because of the mountainous terrain, precipitation is variable, ranging from more than 60 inches per year in parts of the mountains to less than 10 inches per year in the northeast corner of the study area. The major part of the area receives about 30 inches of precipitation per year, and the average annual runoff is about 12 inches per year.

Stream runoff at bankfull stage varies with size of

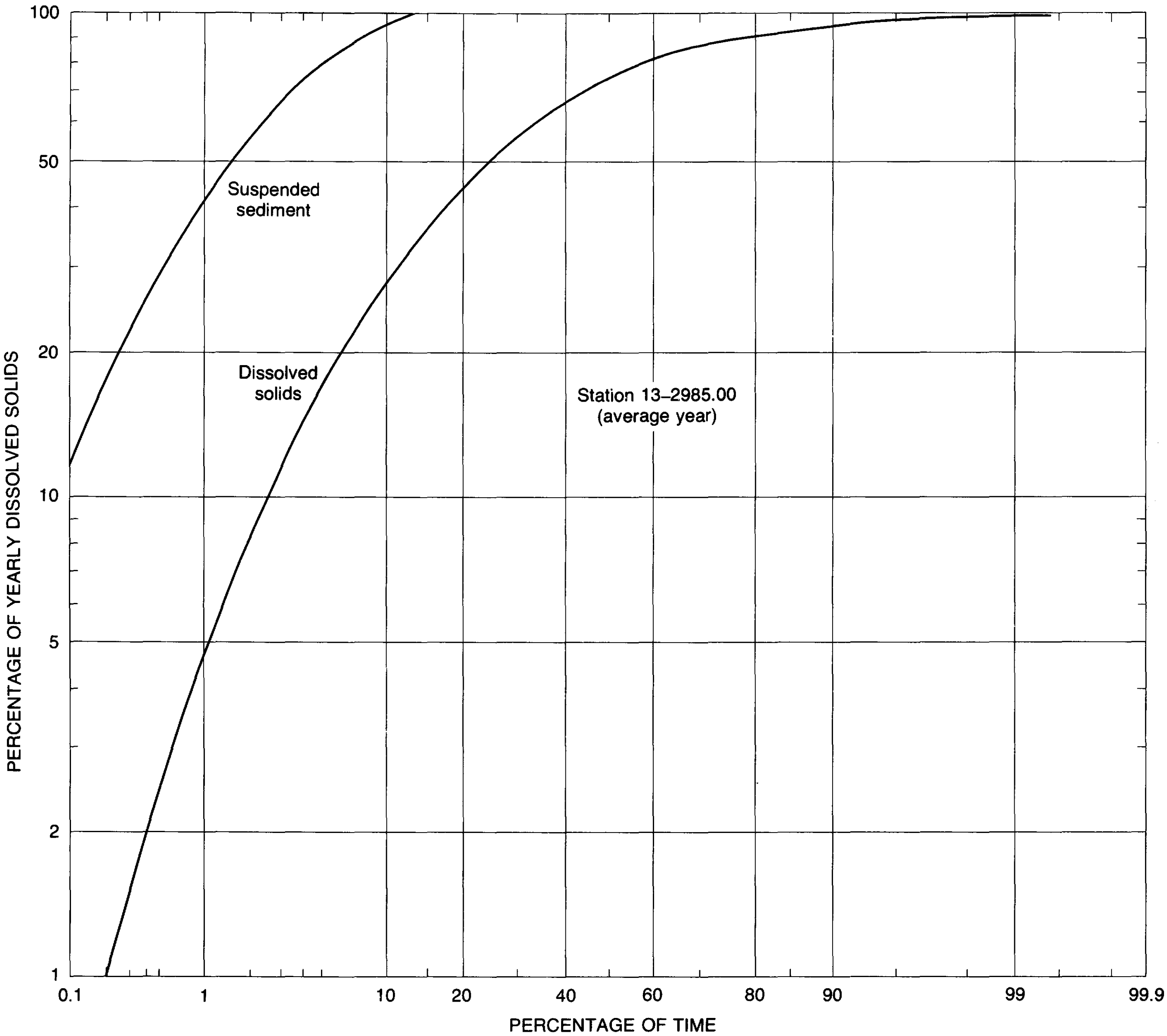

FIGURE 64.—Percentage of annual discharge of dissolved solids as a function of percentage of time.

drainage area according to the approximate relation $R_B = 28.3\,DA^{-0.31}$, but this relation is locally variable, for precipitation is locally greater or less than the mean for the area. More exacting than size of drainage area, the size of stream channel is everywhere related to the magnitude of bankfull discharge by the approximate relations $W_B = 1.37\ Q_B^{0.54}$ and $D_B = 0.25\ Q_B^{0.34}$. Bankfull discharge has a recurrence interval of about 1.5 years, and flows proportional to bankfull discharge tend to have a common frequency of occurrence among streams. Mean annual discharge is about equal to 25 percent of bankfull discharge, and flows equal to or greater than mean annual discharge occur about 25 percent of the time. The magnitude of high- and low-flow stream characteristics is presented in terms of the ratio of discharge to bankful discharge, Q/Q_B, and the frequency and duration characteristics of these flows are approximately the same for all streams in the area.

A recurrence interval of 2 years implies a normal or median year; that is, half the years should produce higher flow, and the remainder should produce lower flows. The median year will have a peak streamflow of about 120 percent of bankfull discharge. Likewise, this median year should have 30 consecutive days with a mean discharge of 90 percent or more of bankfull and 90 consecutive days with a mean discharge of 60 percent or more of bankfull. Conversely, in the low-flow season,

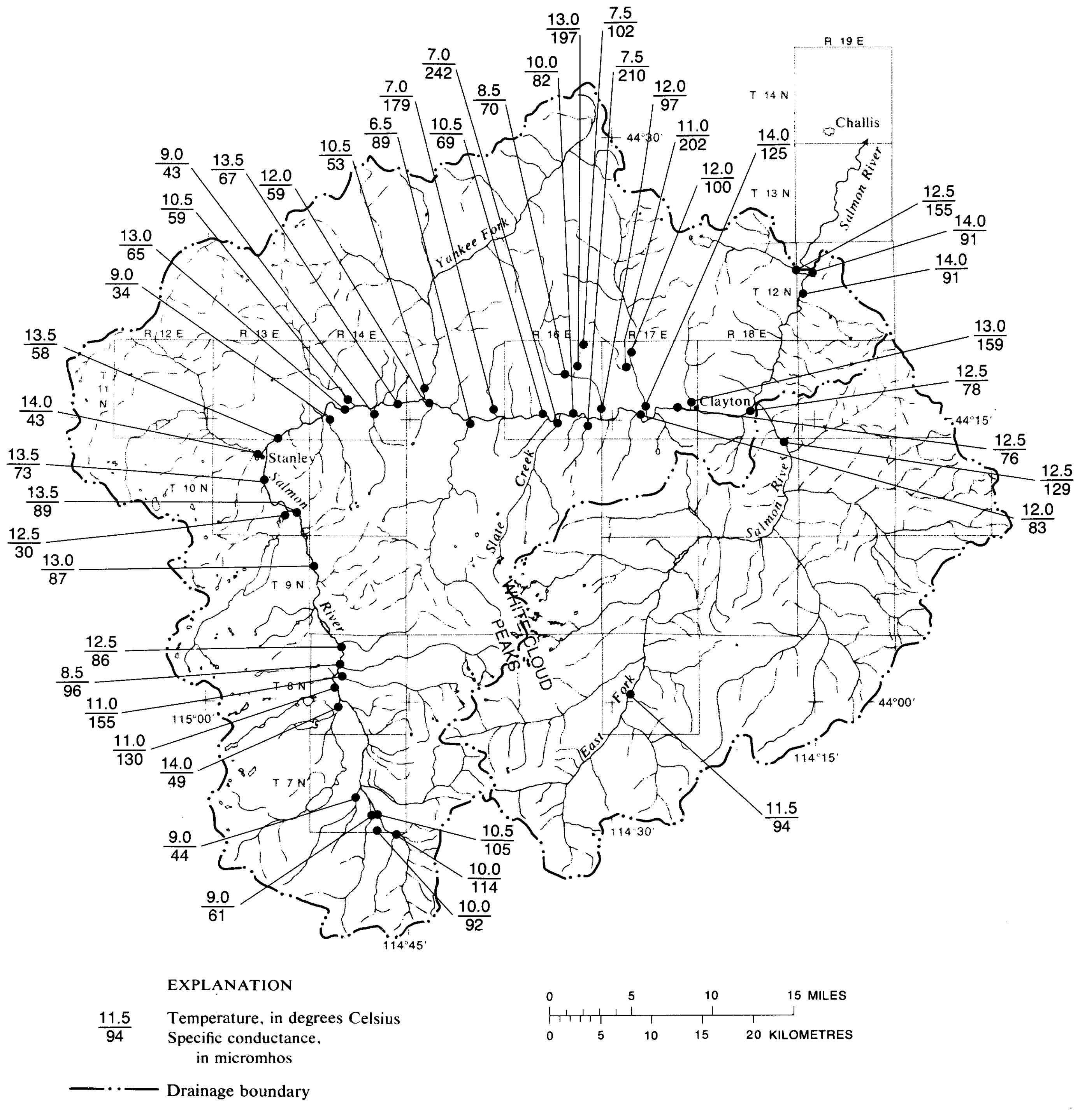

FIGURE 65.—Values of synoptic observations of specific conductance and temperature.

the median year should have 30 consecutive days with a mean discharge of 8.2 percent or less of bankfull and 90 consecutive days with a mean discharge of 9.0 percent or less of bankfull.

Stream waters are mostly calcium bicarbonate, and the waters generally are of high quality. Typified by data from the main stream at the exit from the study area, major cations in the weight ratio Ca:Na:Mg:K are present in the amounts 1.0:0.22:0.12:0.04; major anions in the weight ratio HCO_3:SO_4:Cl:Fl are present in the amounts of 1.0:0.06:0.01:0.005. Dissolved solids vary with discharge approximately as $DS \propto (Q/Q_B)^{-0.20}$. Values of the concentration of dissolved solids at a given value of the discharge ratio are locally variable depending on solubility of upstream rock types and magnitude of runoff. At the exit from the study area, the main stream has a concentration of dissolved solids of 78 milligrams per litre at bankfull stage and 101 milligrams per litre at mean annual discharge. The concentrations of individual major ions follow the trend of dissolved solids. Ions with trace concentrations are erratic with respect to both time and spatial occurrence. The frequency of occurrence of the true trace elements generally is in proportion to their relative abundance in the average composition of the earth's crust. Taking an average of the whole of 2,304 analyses for 21 different trace elements, an element was detected in 56 percent of the samples analyzed and occurred at one time or another at 96 percent of the locations sampled.

Raw stream water is seldom recommended for domestic supply, but on the basis of only chemical composition, stream waters in the area are within even recommended limits of concentration for public water supplies. Waters generally are suitable for any domestic or agricultural use, and with the exception that some forms of stream biota are sensitive to even minute quantities of some of the trace metals, the waters are adequate for biological instream needs.

Suspended sediment transported varies with discharge approximately as $G \propto (Q/Q_B)^{2.5}$. Values of the concentration of suspended sediment at a given value of the discharge ratio are locally variable, depending on erodibility of upstream rock types, man-induced impacts, and the competence of the stream to transport its imposed sediment load. At the exit from the study area, the concentration of suspended sediment in the main stream is 80 milligrams per litre at bankfull discharge and 5 milligrams per litre at mean annual discharge.

On the basis of the average duration of flows of various frequency, the average annual discharge of suspended and dissolved solids is about 200,000 tons. The ratio of quantity of dissolved solids to quantity of suspended solids is about 1.75 to 1.0.

Aspects of the study are continuing and will result in definition of interrelations which include biological parameters and total sediment yields. These observations, and continued monitoring of all aspects of the study, will allow detection and documentation of changes in initial or baseline relations.

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SUMMARY OF DATA—TABLES 40–44

Table 40.—*Summary of selected water-quality characteristics*

[Data, except as indicated, are in milligrams per

Water-data station No.	Date of collection	Discharge (ft^3/s)	Temperature (°C)	pH (field)	pH (lab.)	Specific conductance (field, µmhos)	Specific conductance (lab., µmhos)	Alkalinity as $CaCO_3$	Total hardness	Dissolved solids	Dissolved solids (tons/acre-ft)	Dissolved solids (tons/day)
13-2922.00	6-08-71	121	10.0	----	7.6	----	107	53	49	65	0.09	21.2
	7-21-71	52	7.0	----	7.1	----	115	62	59	74	.10	10.5
	8-09-71	23	11.0	----	8.0	----	152	80	71	94	.13	5.84
	6-20-72	85	7.0	----	7.4	----	103	53	47	65	.09	14.9
2924.00	5-24-71	31	4.0	----	8.5	----	61	30	25	42	.06	3.55
	7-21-71	53	10.5	----	7.2	----	40	22	18	29	.04	4.15
	9-03-71	3.0	10.0	----	7.7	----	78	39	32	52	.07	.42
	6-16-72	90	8.5	----	7.6	----	37	20	15	27	.04	6.56
2932.00	6-09-71	32	6.5	----	7.7	----	140	70	67	97	.13	8.38
	7-21-71	9.3	16.5	----	7.8	----	178	97	89	126	.17	3.16
	8-09-71	3.7	21.0	----	8.1	----	218	115	100	147	.20	1.47
	6-20-72	57	6.0	----	7.7	----	146	74	69	100	.14	15.4
2934.00	6-09-71	114	6.0	----	7.2	----	88	44	39	63	.09	19.4
	7-21-71	34	13.5	----	7.1	----	106	52	53	75	.10	6.97
	8-09-71	20	14.0	----	7.9	----	148	71	66	98	.13	5.29
	6-27-72	87	5.0	----	7.8	----	95	48	42	66	.09	15.5
2950.00	5-24-71	561	9.0	----	7.3	----	60	27	20	50	.07	75.7
	6-21-71	1,110	13.5	----	7.0	----	37	21	14	35	.05	105
	7-19-71	522	13.5	----	7.7	----	43	20	20	35	.05	49.3
	8-30-71	138	12.0	----	7.2	----	65	30	22	46	.06	17.1
	10-04-71	132	11.0	----	7.4	----	64	32	27	53	.07	18.9
	6-16-72	1,090	10.5	----	7.6	----	49	25	19	43	.06	127
	7-24-72	264	12.0	----	7.7	----	55	24	21	42	.06	29.9
2956.50	6-10-71	636	4.5	----	7.6	----	60	29	19	45	.06	77.3
	7-19-71	92	14.5	----	7.4	----	67	41	27	55	.07	13.8
	8-10-71	48	8.0	----	7.7	----	85	44	32	59	.08	7.65
	6-26-72	196	7.5	----	7.9	----	58	29	22	45	.06	23.8
2960.00	5-25-71	889	3.5	----	7.2	----	67	33	24	55	.07	132
	6-22-71	2,710	4.5	----	7.1	----	43	21	13	41	.06	300
	8-30-71	119	12.5	----	7.6	----	79	37	27	62	.08	19.9
	6-16-72	1,850	6.5	----	7.8	----	43	23	16	43	.06	215
2965.00	5-25-71	2,920	4.0	----	7.8	----	72	37	29	58	.08	457
	6-22-71	6,440	6.5	----	7.0	----	52	30	20	45	.06	782
	7-23-71	2,410	12.5	----	7.7	----	61	31	27	48	.07	312
	9-03-71	706	10.0	----	7.4	----	104	51	41	73	.10	139
	10-08-71	716	6.0	----	7.5	----	121	54	54	89	.12	172
	6-16-72	5,820	6.5	----	7.3	----	38	20	15	31	.04	487
	7-24-72	1,340	11.0	----	7.9	----	79	35	32	57	.08	206
	10-05-72	668	8.0	----	7.5	----	122	53	48	78	.11	141
2970.00	5-25-71	175	5.0	----	8.0	----	106	54	49	75	.10	35.4
	6-22-71	560	6.0	----	7.3	----	69	34	29	52	.07	78.6
	9-03-71	103	7.0	----	7.8	----	145	72	66	92	.13	25.6
	6-14-72	400	7.5	----	7.7	----	73	41	35	56	.08	60.5
	7-24-72	153	9.0	----	7.8	----	125	59	59	80	.11	33.0
2971.00	5-25-71	21	6.5	----	7.8	----	186	93	92	129	.18	7.31
	7-23-71	10	9.5	----	7.7	----	193	103	100	132	.18	3.74
	9-03-71	7.2	8.0	----	8.0	----	234	116	110	145	.20	2.82
	6-14-72	28	8.0	----	7.5	----	130	66	58	90	.12	6.80
2972.50	6-10-71	76	9.5	----	7.9	----	277	116	130	171	.23	35.1
	7-02-71	81	7.0	----	7.7	----	230	107	120	151	.21	33.0
	8-10-71	41	8.0	----	8.1	----	268	121	130	164	.22	18.2
	6-15-72	102	11.0	----	7.6	----	243	106	110	148	.20	40.8
2973.00	5-25-71	4.0	8.0	----	7.7	----	227	110	94	160	.22	1.75
	7-22-71	1.2	12.0	----	7.9	----	224	119	96	157	.21	.51
	8-16-71	1.1	9.5	----	8.0	----	259	131	110	171	.23	.51
	9-02-71	7.3	11.0	----	7.7	----	214	107	92	140	.19	2.78
	6-14-72	6.3	8.0	----	7.8	----	182	87	77	129	.18	2.19
2973.10	6-11-71	141	6.5	----	7.5	----	69	34	25	58	.08	22.1
	7-24-71	23	8.0	----	7.4	----	77	38	32	62	.08	3.85
	8-10-71	9.8	13.0	----	7.6	----	104	48	42	79	.11	2.09
	6-18-72	99	8.5	----	7.7	----	57	28	21	48	.07	12.8
2973.12	6-29-72	1.0	7.5	----	8.0	----	101	51	28	79	.11	.21
2973.14	6-29-72	.50	13.0	----	8.0	----	255	85	26	189	.26	.26
2973.16	6-29-72	.50	15.0	----	7.9	----	274	83	15	190	.26	.26
2973.20	6-11-71	4.3	6.5	----	7.8	----	118	55	38	87	.12	1.01
	7-24-71	1.5	11.0	----	7.6	----	224	84	62	159	.22	.64
	8-10-71	1.3	16.0	----	7.6	----	254	78	56	173	.24	.61
	6-18-72	2.3	9.0	----	7.6	----	170	77	44	115	.16	.71
	6-29-72	1.7	13.0	----	8.2	----	197	88	47	134	.18	.62
2973.30	5-26-71	99	8.0	----	7.4	----	108	53	46	86	.12	23.0
	6-22-71	134	4.5	----	7.4	----	67	34	27	57	.08	5.33
	9-02-71	7.8	9.5	----	7.6	----	189	78	75	125	.17	2.65
	6-14-72	105	10.5	----	7.9	----	79	35	31	61	.08	17.3
2973.40	6-11-71	368	7.0	----	7.3	----	78	46	32	72	.10	71.5
	7-24-71	41	16.5	----	7.4	----	112	62	51	92	.13	10.2

and concentrations of major ions at water-data stations

litre. 0=value below limit of detection]

Orthophosphorus as P	Total phosphorus as P	Silica	Calcium	Magnesium	Potassium	Sodium	Bicarbonate (field)	Bicarbonate (lab.)	Carbonate	Chloride	Fluoride	Sulfate	Nitrite and nitrate as N
0.02	0.15	10	17	1.7	0.3	1.7	----	64	0	0.04	0.0	1.8	0.06
.01	.05	9.9	20	2.3	.2	1.6	----	75	0	.6	.2	2.5	.00
.01	.05	11	24	2.7	.4	1.7	----	98	0	.2	.4	5.0	.01
.00	----	9.9	16	1.7	.4	1.3	----	64	0	.3	.1	3.7	.04
.01	.04	8.0	9.0	.5	.2	2.2	----	36	0	.8	.1	3.0	.02
.01	.04	5.8	6.8	.3	.2	1.1	----	27	0	.4	.2	1.0	.00
.00	.04	8.9	12	.4	.6	2.0	----	47	0	.4	.4	4.3	.00
----	.03	5.8	5.5	.2	.4	.7	----	24	0	.2	.0	2.5	.00
.03	.10	22	25	1.1	.7	2.1	----	85	0	.8	.0	3.3	.03
.02	.07	24	33	1.6	.6	2.0	----	118	0	.0	.2	6.5	.02
.04	.08	27	39	1.8	1.0	2.3	----	140	0	.2	.5	6.0	.01
.01	----	21	26	1.1	1.3	.8	----	90	0	.9	.1	5.4	.01
.01	.08	14	14	1.1	.5	2.3	----	54	0	.9	.0	4.0	.02
.02	.06	14	19	1.3	.2	2.1	----	63	0	.5	.1	6.3	.00
.02	.06	17	24	1.4	.6	2.4	----	86	0	.3	.4	9.0	.01
.00	----	13	15	1.1	.4	1.7	----	58	0	.6	.1	5.7	.01
.02	.05	11	6.8	.7	.3	2.9	----	33	0	.6	.5	5.5	.43
.01	.02	8.1	5.1	.3	1.1	1.7	----	25	0	.2	.2	5.3	.00
.01	.05	8.2	7.1	.5	.3	2.1	----	24	0	3.5	.5	1.3	.02
.03	.04	12	8.1	.4	.4	3.3	----	37	0	.3	.7	1.3	.02
.01	.04	12	10	.6	.7	3.4	----	39	0	.6	.4	6.0	.06
.00	.04	13	6.7	.6	.8	2.5	----	31	0	.6	.2	3.4	.01
.00	.02	10	7.2	.7	.3	4.2	----	29	0	1.0	.9	3.7	.00
.02	.06	15	6.4	.8	.4	3.1	----	35	0	.8	.0	1.3	.06
.02	.06	14	9.1	1.1	.5	3.4	----	50	0	.5	.2	.5	.26
.01	.05	14	11.	1.1	.6	3.7	----	54	0	.2	.4	1.3	.05
.00	----	14	7.5	.8	.6	2.6	----	35	0	.7	.1	1.5	.00
.04	.08	17	8.0	1.0	.5	3.8	----	40	0	.2	.1	4.3	.00
.04	.10	17	4.7	.4	.4	3.0	----	25	0	.1	.0	2.5	.00
.03	.05	20	9.5	.8	.8	4.5	----	45	0	.1	.4	3.3	.01
----	.06	16	5.3	.6	.5	2.7	----	28	0	.3	.2	3.3	.02
.04	.06	15	10	1.0	.3	3.6	----	45	0	.5	.2	5.0	.00
.02	.05	12	6.8	.7	.4	2.4	----	36	0	.1	.2	3.5	.00
.01	.05	13	9.5	.8	.4	2.7	----	38	0	.6	.3	2.0	.01
.01	.04	16	15	.9	.6	4.4	----	62	0	.4	.7	3.8	.02
.01	.04	16	19	1.5	1.1	4.5	----	66	0	1.0	.5	6.0	1.60
.00	.03	7.6	5.5	.4	.6	1.8	----	24	0	.4	.4	2.5	.02
.01	.02	14	11	1.1	.5	3.2	----	43	0	1.0	.4	4.7	.00
.01	----	16	17	1.4	.6	4.6	----	65	0	.9	.5	5.0	.00
.03	.06	14	18	1.1	.8	2.2	----	66	0	.8	.0	5.8	.00
.01	.03	11	11	.4	.4	1.7	----	41	0	.0	.0	6.8	.03
.00	.03	15	25	.8	1.0	1.9	----	88	0	.7	.4	4.0	.01
	.03	11	13	.7	.9	1.5	----	50	0	.6	.1	3.3	.02
----	.01	13	22	1.1	.7	1.7	----	72	0	1.0	.1	5.4	.00
.05	.07	21	32	3.0	.7	2.5	----	113	0	.4	.1	13	.03
.02	.05	21	35	3.2	.7	2.3	----	126	0	1.0	.1	6.5	.01
.03	.05	20	40	3.6	.8	2.2	----	141	0	.2	.3	8.0	.02
----	.06	21	20	2.0	.7	2.1	----	80	0	.3	.0	4.6	.00
.05	.30	15	47	3.3	1.5	4.4	----	142	0	1.2	.3	28	.09
.04	.38	14	43	2.9	1.4	3.2	----	130	0	.7	.4	21	.05
.04	.07	14	45	3.2	1.5	3.9	----	147	0	.5	.7	23	.00
.03	----	14	41	2.8	1.5	3.0	----	129	0	.6	.4	21	.03
.08	.17	27	29	5.2	.7	11	----	134	0	1.9	.2	19	.06
.08	.10	27	30	5.2	.7	12	----	145	0	1.3	.2	9.0	.00
.06	.17	25	34	1.8	.9	12	----	160	0	2.4	.5	11	.01
.04	.07	26	22	9.1	2.1	6.8	----	130	0	.9	.4	8.3	.01
----	.20	28	25	3.6	.9	9.5	----	106	0	1.8	.2	7.1	.09
.04	.10	20	8.4	1.1	.5	3.8	----	42	0	.7	.0	2.3	.02
.03	.07	18	10	1.6	.6	3.6	----	46	0	.2	.1	4.8	.00
.02	.07	20	13	2.3	.7	4.4	----	59	0	.6	.3	8.3	.07
.02	----	17	6.7	1.0	.5	2.6	----	34	0	.3	.1	3.1	.00
.03	----	22	8.9	1.4	.5	11	----	62	0	.7	.1	3.8	.00
.18	----	17	9.1	.7	1.8	54	----	104	0	2.1	.7	51	.29
.04	----	18	5.7	.2	.7	53	----	101	0	1.3	.3	59	.50
.04	.12	24	12	2.0	.6	10	----	67	0	1.1	.0	4.5	.03
.02	.04	20	20	2.9	.9	25	----	102	0	.8	.4	38	.14
.03	.17	21	19	2.0	1.0	30	----	95	0	1.5	.8	49	.47
.01	----	20	14	2.3	.8	18	----	94	0	.7	.2	13	.00
.01	----	19	15	2.4	1.1	24	----	107	0	.8	.2	19	.01
.04	.10	19	14	2.6	1.5	4.8	----	64	0	.3	.1	12	.01
.05	.12	19	8.2	1.5	.5	3.6	----	41	0	.5	.0	3.8	.01
.01	.05	18	22	4.9	1.0	7.8	----	95	0	.7	.4	23	.07
----	.07	18	9.7	1.7	.7	3.6	----	43	0	.4	.1	5.5	.02
.07	.13	27	8.2	2.8	1.2	4.0	----	56	0	1.0	.0	.3	.02
.07	.10	28	12	5.2	1.2	4.9	----	75	0	.8	.2	1.8	.10

TABLE 40.—*Summary of selected water-quality characteristics*

Water-data station No.	Date of collection	Discharge (ft^3/s)	Temperature (°C)	pH (field)	pH (lab.)	Specific conductance (field, µmhos)	Specific conductance (lab., µmhos)	Alkalinity as $CaCO_3$	Total hardness	Dissolved solids	Dissolved solids (tons/acre-ft)	Dissolved solids (tons/day)
13.2973.40	8-11-71	23	8.5	----	7.8	----	145	79	61	112	0.15	6.96
	6-19-72	177	6.5	----	7.0	----	82	44	33	69	.09	33.0
2973.50	6-26-71	11	3.5	----	7.5	----	148	68	65	105	.14	3.12
	6-22-71	19	11.0	----	7.6	----	112	56	51	88	.12	4.59
	7-23-71	2.9	8.0	----	7.3	----	221	112	110	151	.21	1.22
	9-02-71	.95	2.5	----	7.9	----	318	142	150	196	.27	.51
	10-07-71	.66	7.0	----	7.9	----	339	150	190	219	.30	.39
	6-14-72	16	9.0	----	7.6	----	140	61	66	99	.13	4.17
	7-24-72	2.0	10.0	----	8.0	----	276	115	140	171	.23	.92
2973.60	5-26-71	215	4.0	----	7.5	----	107	56	45	89	.12	51.7
	6-23-71	343	5.0	----	7.5	----	82	43	30	69	.09	63.9
	9-02-71	7.4	11.0	----	7.7	----	214	107	92	140	.19	2.78
	6-15-72	273	8.0	----	7.6	----	91	47	37	74	.10	54.5
2973.80	6-01-71	7,590	6.0	----	7.2	----	73	41	33	65	.09	1,330
	6-23-71	7,600	9.0	----	7.1	----	68	37	26	51	.07	1,050
	7-22-71	3,120	12.0	----	8.0	----	76	39	37	57	.0	480
	9-01-71	1,180	12.0	----	7.6	----	130	62	54	85	.12	271
	10-08-71	1,070	6.5	----	7.6	----	140	66	74	98	.13	283
	6-19-72	6,560	8.5	----	7.7	----	64	28	28	49	.07	868
	7-25-72	1,950	10.0	----	7.4	----	103	47	44	69	.09	363
	10-04-72	983	7.0	----	7.7	----	138	66	61	91	.12	242
2973.84	7-01-71	97	7.0	----	7.3	----	63	30	29	39	.05	10.2
	7-23-71	103	7.0	----	7.5	----	54	26	25	34	.05	9.46
	8-13-71	41	9.0	----	7.5	----	75	32	32	46	.06	5.09
	9-29-72	5.5	4.5	7.7	7.3	134	125	47	9	71	.10	1.06
2973.88	7-01-71	56	6.0	----	8.1	----	96	46	49	55	.07	8.32
	7-23-71	38	6.5	----	7.8	----	94	48	48	58	.08	5.95
	8-13-71	8.5	16.0	----	8.1	----	128	61	58	76	.10	1.74
	9-29-72	5.9	3.0	8.2	7.8	175	163	68	74	94	.13	1.50
2973.94	9-29-72	26	8.0	8.1	7.7	154	160	63	72	92	.13	6.48
2973.96	5-27-71	90	3.5	----	8.0	----	142	67	64	87	.12	21.1
	6-27-71	169	4.0	----	7.4	----	97	43	42	58	.08	26.5
	9-02-71	16	9.5	----	7.8	----	184	71	73	112	.15	5.05
	5-30-72	172	7.5	----	7.1	----	107	46	44	60	.08	27.9
	6-29-72	155	10.5	----	8.0	----	109	43	48	64	.09	26.8
	10-01-72	8.1	7.0	----	7.5	----	218	80	84	126	.17	2.75
2974.00	5-27-71	314	5.5	----	8.2	----	125	56	56	77	.10	65.3
	6-27-71	569	5.0	----	7.5	----	87	36	37	51	.07	78.4
	9-02-71	60	12.0	----	7.8	----	173	71	73	102	.14	16.6
	6-29-72	500	11.5	----	8.0	----	93	39	38	53	.07	71.6
	7-25-72	135	8.5	----	7.8	----	125	49	56	75	.10	27.3
	10-04-72	39	7.0	8.1	7.8	202	208	79	87	124	.17	13.0
2974.02	10-04-72	6.3	4.5	8.1	7.8	197	184	87	90	111	.15	1.89
2974.04	5-27-71	128	4.0	----	7.7	----	130	70	59	87	.12	30.1
	6-27-71	386	5.0	----	7.6	----	100	50	47	63	.09	65.7
	9-02-71	46	7.0	----	8.0	----	156	78	73	96	.13	12.0
	6-29-72	225	10.5	----	8.2	----	102	53	50	70	.10	42.5
	9-30-72	43	3.0	8.2	7.7	168	161	77	72	97	.13	11.3
	10-04-72	36	4.5	----	7.9	----	163	79	79	102	.14	9.83
2974.18	6-12-72	65	6.5	----	7.6	----	72	39	31	63	.09	11.1
	7-26-72	9.3	8.0	----	7.8	----	80	42	33	63	.09	1.58
	8-11-72	6.6	9.0	----	7.6	----	98	51	36	73	.10	1.30
	5-31-72	51	6.0	----	7.2	----	64	31	24	51	.07	7.02
2974.25	5-27-71	504	7.5	----	8.2	----	131	62	59	79	.11	108
	6-27-71	1,300	5.5	----	7.5	----	99	48	47	64	.09	225
	7-22-71	496	6.0	----	7.9	----	100	52	52	69	.09	92.4
	9-02-71	126	9.0	----	7.8	----	166	76	72	103	.14	35.0
	10-07-71	107	5.0	----	7.7	----	179	76	76	109	.15	31.5
	6-21-72	725	5.0	----	8.0	----	107	48	49	67	.09	131
	7-25-72	230	8.5	----	7.9	----	133	60	57	83	.11	51.5
	10-04-72	97	6.5	----	7.5	----	189	81	80	112	.15	29.3
2974.34	10-02-72	.32	4.0	7.3	7.4	14	14	7	5	12	.02	.01
2974.36	10-02-72	.40	5.0	7.1	7.4	18	19	9	5	14	.02	.02
2974.38	10-02-72	.46	7.0	7.7	7.3	31	30	13	12	20	.03	.02
2974.40	6-23-70	73	1.5	7.1	6.8	20	19	9	6	12	.02	2.96
	8-27-70	3.2	11.0	6.4	7.7	21	21	7	8	15	.02	.09
	10-13-70	2.2	.0	6.1	8.1	24	23	9	10	17	.02	.10
	6-29-71	18	1.0	7.4	7.4	16	16	----	7	17	.02	.83
	8-31-71	4.3	11.0	7.2	6.7	20	19	----	7	13	.02	.15
	10-05-71	.89	5.5	8.2	7.0	24	21	11	7	19	.03	.05
	6-20-72	27	1.5	7.2	6.8	20	16	7	6	12	.02	.87
	7-18-72	18	9.5	6.7	7.7	18	17	11	7	14	.02	.69
	8-29-72	3.8	10.0	7.6	7.5	22	20	10	12	18	.02	.18
	10-03-72	1.5	2.0	7.1	6.4	15	22	10	10	21	.03	.08
2974.45	6-23-70	172	3.5	7.4	7.2	32	32	14	12	21	.03	10.2
	8-27-70	13	9.5	7.6	7.6	74	72	34	34	51	.07	1.86

and concentrations of major ions at water-data stations —Continued

Orthophosphorus as P	Total phosphorus as P	Silica	Calcium	Magnesium	Potassium	Sodium	Bicarbonate (field)	Bicarbonate (lab.)	Carbonate	Chloride	Fluoride	Sulfate	Nitrite and nitrate as N
0.07	0.10	28	14	6.3	1.6	5.6	----	96	0	0.5	0.5	8.0	0.01
.03	----	24	7.8	3.2	1.2	3.3	----	54	0	.6	.1	2.3	.00
.06	.10	22	19	4.2	.6	5.1	----	83	0	.9	.1	37	.05
.05	.07	23	15	3.4	.5	4.3	----	68	0	.8	.0	6.3	.00
.04	.06	20	30	8.9	.8	4.8	----	137	0	.8	.2	18	.01
.06	.07	18	40	13	.9	4.9	----	173	0	1.1	.4	32	.06
.01	.08	17	50	16	1.1	4.8	----	183	0	1.3	.2	38	.02
.01	.07	20	19	4.5	1.3	4.1	----	74	0	.9	.2	12	.02
.04	.05	19	36	11	.8	4.7	----	140	0	1.0	.4	29	.00
.07	.10	26	11	4.2	1.2	4.8	----	68	0	1.1	.1	6.8	.03
.07	.17	24	7.5	2.8	.9	4.9	----	53	0	.6	.0	2.5	.00
.04	.07	26	22	9.1	2.1	6.8	----	130	0	.9	.4	8.3	.01
----	.10	24	9.0	3.6	1.3	3.6	----	57	0	.7	.1	3.6	.01
.04	.15	14	11	1.3	2.5	2.9	----	50	0	.3	.2	8.0	.01
.02	.14	12	9.0	.9	.6	2.5	----	45	0	.4	.1	2.5	.03
.01	.04	12	13	1.1	.3	2.6	----	48	0	1.3	.3	2.0	.00
.01	.04	15	19	1.5	.3	4.5	----	76	0	.5	.7	5.3	.01
.01	.05	15	26	2.1	.9	4.5	----	80	0	.9	.5	7.8	.02
.01	.05	11	9.9	.9	.4	2.6	----	34	0	1.0	.2	5.4	.13
.00	.01	13	15	1.6	.6	3.3	----	57	0	1.0	.6	5.5	.00
.00	----	15	21	2.1	.6	4.6	----	80	0	1.2	.5	7.0	.00
.01	.05	4.8	10	.9	.1	1.1	----	36	0	.3	.1	3.8	.02
.01	.04	3.8	9.2	.5	.3	.8	----	32	0	.4	.1	3.5	.01
.01	.05	4.5	12	.6	.6	1.1	----	39	0	1.4	.3	6.3	.03
----	.02	5.6	20	1.3	.3	2.0	59	57	0	.7	.1	13	.00
.00	.07	6.0	17	1.5	.3	1.1	----	56	0	.3	.1	1.5	.02
.01	.05	5.2	17	1.3	.1	.9	----	58	0	.3	.2	4.3	.00
.01	.05	6.4	20	2.0	.2	1.3	----	74	0	.1	.4	9.0	.05
----	.01	6.8	24	3.5	.7	1.9	81	83	0	1.1	.1	15	.00
----	.00	7.5	25	2.3	.3	3.0	78	77	0	1.0	.1	15	.00
.02	.04	8.1	22	2.1	.4	3.1	----	82	0	1.0	.2	9.5	.05
.01	.05	6.1	15	1.1	.4	1.9	----	53	0	.2	.0	6.8	.03
.00	.03	9.4	26	2.0	1.0	6.6	----	87	0	1.1	.6	22	.06
----	.07	6.9	15	1.5	.4	1.8	----	56	0	.7	.1	5.8	.09
.00	----	5.9	17	1.3	.5	2.4	----	53	0	1.1	.0	9.8	.01
.00	----	10	29	2.8	1.3	11	----	98	0	1.6	.8	21	.02
.00	.03	7.8	19	2.0	.3	2.9	----	68	0	1.0	.1	9.8	.04
.01	.02	6.1	13	1.1	.3	1.9	----	44	0	.2	.0	6.5	.02
.00	.03	9.2	25	2.5	.9	5.4	----	87	0	1.0	.6	15	.01
.00	----	5.6	13	1.3	.4	2.1	----	47	0	.7	.1	7.1	.01
.00	.01	6.9	19	2.1	.6	3.4	----	60	0	1.0	.3	12	.00
.01	----	10	29	3.6	1.0	7.5	85	96	0	2.4	.7	22	.00
----	.02	14	34	1.3	.4	1.1	104	106	0	.9	.1	7.3	.01
.03	.05	13	20	2.2	1.6	2.6	----	85	0	.4	.0	5.3	.01
.03	.14	11	17	1.1	.3	1.8	----	61	0	.2	.0	1.8	.00
.01	.04	13	26	1.9	.4	2.6	----	95	0	.7	.3	4.3	.02
.01	----	11	18	1.3	.3	1.9	----	65	0	2.4	.1	2.8	.03
----	.02	13	25	2.4	.4	3.0	88	94	0	.9	.1	5.9	.00
.01	----	13	28	2.1	.5	2.9	----	96	0	1.2	.1	6.4	.00
.05	.20	19	9.2	2.0	.4	3.1	----	48	0	2.0	.0	3.3	.03
.05	.07	19	9.8	2.0	.1	4.1	----	51	0	.5	.2	1.8	.00
.05	.08	20	11	2.1	.3	5.3	----	62	0	.6	.5	2.3	.03
----	.39	18	7.1	1.5	.2	2.8	----	38	0	.8	.1	1.4	.01
.02	.04	10	20	2.2	.4	3.3	----	76	0	1.0	.3	5.3	.04
.01	.04	9.2	16	1.7	.6	2.5	----	59	0	.5	.0	3.8	.06
.00	.04	7.7	18	1.8	.2	2.3	----	64	0	1.0	.2	5.8	.00
.03	.04	12	25	2.3	.6	4.6	----	93	0	.7	.4	11	.01
.04	.06	12	26	2.7	.9	5.2	----	93	0	1.1	.3	14	.00
.00	.03	8.4	17	1.7	.3	2.6	----	58	0	.8	.1	7.4	.05
.01	.04	10	19	2.4	.6	3.4	----	73	0	1.0	.4	9.9	.00
.01	----	12	27	3.1	.7	5.6	----	99	0	1.1	.3	13	.00
----	.05	2.3	1.7	.2	.6	.4	10	8	0	1.0	.1	2.0	.00
----	.04	2.6	1.7	.3	.1	.7	15	11	0	.7	.1	2.2	.01
----	.00	3.4	4.2	.3	.1	1.0	19	16	0	.7	.2	2.6	.02
----	----	3.6	2.2	.2	.2	.7	8	11	0	.0	.1	.0	----
----	----	1.3	2.9	.2	.6	1.1	11	14	0	.0	.1	1.5	----
----	.13	3.0	3.6	.1	.2	1.0	11	18	0	.1	.2	.0	.00
.00	.01	3.4	2.6	.1	.1	.7	8	8	0	.1	.0	2.5	04
.01	.05	2.9	2.6	.1	.0	.7	11	11	0	.2	.3	.5	.00
.00	.04	2.9	3.0	.0	.2	.7	12	13	0	.3	.1	.8	.02
.00	.01	3.3	2.1	.1	.3	.4	9	9	0	.2	.1	1.0	.08
.00	.01	2.9	2.3	.2	.1	.7	15	13	0	.0	.0	1.6	.00
.00	.03	2.6	4.4	.2	.2	.6	15	12	0	.3	.1	3.7	.02
.00	----	2.9	3.7	.1	.2	.9	15	12	0	.9	.1	2.6	.71
----	----	6.1	4.2	.5	.2	1.0	17	18	0	.0	.0	.0	----
----	----	10	12	.8	.9	1.6	41	42	0	.0	.1	4.2	----

TABLE 40.—*Summary of selected water-quality characteristics*

Water-data station No.	Date of collection	Discharge (ft^3/s)	Temperature (°C)	pH (field)	pH (lab.)	Specific conductance (field, µmhos)	Specific conductance (lab., µmhos)	Alkalinity as $CaCO_3$	Total hardness	Dissolved solids	Dissolved solids (tons/acre-ft)	Dissolved solids (tons/day)
13-2974.45	10-13-70	7.0	0.0	6.6	7.8	84	84	10	38	58	0.08	1.10
	6-12-71	------	3.5	----	7.4	----	47	22	20	33	.04	----
	6-29-71	82	2.5	7.7	7.3	51	50	26	22	38	.05	8.41
	8-31-71	17	9.5	7.8	7.2	66	66	32	29	47	.06	2.16
	10-05-71	8.1	5.5	8.1	7.5	83	83	37	35	55	.07	1.20
	6-20-72	104	2.5	7.3	6.9	53	44	25	19	34	.05	9.55
	7-18-72	61	9.5	7.5	6.0	44	45	20	20	33	.04	5.42
	8-29-72	13	10.0	8.0	7.3	66	67	30	27	44	.06	1.52
	10-03-72	6.5	2.5	7.6	6.6	84	82	39	41	58	.08	1.01
2974.50	6-24-70	198	7.0	7.5	7.2	40	38	16	15	28	.04	15.0
	8-10-70	21	12.0	----	7.4	----	76	----	34	57	.08	3.36
	8-28-70	14	10.5	7.3	7.7	88	88	38	39	52	.07	2.02
	10-12-70	9.4	5.0	8.1	8.0	104	106	53	45	71	.10	1.81
	5-27-71	55	7.0	----	7.2	----	80	----	32	59	.08	8.76
	6-28-71	120	7.0	7.9	7.5	56	49	25	22	42	.06	13.6
	7-22-71	92	11.0	7.8	7.8	45	45	24	25	36	.05	8.94
	8-30-71	19	11.0	8.2	7.4	86	85	42	35	59	.08	3.03
	10-06-71	12	5.5	----	7.6	----	107	48	47	73	.10	2.31
	6-20-72	107	6.5	7.9	6.9	64	56	26	24	41	.06	11.8
	7-17-72	66	10.5	7.6	7.0	66	52	25	21	38	.05	6.81
	8-30-72	16	10.0	8.2	7.3	62	90	41	36	59	.08	2.60
	10-02-72	9.0	5.0	7.9	6.5	115	105	48	47	73	.10	1.78
2974.62	10-03-72	.07	1.5	7.9	7.2	42	41	21	16	27	.04	.01
2974.66	10-03-72	1.8	2.5	7.1	6.6	50	47	17	15	31	.04	.15
2974.70	10-03-72	7.8	7.0	7.5	7.4	68	65	25	26	45	.06	.95
2974.74	10-03-72	.31	1.5	7.9	7.6	134	122	62	49	90	.12	.08
2974.80	6-22-70	164	7.0	7.4	7.2	34	35	15	14	22	.03	9.74
	8-26-70	13	11.5	7.4	7.7	84	80	32	26	50	.07	180
	10-12-70	9.3	3.5	7.3	8.3	94	92	35	41	66	.09	1.66
	6-28-71	82	3.5	7.6	7.3	50	54	20	20	40	.05	8.86
	8-31-71	21	11.0	8.0	7.3	74	71	30	29	48	.07	2.72
	10-06-71	6.9	2.0	7.4	7.5	94	91	35	40	61	.08	1.13
	6-12-72	71	5.5	7.6	7.2	56	47	23	21	35	.05	6.72
	7-18-72	46	11.5	7.7	6.3	51	49	20	22	35	.05	4.38
	8-29-72	16	11.0	8.1	7.4	79	78	30	34	50	.07	2.19
	10-03-72	11	5.0	7.8	6.8	94	94	34	42	62	.08	1.84
2974.85	6-22-70	26	8.5	7.9	7.2	97	105	39	48	67	.09	4.91
	8-26-70	3.1	10.0	7.4	7.6	159	160	61	76	105	.14	.81
	10-12-70	2.4	3.0	7.4	8.0	94	157	63	76	110	.15	.72
	6-28-71	17	3.0	7.9	7.5	117	118	54	56	83	.11	3.81
	8-31-71	3.7	8.5	8.4	7.8	148	155	66	70	102	.14	1.02
	10-06-71	3.6	2.0	7.6	7.7	156	157	67	76	105	.14	1.03
	6-12-72	17	5.0	8.0	7.2	128	113	51	51	76	.10	3.39
	7-18-72	9.9	9.5	8.0	7.7	141	130	53	59	87	.12	2.32
	8-29-72	4.4	10.0	8.3	7.5	153	154	62	69	97	.13	1.14
	10-03-72	3.5	3.5	8.1	7.3	157	158	65	78	103	.14	.98
2975.00	5-31-71	63	4.0	----	8.0	----	99	44	45	71	.10	12.1
	6-26-71	198	5.0	----	7.4	----	61	28	27	45	.06	24.1
	9-02-71	27	8.0	----	7.5	----	110	45	44	60	.08	4.37
	6-20-72	106	3.5	----	7.8	----	71	30	32	52	.07	14.9
	7-25-72	44	8.5	----	7.7	----	90	34	40	61	.08	7.20
	10-02-72	16	3.5	7.8	7.5	137	131	46	60	90	.12	3.79
2975.30	5-31-71	25	5.0	----	7.4	----	152	77	57	117	.16	7.90
	6-23-71	21	4.0	----	7.6	----	133	62	47	98	.13	5.66
	8-15-71	3.9	19.0	----	7.1	----	155	80	53	111	.15	1.17
	6-21-72	16	12.5	----	8.0	----	129	60	47	95	.13	4.21
2975.80	10-04-72	23	5.5	8.3	7.9	195	195	91	80	115	.16	7.27
2975.90	9-28-72	3.3	7.0	8.0	8.1	110	107	51	44	76	.10	.67
2976.00	6-01-71	186	6.0	----	7.5	----	162	82	70	105	.14	52.7
	6-23-71	275	10.0	----	7.5	----	133	66	58	86	.12	64.3
	9-01-71	30	7.0	----	7.8	----	188	90	78	112	.15	9.25
	6-15-72	200	7.5	----	7.9	----	141	66	61	87	.12	47.0
	10-04-72	26	6.5	8.2	7.8	196	195	90	85	117	.16	8.25
2976.70	6-13-71	13	13.5	----	7.7	----	167	84	69	131	.18	4.60
	7-20-71	4.1	16.0	----	7.6	----	213	113	93	161	.22	1.78
	8-11-71	3.3	16.5	----	7.8	----	236	125	100	176	.24	1.57
	5-31-72	16	11.0	----	7.8	----	172	88	72	129	.18	5.57
	9-28-72	3.8	4.5	8.3	8.0	262	240	117	100	171	.23	1.73
2976.80	6-13-71	3.9	16.5	----	8.1	----	461	221	200	293	.40	3.09
	7-20-71	1.7	15.0	----	7.5	----	469	248	220	314	.43	1.44
	8-11-71	.86	17.0	----	8.2	----	486	267	220	333	.45	.77
	5-31-72	5.9	13.0	----	7.8	----	374	186	170	240	.33	3.82
	9-28-72	1.3	3.0	8.1	8.3	410	387	180	170	247	.34	.85
2977.00	6-01-71	12	7.0	----	7.6	----	283	134	120	190	.26	6.16
	6-23-71	3.8	14.0	----	7.7	----	340	170	140	224	.30	2.30
	8-15-71	2.6	9.0	----	8.0	----	402	205	170	262	.36	1.84
	6-21-72	11	10.5	----	8.1	----	316	150	130	208	.28	6.07
	9-28-72	4.3	5.5	8.3	8.1	340	313	148	130	204	.28	2.37
2978.80	9-30-72	.25	20.0	7.8	7.7	1,020	1,034	376	260	636	.87	.43
2979.00	9-28-72	.15	9.0	8.5	8.2	1,280	957	326	200	601	.82	.24

and concentrations of major ions at water-data stations —Continued

Orthophosphorus as P	Total phosphorus as P	Silica	Calcium	Magnesium	Potassium	Sodium	Bicarbonate (field)	Bicarbonate (lab.)	Carbonate	Chloride	Fluoride	Sulfate	Nitrite and nitrate as N
----	0.04	11	14	0.8	0.3	1.9	13	47	0	0.3	0.3	6.5	0.02
.01	.20	9.5	7.2	.4	.1	1.5	----	27	0	.8	.0	.5	.03
.01	.04	9.7	7.6	.7	.3	1.3	28	32	0	.3	.0	2.0	.02
.01	.06	9.6	11	.4	.1	1.3	36	39	0	.4	.4	3.3	.01
.01	.04	11	13	.5	.3	1.8	49	45	0	.7	.2	5.3	.01
.00	.03	8.5	6.8	.5	.2	.8	28	30	0	.2	.1	2.3	.03
.00	.03	7.4	7.1	.5	.1	.9	35	24	0	1.0	.1	3.4	.01
.01	.03	9.2	10	.4	.4	1.2	40	37	0	.3	.1	3.8	----
.01	----	11	14	1.5	.3	1.7	46	47	0	.6	.2	5.2	.00
----	----	7.0	5.1	.6	.2	1.3	20	22	0	.0	.1	1.0	----
----	----	12	12	1.0	.2	2.4	46	42	0	.0	.2	4.4	----
----	----	13	14	1.0	.5	3.0	46	53	0	2.0	.1	5.2	----
----	----	15	16	.4	1.2	4.0	65	62	0	.6	.3	3.2	.02
.03	.08	14	11	.5	1.0	3.0	----	50	0	.4	.1	4.5	.00
.02	.04	9.8	7.3	.4	.8	2.0	31	36	0	.1	.0	3.0	.00
.00	.03	8.5	9.0	.2	.7	1.4	29	29	0	.4	.1	.5	.03
.01	.05	13	13	.3	.7	2.7	47	51	0	.7	.4	3.0	.00
.01	.06	15	17	1.1	.3	3.7	----	59	0	.8	.2	5.3	.01
.00	.07	11	8.3	.7	.3	1.5	33	32	0	.3	.1	2.6	.03
.00	.03	9.1	7.5	.5	.3	1.7	61	31	0	1.0	.1	2.7	.00
.01	.02	12	13	.8	.3	2.8	56	50	0	.8	.2	4.4	.00
.01	----	14	17	1.2	.3	3.8	59	59	0	1.9	.3	5.3	.01
----	.01	6.9	6.2	.2	.4	.2	26	25	0	.2	.0	.9	.01
----	.01	7.6	5.6	.2	.2	1.4	23	21	0	.6	.1	5.2	.00
----	.02	7.8	10	.3	.1	1.3	27	31	0	.9	.3	8.6	.01
----	.05	22	17	1.6	.3	5.9	68	76	0	1.2	.1	4.4	.00
----	----	5.9	4.8	.4	.2	1.0	18	18	0	.0	.1	2.4	----
----	----	9.3	13	.8	.6	1.7	39	41	0	1.0	.1	9.0	----
----	----	11	15	.9	.3	2.0	42	54	0	.4	.3	9.5	.02
.02	----	9.5	7.3	.5	.2	1.5	25	35	0	.1	.0	3.0	.00
.01	.05	9.0	11	.4	.3	1.3	37	38	0	.4	.4	6.5	.00
.01	.05	10	15	.7	.3	1.8	44	43	0	.7	.2	9.8	.01
.00	.04	8.2	7.4	.5	.3	.9	27	28	0	.3	.2	3.1	.08
.00	.02	7.1	8.1	.5	.2	1.0	32	24	0	1.0	.1	4.7	.00
.01	.03	9.0	12	.9	.2	1.3	44	37	0	.2	.1	7.9	.00
.01	----	10	15	1.0	.3	1.7	46	42	0	1.6	.2	11	.01
----	----	11	16	1.8	.6	1.2	48	45	0	.0	.1	14	----
----	----	16	25	3.1	1.5	1.9	74	81	0	1.0	.1	16	----
----	----	16	26	2.8	.7	2.0	77	80	0	.6	.7	18	.02
.04	.08	14	19	2.0	.5	1.6	57	66	0	.1	.0	12	.07
.04	.11	16	24	2.5	.4	1.9	73	80	0	.7	.3	16	.00
.03	.09	17	26	2.6	.5	1.9	----	82	0	.8	.2	15	.03
.01	.09	15	17	2.0	.7	1.3	61	62	0	.4	.2	8.8	.05
.02	.08	14	20	2.2	.5	1.6	93	65	0	1.0	.1	15	.04
.03	.05	15	24	2.3	.5	1.7	80	76	0	.7	.1	15	.00
.03	----	15	27	2.6	.5	2.0	88	79	0	1.2	.1	15	.02
.20	1.00	16	14	2.4	1.0	3.1	----	54	0	2.0	.1	5.5	.03
.09	1.20	11	9.0	1.2	.7	1.7	----	34	0	.7	.0	3.5	.00
.01	.05	13	16	1.1	.5	2.5	----	49	0	.8	.4	2.0	.01
----	.05	11	11	1.1	.2	2.0	----	36	0	.7	.0	8.2	.03
.01	.02	11	14	1.3	.3	1.9	----	42	0	1.0	.3	10	.00
.01	----	14	21	1.9	.6	3.5	61	56	0	1.2	.2	18	.38
.09	.11	25	18	2.9	1.8	10	----	94	0	1.9	.1	10	.11
.08	.10	26	15	2.3	.2	9.8	----	76	0	1.5	.0	5.0	.04
.06	.15	22	17	2.6	.6	11	----	98	0	2.7	.4	4.0	.63
----	.11	24	15	2.3	.4	9.3	----	73	0	1.7	.1	6.0	.00
----	.02	13	23	5.5	.4	7.2	117	111	0	1.8	.2	9.7	.00
----	.07	19	13	2.9	.8	4.3	61	62	0	2.2	.2	3.1	.00
.04	.15	15	20	5.0	.8	5.8	----	100	0	1.4	.1	7.8	.02
.04	.30	14	17	3.9	.5	4.9	----	81	0	1.2	.0	4.5	.09
.01	.04	14	23	5.1	.7	6.9	----	110	0	1.6	.4	5.8	.01
----	.16	13	18	4.0	.6	4.3	----	81	0	1.2	.1	5.3	.06
.01	----	13	25	5.6	.5	7.4	102	110	0	2.1	.2	7.9	.00
.10	.12	36	16	7.1	2.8	7.5	----	102	0	3.3	.1	7.8	.03
.15	.18	41	22	9.3	3.6	8.3	----	138	0	3.9	.3	4.3	.05
.17	.29	44	22	11	3.7	10	----	152	0	5.0	.5	4.8	.04
----	.23	34	17	7.2	2.8	7.8	----	107	0	3.6	.2	4.1	.01
----	.17	39	23	11	4.3	10	166	143	0	66	.3	6.8	.01
.09	.20	46	42	24	4.7	18	----	270	0	11	.3	14	.07
.12	.33	45	47	24	5.3	20	----	302	0	10	.4	13	.06
.11	.19	46	49	24	4.9	21	----	325	0	12	.7	15	.02
----	.42	38	37	19	3.5	14	----	227	0	7.6	.4	8.9	.00
----	.23	40	36	19	3.5	16	183	219	0	11	.4	13	.00
.14	.20	38	27	12	3.3	12	----	163	0	5.7	.2	11	.03
.12	.40	38	34	14	2.8	16	----	207	0	6.4	.3	9.8	.16
.10	.14	36	40	16	2.7	22	----	250	0	7.8	.6	13	.19
----	.15	37	32	13	2.8	14	----	183	0	7.2	.3	12	.02
----	.14	40	30	14	3.4	13	185	181	0	7.6	.3	7.0	.00
----	.03	21	59	27	19	120	454	459	0	20	4.1	140	.00
----	.01	22	35	27	19	140	385	397	0	21	3.0	140	.00

TABLE 40.—*Summary of selected water-quality characteristics*

Water-data station No.	Date of collection	Discharge (ft³/s)	Temperature (°C)	pH (field)	pH (lab.)	Specific conductance (field, μmhos)	Specific conductance (lab., μmhos)	Alkalinity as $CaCO_3$	Total hardness	Dissolved solids	Dissolved solids (tons/acre-ft)	Dissolved solids (tons/day)
13-2980.00	6-01-71	1,070	5.0	----	8.0	----	144	71	65	96	0.13	277
	6-13-71	2,500	9.5	----	7.4	----	119	61	52	77	.10	523
	6-23-71	2,670	7.0	----	7.3	----	103	51	48	76	.10	548
	7-22-71	943	7.0	----	7.3	----	131	55	52	82	.11	209
	9-01-71	268	11.0	----	7.6	----	197	91	83	119	16	86.1
	10-07-71	201	5.5	----	7.7	----	194	89	83	121	.16	65.7
	5-29-72	1,377	6.5	----	7.1	----	135	59	59	81	.11	301
	6-15-72	1,740	8.0	----	7.7	----	108	51	48	70	.10	329
	7-25-72	390	9.0	----	7.6	----	157	69	71	97	.13	102
	10-04-72	183	7.0	----	8.0	----	199	89	90	122	.17	60.3
13-2985.00	5-26-71	4,680	8.5	----	7.9	----	96	45	39	65	.09	821
	6-26-71	10,100	8.0	----	7.4	----	79	43	40	64	.09	1,750
	7-23-71	3,700	12.5	----	7.6	----	94	48	44	64	.09	639
	9-01-71	1,160	13.0	----	7.7	----	157	75	66	99	.13	310
	10-07-71	1,100	11.5	----	7.7	----	159	72	69	93	.13	276
	5-17-72	13,000	7.0	----	7.2	----	95	41	33	59	.08	2,070
	6-14-72	8,760	8.0	----	7.2	----	76	38	35	57	.08	1,350
	7-24-72	2,020	14.5	----	7.7	----	119	54	54	78	.11	425
	10-05-72	1,090	7.0	----	7.2	----	162	75	73	104	.14	306

TABLE 41.—*Summary of concentrations of dissolved trace elements at water-data stations*
[Data, except as indicated, are in micrograms per litre. 0=value below limit of detection]

Water-data station No.	Date of collection	Discharge (ft³/s)	Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Lithium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Strontium	Vanadium	Zinc
13-2950.00	5-24-71	561	500	--	0	0	0	0	0	0	4	100	1	0	20	0.1	1	5	0	0	310	0.3	0
	6-21-71	1,110	500	0	0	0	0	0	1	0	10	260	7	17	85	.2	5	0	0	0	10	.0	10
	7-19-71	522	400	--	0	0	--	0	1	0	5	40	0	7	10	.1	3	3	0	0	170	.4	0
	8-30-71	138	500	2	0	0	20	0	0	0	2	20	0	9	0	.0	1	4	4	0	180	.2	30
	10-04-71	132	100	4	0	10	10	0	0	2	5	40	0	0	0	.7	3	3	10	0	90	.0	20
	6-16-72	1,090	0	0	0	0	20	1	0	2	1	30	1	0	10	.1	0	0	0	0	40	.6	20
	7-24-72	264	10	1	0	0	0	0	0	0	0	40	2	10	10	.2	3	2	0	0	30	.0	10
2965.00	5-25-71	2,290	300	--	0	0	10	0	0	1	6	120	0	0	20	.2	3	0	10	0	250	.9	10
	6-22-71	6,440	400	10	0	0	0	0	0	0	2	60	4	15	440	.1	0	2	0	0	10	.0	0
	7-23-71	2,410	300	0	50	0	10	0	0	1	2	20	0	9	0	.1	0	3	0	0	10	.0	0
	9-03-71	706	200	4	0	0	20	0	0	0	1	40	0	12	60	.1	2	2	5	0	130	.6	10
	10-08-71	716	100	3	0	0	10	0	0	0	5	10	1	50	0	.4	2	3	7	0	100	.0	10
	6-16-72	5,820	0	0	0	0	20	0	0	1	1	50	2	0	0	.0	0	0	1	0	30	1.3	10
	7-14-72	1,340	10	2	100	0	0	0	0	0	0	20	1	10	0	.1	2	2	0	0	40	.0	0
	10-05-72	668	0	2	0	0	10	1	0	3	0	20	3	0	10	.1	2	6	0	1	80	.8	10
2973.50	5-26-71	11	600	--	0	0	0	1	0	0	3	80	1	0	10	.1	1	4	10	0	280	1.8	50
	6-22-71	19	500	0	0	0	0	1	1	0	9	30	6	13	75	.2	10	0	3	0	80	.8	30
	7-23-71	3.0	200	0	50	0	0	1	0	0	3	10	0	12	0	0	2	4	10	0	110	.8	30
	9-02-71	.95	200	0	0	0	30	0	0	0	1	0	0	9	0	.0	3	0	5	0	320	.9	20
	10-07-71	.66	100	2	0	0	10	0	0	0	6	20	2	30	10	.2	7	5	7	0	290	.7	20
	6-14-72	16	0	0	0	0	20	2	0	4	1	110	1	0	10	.1	0	0	0	0	70	1.5	50
	7-24-72	2.0	0	0	200	0	20	1	0	0	0	10	1	10	20	.3	----	3	1	0	60	.2	30
2973.80	6-01-71	7,590	300	--	0	0	80	0	0	1	5	120	1	0	10	.1	----	0	20	0	150	1.6	10
	6-23-71	7,600	500	1	0	10	0	0	0	0	1	50	7	15	180	.1	4	0	2	0	50	.0	0
	7-22-71	3,120	200	0	0	0	0	0	0	0	19	30	3	0	10	.1	3	7	0	0	50	.3	0
	9-01-71	1,180	200	0	100	0	20	0	0	4	11	10	0	0	30	.1	1	0	4	0	140	.2	20
	10-08-71	1,070	200	5	100	0	20	0	0	1	2	10	0	10	0	.2	0	4	20	0	130	.0	10
	6-19-72	6,560	50	1	0	0	20	1	6	1	1	60	4	0	0	.0	2	6	1	0	70	.7	10
	7-25-72	1,950	0	4	0	0	0	0	0	0	1	20	1	10	0	.3	2	2	1	0	50	.0	0
	10-04-72	983	0	2	0	0	0	1	0	2	0	20	4	0	0	.1	2	2	0	1	80	1.2	10
2973.96	10-04-72	8.1	0	2	0	0	60	1	0	2	0	20	4	0	30	.0	4	2	0	0	310	.6	10
2974.00	7-25-72	135	0	2	0	0	20	0	0	0	1	10	0	0	0	.1	2	2	0	0	80	.0	20
	10-04-72	39	0	6	0	0	30	1	0	3	0	30	6	0	20	.2	2	2	0	0	260	.6	20
2974.04	10-04-72	36	0	8	0	0	10	1	0	2	0	10	3	0	0	.0	3	1	0	0	100	1.3	10
2974.25	5-27-71	504	400	----	0	0	0	0	0	0	3	40	0	0	0	.1	4	4	0	0	310	1.2	0
	6-27-71	1,300	400	0	0	0	0	0	0	0	1	10	6	19	140	.1	5	0	0	0	130	.0	0
	7-22-71	496	300	1	----	----	0	0	0	0	3	30	0	0	10	.0	0	9	0	0	60	.3	0
	9-02-71	126	200	0	100	10	30	0	0	0	4	0	0	12	0	.1	1	0	4	0	290	.6	0
	10-07-71	107	200	5	0	0	30	0	1	0	3	20	10	70	10	.3	6	3	10	0	270	.3	10
	6-21-72	725	50	0	0	0	20	0	0	1	1	20	3	0	0	.0	1	2	1	0	160	1.1	10
	7-25-72	230	0	0	0	0	10	0	0	0	0	20	1	10	20	.2	1	3	0	0	150	.3	20
	10-01-72	97	0	3	0	0	10	1	0	3	0	10	8	0	20	.0	0	2	0	1	160	1.0	10
2974.40	6-23-70	73	0	0	0	0	----	1	0	3	3	10	7	----	0	----	0	2	3	1	120	.0	0
	8-27-70	3.2	0	0	500	10	0	0	0	0	0	50	1	----	0	----	0	16	2	0	160	.0	0
	10-13-70	2.2	0	20	0	----	0	----	----	--	----	30	----	10	0	----	----	----	40	----	210	.0	0
	6-29-71	18	200	0	0	0	0	0	----	0	1	10	4	18	110	.1	0	0	0	0	3	.0	8
	8-31-71	4.3	200	3	100	0	40	0	0	0	0	10	0	0	0	.3	4	4	6	0	160	.0	0

and concentrations of major ions at water-data stations —Continued

Orthophosphorus as P	Total phosphorus as P	Silica	Calcium	Magnesium	Potassium	Sodium	Bicarbonate (field)	Bicarbonate (lab.)	Carbonate	Chloride	Fluoride	Sulfate	Nitrite and nitrate as N
0.02	0.10	12	21	3.0	0.4	4.6	----	87	0	1.4	0.1	11	0.03
.02	.20	11	17	2.3	.6	4.5	----	74	0	.7	.0	4.3	.11
.05	.35	10	15	2.6	.7	3.6	----	62	0	1.0	.0	7.8	.10
.01	.07	9.9	17	2.4	.5	3.3	----	67	0	8.9	.3	6.5	.00
.03	.04	14	27	3.8	.8	6.2	----	111	0	1.3	.4	9.8	.09
.01	.09	13	27	3.9	.7	6.5	----	109	0	1.5	.2	14	.00
----	.47	11	19	2.8	.4	4.3	----	72	0	.3	.2	6.8	.12
.00	.07	10	16	2.0	.9	2.9	----	62	0	.8	.2	5.9	.06
.00	.02	12	23	3.2	.5	4.6	----	84	0	2.0	.3	9.8	.01
.01	----	13	29	4.2	.7	6.8	----	108	0	1.9	.3	13	.00
.04	.06	14	13	1.7	.6	3.5	----	55	0	1.1	.2	3.5	.01
.02	.20	12	14	1.2	.4	2.7	----	53	0	.1	.1	6.8	.00
.01	.04	11	15	1.5	.5	3.0	----	58	0	.9	.3	3.3	.00
.01	.04	15	22	2.6	.8	5.2	----	91	0	.7	.6	5.8	.03
.00	.05	14	23	2.8	.9	5.3	----	88	0	1.5	.4	1.3	.11
----	.33	12	9.6	2.3	1.5	2.8	----	50	0	1.2	.2	4.4	.13
.01	.07	12	12	1.2	.9	2.8	----	46	0	.8	.3	3.9	.04
.00	.02	13	18	2.2	.6	3.7	----	66	0	1.0	.5	6.1	.00
.00	----	14	24	3.1	.7	5.4	----	92	0	1.4	.5	8.7	.00

TABLE 41.—*Summary of concentrations of dissolved trace elements at water-data stations*—Continued

Water-data station No.	Date of collection	Discharge (ft³/s)	Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Lithium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Strontium	Vanadium	Zinc
13-2974.40	10-05-71	0.89	100	0	4.500	0	30	0	0	2	0	10	5	0	0	0.2	4	1	6	0	70	0.0	0
	6-20-72	27	0	0	0	0	10	1	2	1	1	20	1	10	0	.0	1	3	3	0	50	.1	10
	7-18-72	18	10	1	0	0	30	1	0	0	0	10	1	0	1	.0	1	3	0	0	50	.0	10
	8-29-72	3.8	10	2	0	0	0	1	0	0	1	30	4	0	10	.6	2	3	0	0	70	.0	10
	10-03-72	1.5	0	3	0	0	0	1	0	2	1	20	3	0	0	.1	3	2	0	0	40	.4	0
2974.45	6-23-70	172	0	1	0	0	----	1	0	3	1	20	7	----	0	----	2	5	3	1	90	----	0
	8-27-70	13	0	0	0	30	0	0	0	0	0	40	1	----	10	----	5	5	13	0	170	1.0	0
	10-13-70	7.0	0	0	0	0	0	0	1	0	2	40	0	0	0	----	5	6	18	0	380	.5	0
	6-29-71	82	200	0	0	0	0	0	----	0	2	10	3	9	250	.1	9	0	0	0	40	.2	8
	8-31-71	17	200	2	300	0	30	0	----	0	1	30	0	5	0	.2	7	8	5	0	160	.8	0
	10-05-71	8.1	100	1	100	0	0	0	0	1	1	20	0	0	10	.2	9	0	5	0	150	3.8	10
	6-20-72	104	10	0	0	0	10	1	0	0	1	30	1	0	0	.0	4	3	0	0	60	.4	10
	7-18-72	61	10	0	0	0	70	0	0	0	1	20	3	0	17	.0	4	4	0	0	70	.6	10
	8-29-72	13	10	3	0	0	0	1	0	0	0	40	3	0	58	.4	9	8	0	0	100	.0	10
	10-03-72	6.5	0	4	0	0	10	1	0	3	0	30	4	0	10	.0	11	2	0	1	110	1.0	10
2974.50	6-24-0	198	0	0	0	0	----	1	0	2	1	20	6	----	0	----	3	4	1	1	110	----	0
	8-28-70	14	0	0	200	0	0	1	0	0	1	30	1	----	0	----	6	0	6	0	200	1.0	0
	10-12-70	9.4	0	0	0	0	0	0	----	0	0	40	0	0	0	.0	0	2	18	0	260	1.0	20
	5-27-71	55	400	----	0	0	0	0	----	0	1	60	0	0	0	.1	4	2	0	0	190	1.3	10
	6-28-71	120	600	2	300	0	10	0	----	0	3	30	2	7	140	.2	0	0	2	0	90	.2	0
	7-22-71	92	200	0	50	0	20	0	0	0	8	10	0	11	30	.1	3	4	0	0	60	.5	0
	8-30-71	19	200	10	0	0	10	0	0	0	3	20	0	7	0	.2	3	2	10	0	140	1.6	0
	10-06-71	12	100	1	400	0	10	0	0	1	0	20	1	20	0	.1	6	0	2	0	130	.4	60
	6-20-72	107	10	0	0	0	10	1	0	0	1	20	2	0	0	.0	4	3	2	0	70	.9	30
	7-17-72	66	10	0	0	0	0	1	0	1	1	20	1	0	0	.1	0	2	0	0	80	.2	0
	8-30-72	16	20	0	0	0	10	1	0	0	3	20	3	0	20	.4	8	3	0	0	130	1.1	20
	10-02-72	9.0	0	5	0	0	0	1	0	4	3	40	6	0	20	.1	9	2	0	1	80	1.3	30
2974.80	6-22-70	164	0	0	0	0	----	1	0	3	2	20	7	----	0	----	1	7	2	0	40	----	0
	8-26-70	13	0	0	----	0	0	0	0	0	2	10	0	----	0	----	2	3	36	0	44	1.0	20
	10-12-70	9.3	0	106	0	10	0	0	----	0	4	40	0	0	0	----	3	2	66	0	140	1.2	0
	6-28-71	82	300	4	0	0	10	0	1	0	3	20	6	10	2.5	.2	0	0	3	0	120	.6	0
	8-31-71	21	100	8	100	0	20	0	0	0	0	10	0	7	0	.3	8	4	2	0	80	1.2	0
	10-06-71	6.9	200	0	900	10	10	0	0	1	0	20	0	0	0	.2	5	1	9	0	60	.8	20
	6-19-72	71	10	0	0	0	20	1	0	0	1	40	2	0	0	.0	6	2	0	0	40	.8	10
	7-18-72	46	10	1	0	0	30	0	0	0	0	10	3	0	8	.0	7	3	1	0	50	.9	10
	8-29-72	16	10	0	0	0	0	1	0	0	0	10	3	0	30	.4	9	7	0	0	80	1.1	10
	10-03-72	11	0	6	0	0	0	1	0	3	0	60	3	0	10	.2	10	3	0	1	20	1.2	10
2974.85	6-22-70	26	0	0	0	0	----	4	0	3	4	20	9	----	10	----	2	9	4	1	50	.0	150
	8-26-70	3.1	0	0	0	10	0	2	0	0	2	10	1	----	10	----	0	5	9	0	78	.3	10
	10-12-70	2.4	0	0	100	10	0	1	----	3	3	20	0	0	0	----	----	5	13	0	180	2.7	10
	6-28-71	17	300	20	0	0	10	1	----	0	10	20	7	3	180	.1	2	0	14	0	0	1.7	100
	8-31-71	3.7	200	4	100	0	30	1	0	0	2	10	0	2	0	.1	4	4	----	0	100	2.4	80
	10-06-71	3.6	200	0	600	0	0	2	0	1	0	20	0	40	10	.2	1	1	5	0	50	2.3	90
	6-19-72	17	10	0	0	0	10	2	0	0	1	20	1	10	0	.0	2	3	3	0	50	2.2	130
	7-18-72	9.9	10	2	0	0	30	3	0	0	1	30	0	0	0	.0	1	4	2	0	50	2.6	170
	8-29-72	4.4	20	15	0	0	0	2	0	0	1	20	3	0	0	.4	1	4	2	0	70	2.2	90
	10-03-72	3.5	0	6	0	0	10	2	0	2	0	10	3	0	10	.0	2	3	0	1	30	3.4	10
2975.00	7-25-72	44	0	0	100	0	0	0	0	0	1	10	1	0	0	.1	6	3	0	0	40	.0	10
	10-02-72	16	0	2	0	0	0	3	0	2	9	30	5	0	10	.1	9	3	0	0	40	1.7	30
2976.00	10-04-72	26	0	2	400	0	10	1	0	2	0	30	6	0	0	.1	0	3	0	1	250	3.2	20

TABLE 41.—*Summary of concentrations of dissolved trace elements at water-data stations*—Continued

Water-data station No.	Date of collection	Discharge (ft³/s)	Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Lithium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Strontium	Vanadium	Zinc
13-2980.00	6-01-71	1,070	300	----	100	0	10	0	0	2	4	40	1	0	0	0.1	1	3	0	0	250	2.1	10
	6-23-71	2,670	1,500	2	200	0	30	0	3	0	24	1,100	11	16	570	.1	34	1	2	0	210	4.5	30
	7-22-71	943	0	----	50	0	----	0	0	1	1	10	0	18	0	.0	0	4	0	0	160	1.4	10
	9-01-71	268	200	0	0	10	40	0	0	0	4	10	0	16	0	.0	0	4	4	0	270	2.0	20
	10-07-71	201	200	1	0	0	20	0	0	1	3	20	0	60	10	1.0	5	4	4	0	300	7.2	20
	6-15-72	1,740	0	0	0	0	20	1	0	4	2	40	3	0	0	.0	0	0	1	0	120	1.3	0
	7-25-72	390	0	1	0	0	10	1	0	0	2	10	2	10	30	.2	2	3	0	0	50	1.0	20
	10-04-72	183	0	7	0	0	40	1	0	2	3	20	4	0	10	.1	2	6	0	1	190	1.8	10
2985.00	5-26-71	4,680	500	----	0	0	30	0	0	0	2	60	1	0	20	.3	7	0	0	0	130	.2	30
	6-26-71	10,100	500	10	0	0	0	0	0	0	1	90	9	12	220	.1	0	0	0	0	40	.0	7
	7-23-71	3,700	100	0	0	0	10	0	0	0	2	20	0	1	30	.0	0	7	0	0	20	.1	0
	9-01-71	1,160	200	0	400	0	30	0	0	0	7	210	9	14	10	.1	0	2	10	0	180	.8	40
	10-07-71	1,100	100	0	0	10	30	0	0	2	1	20	0	40	0	.2	4	1	7	0	170	.0	10
	6-14-72	8,760	0	0	0	0	20	1	0	1	3	80	3	0	10	.0	0	1	0	0	50	.9	30
	7-24-72	2,020	10	0	0	0	0	0	0	0	1	50	1	10	0	.1	2	2	1	0	50	.0	70
	10-05-72	1,090	0	5	700	0	10	1	0	2	0	10	4	0	0	.1	3	3	0	1	120	.9	10

TABLE 42.—*Summary of suspended sediment and turbidity data*

Water-data station No.	Date	Water discharge, Q (ft³/sec)	Suspended-sediment concentration (mg/l)	Sediment discharge, G (tons/day)	Unit sediment discharge (tons/day/mi²)	Turbidity (JTU)	Discharge ratio, Q/Q_B
13-2922.00	6- 8-71	121	50	16.3	0.93	10	0.34
	7-21-71	52	3	.42	.02	2	.14
	8- 9-71	23	3	.19	.01	7	.06
	6-20-72	85	27	6.19	.35	4	.24
2924.00	5-24-71	31	1	.08	.01	4	.16
	7-21-71	53	2	.29	.02	2	.27
	9- 3-71	3.0	1	.01	.00	6	.02
	6-16-72	85	8	1.83	.12	8	.44
2932.00	6- 9-71	32	57	4.92	.28	15	.16
	7-21-71	9.3	6	.15	.01	2	.05
	8- 9-71	3.7	9	.09	.01	8	.02
	6-20-72	57	1,260	194	11.09	12	.29
2934.00	6- 9-71	114	34	10.4	.56	8	.55
	7-21-71	34	2	.18	.01	2	.16
	8- 9-71	20	3	.16	.01	6	.10
	6-27-72	87	369	86.5	4.68	4	.42
2950.00	4-28-71	215	7	4.06	.03	----	.22
	5-24-71	561	4	6.05	.04	3	.56
	6-21-71	1,110	3	8.98	.06	2	1.11
	7-19-71	522	2	2.81	.02	1	.52
	8-30-71	138	8	2.98	.02	6	.14
	10- 4-71	132	3	1.07	.01	----	.13
	6-16-72	1,090	10	29.4	.20	2	1.09
	7-24-72	264	4	2.85	.02	1	.26
2956.50	6-10-71	636	53	90.9	1.78	25	1.34
	7-19-71	92	2	.50	.01	2	.19
	8-10-71	48	4	.52	.01	6	.10
	6-26-72	196	6	3.17	.06	2	.41
2960.00	5-25-71	889	12	28.8	.15	8	1.25
	6-22-71	2,710	45	329	1.69	18	3.81
	8-30-71	119	2	.64	.00	8	.17
	6- 2-72	3,700	471	4,700	24.10	71	5.20
	6-16-72	1,850	38	190	.97	10	2.60
2965.00	4-28-71	919	5	12.4	.02	----	.25
	5-25-71	2,920	17	134	.17	6	.78
	6-22-71	6,440	32	556	.69	14	1.72
	7-23-71	2,410	7	45.5	.06	1	.64
	9- 3-71	706	3	5.71	.01	8	.19
	10- 8-71	716	1	1.93	.00	----	.19
	6-16-72	5,820	41	643	.80	10	1.56
	7-24-72	1,340	3	10.8	.01	1	.35

TABLE 42.—*Summary of suspended sediment and turbidity data*—Continued

Water-data station No.	Date	Water discharge, Q (ft³/sec)	Suspended-sediment concentration (mg/l)	Sediment discharge, G (tons/day)	Unit sediment discharge (tons/day/mi²)	Turbidity (JTU)	Discharge ratio, Q/Q_B
13–2970.00	5–25–71	175	16	7.55	0.10	8	0.29
	6–22–71	560	34	51.3	.65	6	.93
	9– 3–71	103	2	.56	.01	6	.17
	6– 2–72	560	98	148	1.87	13	.93
	6–14–72	400	37	39.9	.51	4	.66
	7–24–72	153	4	1.65	.02	1	.25
2971.00	5–25–71	21	7	.40	.05	3	.09
	7–23–71	11	1	.03	.00	1	.05
	9– 3–71	7.2	1	.02	.00	6	.03
	6– 2–72	32	230	19.8	2.48	15	.14
	6–14–72	28	21	1.59	.20	2	.13
2972.50	6–10–71	76	314	64.3	2.07	32	.63
	6–14–71	92	2,105	522	16.84	235	.77
	7– 2–71	81	582	127	4.10	65	.68
	8–10–71	41	5	.55	.02	7	.34
	5–29–72	43	45	5.22	.17	4	.36
	6– 1–72	81	247	53.94	1.74	22	.68
	6– 2–72	81	445	97.2	3.14	31	.68
	6–15–72	109	987	290	9.35	51	.91
	6–16–72	98	916	242	7.81	47	.82
	6–17–72	99	890	238	7.68	40	.83
2973.00	5–25–71	4.0	73	.79	.13	15	.04
	7–22–71	1.2	7	.02	.00	4	.01
	8–16–71	1.1	12	.04	.01	8	.01
	6– 3–72	6.0	1,700	27.5	4.58	42	.06
	6–14–72	6.3	365	6.20	1.03	20	.06
2973.10	2–24–71	15	5	.20	.01	2	.07
	6–11–71	141	57	21.7	.96	10	.68
	7–24–71	23	7	.43	.02	2	.11
	8–10–81	9.8	3	.08	.00	7	.05
	6–18–72	99	35	9.34	.42	5	.48
2973.20	2–24–71	1.5	4	.02	.01	2	.03
	6–11–71	4.3	69	.80	.32	42	.08
	7–24–71	1.5	7	.03	.01	10	.03
	8–10–71	1.3	128	.45	.18	42	.02
	6–18–72	2.3	10	.06	.02	4	.04
2973.30	5–26–71	99	93	24.8	.83	12	.36
	6–22–71	135	103	9.72	.32	22	.13
	9– 2–71	7.9	1	.02	.00	7	.03
	6–14–72	105	35	9.91	.33	4	.38
2973.40	6–11–71	368	100	99.2	1.65	20	1.12
	7–24–71	41	3	.33	.01	3	.13
	8–11–71	23	5	.31	.01	8	.07
	6– 3–72	480	388	502	8.37	36	1.46
	6–19–72	178	42	20.2	.34	6	.54
2973.50	4–29–71	22	4	.24	.04	----	.41
	5–26–71	11	30	.89	.15	11	.21
	6–22–71	19	17	.87	.15	7	.36
	7–23–71	3.0	1	.01	.00	1	.06
	9– 2–71	.9	1	.00	.00	6	.02
	10– 7–71	.7	1	.00	.00	----	.01
	6– 3–72	20	813	43.8	7.30	45	.38
	6–14–72	16	30	1.29	.22	2	.30
	7–24–72	2.0	5	.03	.01	1	.04
2973.60	5–26–71	215	60	34.8	.44	14	.47
	6–23–71	343	55	50.9	.64	19	.75
	9– 2–71	7.4	1	.02	.00	6	.02
	6– 3–72	550	605	897	11.21	55	1.20
	6–15–72	365	103	101	1.26	6	.80
2973.80	5– 6–71	3,580	37	357	.31	----	.70
	6– 1–71	7,590	49	1,000	.85	20	1.48
	6–23–71	7,600	109	2,230	1.91	28	1.48
	7–22–71	3,120	3	25.2	.02	12	.61
	9– 1–71	1,180	5	15.9	.01	10	.23

TABLE 42.—*Summary of suspended sediment and turbidity data*—Continued

Water-data station No.	Date	Water discharge, Q (ft³/sec)	Suspended-sediment concentration (mg/l)	Sediment discharge, G (tons/day)	Unit sediment discharge (tons/day/mi²)	Turbidity (JTU)	Discharge ratio, Q/Q_B
13-2973.80	10- 8-71	1,070	2	5.77	0.00	----	0.21
	6-19-72	6,560	70	1,240	1.06	6	1.28
	7-25-72	1,950	8	42.1	.04	2	.38
	10- 4-72	980	6	15.9	.01	5	.19
2973.84	7- 1-71	97	2	.52	.03	2	.31
	7-23-71	103	2	.56	.03	2	.33
	8-13-71	41	1	.11	.01	8	.13
2973.88	7- 1-71	56	6	.91	.11	3	.45
	7-23-71	38	2	.21	.02	2	.31
	8-13-71	8.5	2	.05	.01	6	.07
2973.96	5-27-71	90	26	6.31	.24	13	.41
	6-27-71	169	42	19.1	.73	11	.77
	9- 2-71	17	1	.05	.00	5	.08
	5-30-72	172	93	43.1	1.65	8	.79
	6- 1-72	180	133	64.1	2.46	16	.82
	6- 3-72	172	78	36.2	1.39	10	.79
	10- 1-72	8.1	6	.13	.00	4	.04
2974.00	5-27-71	314	18	15.2	.20	6	.35
	6-27-71	569	19	29.1	.39	8	.64
	9- 2-71	60	0	0	.00	6	.07
	5-30-72	650	54	94.6	1.25	8	.73
	6- 1-72	900	124	301	3.98	17	1.01
	6- 3-72	760	123	252	3.34	22	.85
	7-25-72	135	0	0	.00	0	.15
	10- 4-72	39	4	.42	.01	3	.04
2974.04	5-27-71	128	19	6.56	.13	5	.31
	6-27-71	386	199	207	4.23	31	.94
	9- 2-71	46	1	.12	.00	6	.11
	5-30-72	390	218	229	4.68	23	.95
	6- 1-72	500	362	488	9.98	36	1.22
	6- 3-72	500	632	852	17.43	38	1.22
	10- 4-72	36	6	.58	.01	4	.09
2974.18	6-12-71	65	110	19.3	2.97	17	.97
	7-26-71	9.3	2	.05	.01	2	.14
	8-11-71	6.6	3	.05	.01	6	.10
	5-31-72	51	378	52.0	8.00	31	.76
	6- 1-72	60	408	66.0	10.15	52	.89
	6- 3-72	44	110	13.0	2.00	17	.65
2974.25	5- 7-71	228	9	5.53	.03	----	.21
	5-27-71	504	21	28.5	.17	7	.46
	6-27-71	1,300	90	315	1.93	22	1.18
	7-22-71	496	4	5.35	.03	2	.45
	9- 2-71	126	1	.34	.00	6	.11
	10- 7-71	107	1	.29	.00	----	.10
	6- 1-72	2,600	206	1,440	8.80	27	2.36
	6-21-72	725	36	70.4	.43	4	.66
	7-25-72	230	3	1.86	.01	0	.21
	10- 4-72	97	5	1.31	.01	3	.09
2974.40	6-29-71	18	1	.05	.02	1	.30
	8-31-71	4.3	1	.01	.00	6	.07
	10- 5-71	.9	1	.00	.00	----	.02
	6-20-72	27	3	.22	.08	1	.45
	7-18-72	18	1	.05	.02	1	.30
	8-29-72	3.8	4	.04	.01	1	.06
	10- 3-72	1.5	8	.03	.01	2	.03
2974.45	6-29-71	82	4	.88	.09	1	.30
	8-31-71	16	1	.04	.00	7	.06
	10- 5-71	8.1	1	.02	.00	----	.03
	6-20-72	104	5	1.40	.14	2	.39
	7-18-72	61	2	.33	.03	1	.23
	8-29-72	13	3	.11	.01	1	.05
	10- 3-72	6.5	4	.07	.01	3	.02
2974.50	5- 7-71	19.1	5	.26	.01	----	.06
	5-27-71	55	13	1.93	.11	4	.17

TABLE 42.—*Summary of suspended sediment and turbidity data*—Continued

Water-data station No.	Date	Water discharge, Q (ft³/sec)	Suspended-sediment concentration (mg/l)	Sediment discharge, G (tons/day)	Unit sediment discharge (tons/day/mi²)	Turbidity (JTU)	Discharge ratio, Q/Q_B
13-2974.50	6-27-71	120	31	10.0	0.55	6	0.38
	7-22-71	92	8	1.98	.11	1	.29
	8-30-71	19	2	.10	.01	8	.06
	10- 6-71	12	3	.10	.01	----	.04
	12- 7-81	7.6	1	.02	.00	----	.02
	1-17-72	7.1	2	.04	.00	----	.02
	2-17-72	6.9	1	.02	.00	3	.02
	3-21-72	6.4	1	.02	.00	8	.02
	4-25-72	4.2	1	.01	.00	----	.01
	5-25-72	28	4	.30	.02	1	.09
	5-31-72	210	92	52.1	2.87	----	.67
	6- 1-72	213	113	64.9	3.58	11	.68
	6- 3-72	300	245	198	10.92	9	.95
	6-20-72	107	20	5.77	.32	5	.34
	7-17-72	66	4	.71	.04	1	.21
	8-30-72	16	5	.22	.01	2	.05
	10- 2-72	9.0	5	.12	.01	3	.03
2974.80	6-28-71	82	13	2.87	.23	4	.44
	8-31-71	21	3	.17	.01	6	.11
	10- 6-71	6.9	2	.04	.00	----	.04
	6-19-72	71	16	3.06	.24	2	.38
	7-19-72	46	3	.37	.03	1	.25
	8-29-72	16	2	.09	.01	1	.09
	10- 3-72	11	5	.15	.01	2	.06
2974.85	6-28-71	17	60	2.75	.80	12	.21
	8-31-71	3.7	7	.07	.02	9	.05
	10- 6-71	3.6	2	.02	.01	----	.05
	6-19-72	17	103	4.72	1.38	9	.21
	7-18-72	9.9	14	.37	.11	1	.12
	8-29-72	4.4	4	.05	.01	2	.06
	10- 3-72	3.5	15	.14	.04	3	.04
2975.00	5-31-71	63	2,387	405	14.79	540	.29
	6-12-71	90	884	214	7.81	49	.41
	6-26-71	198	1,843	984	35.93	60	.90
	7-26-71	80	14	3.02	.11	1	.36
	9- 2-71	27	2	.15	.01	6	.12
	5-31-72	155	399	167	6.10	48	.70
	6- 1-72	210	1,331	754	27.53	65	.95
	6- 3-72	140	573	216	7.89	44	.63
	6-20-72	106	64	18.3	.67	6	.48
	7-25-72	44	8	.95	.03	1	.20
	10- 2-72	16	6	.26	.01	5	.07
2975.30	5-31-71	25	17	1.15	.04	10	.10
	6-23-71	21	8	.45	.02	6	.09
	8-15-71	3.9	9	.09	.00	7	.02
	5-31-72	21	23	1.30	.05	8	.09
	6-21-72	16	11	.47	.02	3	.07
2976.00	6- 1-71	186	89	44.6	.40	22	.32
	6-23-71	275	233	173	1.54	52	.47
	7-26-71	73	12	2.36	.02	10	.12
	9- 1-71	31	3	.25	.00	6	.05
	5-31-72	350	403	380	3.38	35	.60
	6- 1-72	450	320	388	3.45	20	.77
	6-15-72	200	160	86.3	.77	20	.34
	10- 4-72	26	7	.49	.00	5	.04
2976.70	6-13-71	13	43	1.51	.04	12	.35
	7-20-71	4.1	22	.24	.01	15	.11
	8-11-71	3.3	26	.23	.01	19	.09
	5-31-72	4.8	86	1.11	.03	15	.13
2976.80	6-13-71	3.9	82	.86	.03	14	.21
	7-20-71	1.7	230	1.05	.03	35	.09
	8-11-71	.9	31	.08	.00	20	.05
	5-31-72	8.3	139	3.11	.10	20	.44
2977.00	6- 1-71	12	153	4.95	.06	22	.14
	6-23-71	3.8	17	.17	.00	7	.04
	8-15-71	2.6	53	.37	.00	15	.03

TABLE 42.—*Summary of suspended sediment and turbidity data*—Continued

Water-data station No.	Date	Water discharge, *Q* (ft³/sec)	Suspended-sediment concentration (mg/l)	Sediment discharge, *G* (tons/day)	Unit sediment discharge (tons/day/mi²)	Turbidity (JTU)	Discharge ratio, Q/Q_B
13–2977.00	5–31–72	5.0	45	0.61	0.01	9	0.06
	6–21–72	11	28	.83	.01	4	.13
2980.00	5– 6–71	460	78	96.7	.18	----	.25
	6– 1–71	1,070	52	150	.28	22	.58
	6–13–71	2,500	301	2,030	3.82	47	1.35
	6–23–71	2,670	555	4,000	7.52	62	1.44
	7–22–71	943	51	130	.24	10	.51
	9– 1–71	268	4	2.89	.01	6	.14
	10– 7–71	201	1	.54	.00	----	.11
	5–29–72	1,380	275	1,020	1.92	34	.74
	5–30–72	1,720	341	1,580	2.97	40	.93
	5–31–72	2,250	373	2,260	4.25	55	1.21
	6– 1–72	2,700	438	3,190	6.00	61	1.45
	6– 2–72	3,170	420	3,690	6.94	65	1.71
	6– 3–72	3,200	408	3,520	6.62	59	1.72
	6– 4–72	2,450	279	1,840	3.46	46	1.32
	6–15–72	1,740	178	835	1.57	34	.94
	7–25–72	390	12	12.6	.02	2	.21
	10– 4–72	199	6	3.22	.01	5	.11
2983.00	6–16–72	4.0	245,300	2,645	281.98	40,600	----
	6–16–72	4.0	111,700	1,204	128.34	----	----
2985.00	4–29–71	1,430	17	65.5	.04	----	.26
	5–26–71	4,680	56	707	.39	32	.85
	6–26–71	10,100	172	4,680	2.60	39	1.84
	7–23–71	3,700	7	69.8	.04	2	.67
	9– 1–71	1,160	2	6.25	.00	8	.21
	10– 7–71	1,100	2	5.93	.00	----	.20
	5–29–72	7,200	194	3,770	2.09	20	1.31
	5–30–72	8,870	555	13,300	7.39	40	1.61
	5–31–72	10,500	372	10,500	5.83	54	1.91
	6– 1–72	12,300	641	21,300	11.83	65	2.24
	6– 2–72	13,600	583	21,400	11.88	66	2.47
	6– 3–72	13,600	465	17,000	9.44	60	2.47
	6– 4–72	12,400	349	11,700	6.50	47	2.26
	6–15–72	8,760	130	3,070	1.71	21	1.59
	7–24–72	2,020	9	49.0	.03	1	.37
	10– 5–72	1,090	7	11.8	.01	4	.20

TABLE 43.—*Summary of regression equation data, significant major ion concentration as a function of discharge*

Graph plotting No.	U.S. Geological Survey Station No.	Correlation coefficient, *r*	Exponent, or slope of relation	Value of parameter: Bankfull (Q/Q_B=1.0)	Value of parameter: Mean annual (Q/Q_B=0.25)
	Calcium				
1	13–2922.00	−0.945	−0.234	13	17
2	2924.00	−.940	−.211	5.2	7.0
3	2932.00	−.962	−.165	20	25
4	2934.00	−.989	−.298	12	18
5	2950.00	−.440	−.039	7.1	7.5
6	2956.50	−.983	−.207	6.6	8.8
7	2960.00	−.914	−.220	6.9	9.3
8	2965.00	−.964	−.449	7.8	15
9	2970.00	−.991	−.485	11	21
10	2971.00	−.874	−.413	9.9	18
11	2972.50	−.536	−.080	42	47
12	2973.00	−.893	−.164	16	20
13	2973.10	−.888	−.200	6.7	8.9
14	2973.20	−.907	−.408	4.1	7.3
15	2973.30	−.613	−.221	8.2	11
16	2973.40	−.953	−.213	7.7	10
17	2973.50	−.988	−.321	12	18
18	2973.60	−.973	−.252	7.9	11
19	2973.80	−.963	−.419	11	20
20	2973.84	−.997	−.256	7.2	10
21	2973.88	−.936	−.140	15	18
22	2973.96	−.908	−.225	15	21
23	2974.00	−.937	−.268	12	18
24	2974.04	−.987	−.208	16	22
25	2974.18	−.755	−.120	8.0	9.4
26	2974.25	−.948	−.199	16	21
27	2974.40	−.741	−.128	2.2	2.6
28	2974.45	−.962	−.306	4.5	6.9
29	2974.50	−.858	−.265	6.2	9.0

TABLE 43.—*Summary of regression equation data, significant major ion concentration as a function of discharge*—Continued

Graph plotting No.	U.S. Geological Survey Station No.	Correlation coefficient, *r*	Exponent, or slope of relation	Value of parameter: Bankfull (Q/Q_B=1.0)	Value of parameter: Mean annual (Q/Q_B=0.25)
	Calcium—Continued				
30	13–2974.80	−0.989	−0.359	5.0	8.3
31	2974.85	−.972	−.215	13	17
32	2975.00	−.984	−.316	8.8	14
33	2975.30	−.183	−.020	15	16
34	2976.00	−.954	−.136	16	19
35	2976.70	−.964	−.210	14	18
36	2976.80	−.494	−.086	35	39
37	2977.00	−.771	−.165	21	26
38	2980.00	−.954	−.222	17	23
39	2985.00	−.957	−.307	14	21
	Mean		−.235		
	Median	−.948	−.222		
	Sodium				
1	13–2922.00	−0.332	−0.058	1.4	1.5
2	2924.00	−.710	−.253	.8	1.2
3	2932.00	−.743	−.300	.8	1.2
4	2934.00	−.438	−.083	1.9	2.1
5	2950.00	−.749	−.260	2.2	3.1
6	2956.50	−.587	−.080	2.9	3.2
7	2960.00	−.904	−.151	3.5	4.4
8	2965.00	−.906	−.330	2.6	4.1
9	2970.00	−.556	−.113	1.6	1.9
10	2971.00	−.017	.002	2.3	2.3
11	2972.50	−.549	−.247	3.2	4.4

TABLE 43.—*Summary of regression equation data, significant major ion concentration as a function of discharge*—Continued

Graph plotting No.	U.S. Geological Survey Station No.	Correlation coefficient, *r*	Exponent, or slope of relation	Value of parameter: Bankfull (Q/Q_B=1.0)	Value of parameter: Mean annual (Q/Q_B=0.25)
	Sodium—Continued				
12	13-2973.00	-0.815	-0.211	4.8	6.4
13	2973.10	-.602	-.108	3.0	3.5
14	2973.20	-.998	-.903	1.0	3.6
15	2973.30	-.759	-.228	3.0	4.2
16	2973.40	-.835	-.151	3.6	4.4
17	2973.50	-.556	-.031	4.3	4.5
18	2973.60	-.834	-.119	4.1	4.9
19	2973.80	-.926	-.285	2.8	4.1
20	2973.84	-.941	-.265	.7	1.0
21	2973.88	-.847	-.244	.8	1.1
22	2973.96	-.990	-.532	1.7	3.6
23	2974.00	-.975	-.455	1.7	3.1
24	2974.04	-.931	-.204	1.8	2.4
25	2974.18	-.943	-.233	2.8	3.9
26	2974.25	-.922	-.327	2.3	3.6
27	2974.40	-.491	-.098	.6	.7
28	2974.45	-.849	-.206	.8	1.1
29	2974.50	-.755	-.245	1.4	2.0
30	2974.80	-.791	-.205	.9	1.2
31	2974.85	-.934	-.195	1.0	1.4
32	2975.00	-.735	-.231	1.7	2.4
33	2975.30	-.785	-.065	8.3	9.1
34	2976.00	-.888	-.177	4.2	5.3
35	2976.70	-.829	-.147	6.7	8.2
36	2976.80	-.683	-.143	13	16
37	2977.00	-.771	-.268	7.3	11
38	2980.00	-.808	-.226	3.7	5.1
39	2985.00	-.946	-.278	3.2	4.7
	Mean		-.222		
	Median	-.815	-.226		
	Magnesium				
1	13-2922.00	-0.965	-0.303	1.2	1.8
2	2924.00	-.576	-.151	.2	.3
3	2932.00	-.971	-.203	.8	1.1
4	2934.00	-.991	-.148	1.0	1.2
5	2950.00	-.197	-.070	.5	.5
6	2956.50	-.870	-.143	.8	1.0
7	2960.00	-.615	-.176	.7	.9
8	2965.00	-.809	-.365	.7	1.2
9	2970.00	-.777	-.457	.5	.9
10	2971.00	-.866	-.347	1.1	1.8
11	2972.50	-.648	-.129	2.8	3.4
12	2973.00	.596	.387	17	9.9
13	2973.10	-.967	-.297	.9	1.3
14	2973.20	-.404	-.131	1.5	1.8
15	2973.30	-.682	-.300	1.4	2.1
16	2973.40	-.996	-.300	2.8	4.2
17	2973.50	-.988	-.439	2.4	4.3
18	2973.60	-.973	-.272	3.0	4.4
19	2973.80	-.889	-.334	1.1	1.8
20	2973.84	-.749	-.236	.5	.7
21	2973.88	-.879	-.350	1.0	1.6
22	2973.96	-.656	-.175	1.4	1.7
23	2974.00	-.919	-.346	1.1	1.8
24	2974.04	-.852	-.271	1.2	1.7
25	2974.18	-.575	-.076	1.7	1.9
26	2974.25	-.908	-.206	1.7	2.2
27	2974.40	.262	.073	.2	.1
28	2974.45	-.390	-.128	.4	.5
29	2974.50	-.434	-.196	.4	.5
30	2974.80	-.772	-.252	.4	.5
31	2974.85	-.937	-.185	1.5	1.9
32	2975.00	-.311	-.110	1.2	1.4
33	2975.30	-.031	-.004	2.5	2.5
34	2976.00	-.824	-.116	3.8	4.5
35	2976.70	-.950	-.267	5.6	8.1
36	2976.80	-.295	-.048	20	21
37	2977.00	-.932	-.145	9.3	11
38	2980.00	-.792	-.326	2.4	3.7
39	2985.00	-.746	-.268	1.7	2.5
	Mean		-.200		
	Median	-.809	-.236		
	Bicarbonate (Lab analysis)				
1	13-2922.00	-0.976	-0.267	46	66
2	2924.00	-.947	-.189	22	29
3	2932.00	-.955	-.183	67	86
4	2934.00	-.915	-.231	46	64
5	2950.00	-.695	-.144	27	33
6	2956.50	-.894	-.184	35	45
7	2960.00	-.897	-.182	35	43
8	2965.00	-.906	-.340	35	56
9	2970.00	-.995	-.425	40	73
10	2971.00	-.908	-.349	43	70

TABLE 43.—*Summary of regression equation data, significant major ion concentration as a function of discharge*—Continued

Graph plotting No.	U.S. Geological Survey Station No.	Correlation coefficient, *r*	Exponent, or slope of relation	Value of parameter: Bankfull (Q/Q_B=1.0)	Value of parameter: Mean annual (Q/Q_B=0.25)
	Bicarbonate (lab analysis)—Continued				
11	13-2972.50	-0.863	-0.143	127	155
12	2973.00	-.817	-.136	83	101
13	2973.10	-.850	-.156	35	43
14	2973.20	-.874	-.339	30	48
15	2973.30	-.652	-.211	38	51
16	2973.40	-.941	-.199	53	69
17	2973.50	-.993	-.296	52	78
18	2973.60	-.988	-.222	52	82
19	2973.80	-.912	-.325	46	71
20	2973.84	-.984	-.181	27	35
21	2973.88	-.992	-.172	48	61
22	2973.96	-.899	-.187	55	71
23	2974.00	-.899	-.248	43	61
24	2974.04	-.965	-.199	61	80
25	2974.18	-.787	-.136	42	51
26	2974.25	-.941	-.206	58	73
27	2974.40	-.561	-.090	9.7	11
28	2974.45	-.913	-.234	20	28
29	2974.50	-.771	-.209	27	36
30	2974.80	-.869	-.260	21	30
31	2974.85	-.912	-.200	43	56
32	2975.00	-.829	-.190	34	44
33	2975.30	-.507	-.089	65	74
34	2976.00	-.869	-.118	77	91
35	2976.70	-.974	-.228	84	116
36	2976.80	-.482	-.105	211	244
37	2977.00	-.841	-.201	113	149
38	2980.00	-.896	-.200	68	90
39	2985.00	-.950	-.260	57	81
	Mean		-.211		
	Median	-.906	-.200		
	Sulfate				
1	13-2922.00	-0.765	-0.465	1.3	2.5
2	2924.00	-.640	-.263	1.4	2.0
3	2932.00	-.526	-.131	3.7	4.4
4	2934.00	-.924	-.379	3.5	6.0
5	2950.00	.089	.084	2.0	1.7
6	2956.50	.314	.143	1.3	1.0
7	2960.00	-.337	-.054	3.3	3.6
8	2965.00	-.569	-.230	3.2	4.8
9	2970.00	.184	.076	5.3	4.7
10	2971.00	-.130	-.089	5.9	6.6
11	2972.50	-.209	-.072	22	25
12	2973.00	-.168	-.070	8.0	8.8
13	2973.10	-.985	-.443	2.0	3.7
14	2973.20	-.983	-1.960	.0	.4
15	2973.30	-.534	-.355	4.4	7.3
16	2973.40	-.845	-.893	.6	1.9
17	2973.50	-.704	-.343	8.5	14
18	2973.60	-.743	-.227	3.4	4.7
19	2973.80	-.378	-.223	4.2	5.8
20	2973.84	-.992	-.441	2.3	4.2
21	2973.88	-.949	-.862	1.0	3.4
22	2973.96	-.993	-.528	5.6	12
23	2974.00	-.968	-.389	5.9	10
24	2974.04	-.883	-.440	2.1	3.9
25	2974.18	.133	.042	2.2	2.1
26	2974.25	-.942	-.452	4.5	8.4
27	2974.40	.068	.037	1.6	1.5
28	2974.45	-.911	-.323	1.6	2.5
29	2974.50	-.547	-.317	1.5	2.3
30	2974.80	-.982	-.516	2.1	4.4
31	2974.85	-.709	-.163	9.4	12
32	2975.00	-.332	-.283	4.2	6.2
33	2975.30	.743	.342	16	9.8
34	2976.00	-.482	-.104	5.1	5.8
35	2976.70	.097	.036	5.7	5.5
36	2976.80	-.724	-.186	8.4	11
37	2977.00	.145	.051	12	11
38	2980.00	-.816	-.296	6.4	9.6
39	2985.00	-.091	-.051	4.4	4.1
	Mean		-.275		
	Median	-.704	-.263		
	Chloride				
1	13-2922.00	0.479	0.302	0.6	0.4
2	2924.00	-.286	-.107	.3	.4
3	2932.00	.990	.578	2.0	.9
4	2934.00	.942	.528	1.1	.5
5	2950.00	-.028	-.029	.6	.7
6	2956.50	.871	.488	.8	.4
7	2960.00	.386	.151	.2	.1
8	2965.00	-.702	-.570	.3	.7
9	2970.00	-.516	-.196	.6	.8

TABLE 43.—*Summary of regression equation data, significant major ion concentration as a function of discharge*—Continued

Graph plotting No.	U.S. Geological Survey Station No.	Correlation coefficient, *r*	Exponent, or slope of relation	Value of parameter	
				Bankfull (Q/Q_B=1.0)	Mean annual (Q/Q_B=0.25)
Chloride—Continued					
10	13-2971.00	−0.028	−0.030	0.4	0.4
11	2972.50	.370	.356	.9	.5
12	2973.00	−.427	−.177	.8	1.1
13	2973.10	.125	.060	.4	.4
14	2973.20	−.097	−.063	.8	.8
15	2973.30	−.934	−.276	.3	.4
16	2973.40	.638	.153	.9	.7
17	2973.50	−.795	−.101	.7	.8
18	2973.60	−.379	−.056	.7	.8
19	2973.80	−.553	−.559	.4	.9
20	2973.84	−.466	−.233	.4	.5
21	2973.88	−.192	−.171	.2	.3
22	2973.96	−.609	−.332	.5	.8
23	2974.00	−.762	−.537	.4	.7
24	2974.04	−.367	−.321	.5	.7
25	2974.18	.813	.430	1.4	.7
26	2974.25	−.586	−.166	.7	.9
27	2974.40	−.489	−.295	.1	.2
28	2974.45	−.245	−.114	.3	.4
29	2974.50	−.699	−.498	.2	.4
30	2974.80	−.515	−.499	.2	.3
31	2974.85	−.664	−.669	.1	.3
32	2975.00	−.353	−.156	.8	1.0
33	2975.30	−.874	−.260	.9	1.3
34	2976.00	−.903	−.186	1.1	1.3
35	2976.70	−.726	−.265	2.7	3.9
36	2976.80	−.767	−.171	7.0	8.9
37	2977.00	−.581	−.111	5.1	5.9
38	2980.00	−.358	−.304	1.0	1.5
39	2985.00	−.447	−.367	.7	1.1
	Mean		−.138		
	Median	−.553	−.171		
Total dissolved solids					
1	13-2922.00	−0.973	−0.231	49	67
2	2924.00	−.914	−.188	25	32
3	2932.00	−.966	−.156	78	97
4	2934.00	−.946	−.231	54	74
5	2950.00	−.592	−.107	39	45
6	2956.50	−.900	−.112	45	52
7	2960.00	−.929	−.132	51	61
8	2965.00	−.902	−.329	45	71
9	2970.00	−.997	−.342	50	80
10	2971.00	−.827	−.272	58	85
11	2972.50	−.569	−.099	150	172
12	2973.00	−.804	−.099	107	123
13	2973.10	−.842	−.140	49	59
14	2973.20	−.985	−.568	20	44
15	2973.30	−.649	−.193	54	71
16	2973.40	−.937	−.165	68	85
17	2973.50	−.997	−.258	70	100
18	2973.60	−.971	−.170	70	89
19	2973.80	−.910	−.276	57	84
20	2973.84	−.987	−.232	28	39
21	2973.88	−.975	−.221	45	61
22	2973.96	−.964	−.241	59	83
23	2974.00	−.935	−.285	48	72
24	2974.04	−.977	−.194	64	83
25	2974.18	−.694	−.088	56	63
26	2974.25	−.970	−.226	63	86
27	2974.40	−.768	−.106	12	14
28	2974.45	−.934	−.243	24	33
29	2974.50	−.906	−.253	29	41
30	2974.80	−.942	−.295	25	38
31	2974.85	−.754	−.321	37	58
32	2975.00	−.851	−.224	45	61
33	2975.30	−.200	−.023	98	101
34	2976.00	−.870	−.109	82	96
35	2976.70	−.983	−.189	109	141
36	2976.80	−.539	−.099	228	262
37	2977.00	−.815	−.145	145	178
39	2980.00	−.939	−.219	67	90
39	2985.00	−.936	−.186	78	101
	Mean		−.204		
	Median	−.914	−.194		

TABLE 44.—*Summary of regression equation data, miscellaneous water-quality parameters as a function of discharge*

U.S. Geological Survey Station No.	Correlation coefficient, *r*	Exponent, or slope of relation	Value of parameter	
			Bankfull (Q/Q_B=1.0)	Mean annual (Q/Q_B=0.25)
Potassium				
13-2950.00	0.353	0.217	0.6	0.4
2965.00	−.528	−.222	.4	.6
2973.50	−.408	−.096	.6	.7
2973.80	.057	.041	.7	.7
2974.00	−.970	−.450	.3	.5
2974.04	−.152	−.096	.4	.5
2974.25	−.581	−.295	.2	.3
2974.40	−.248	−.089	.2	.2
2974.45	−.397	−.208	.2	.2
2974.50	.070	.035	.5	.5
2974.80	−.610	−.195	.2	.2
2974.85	−.144	−.061	.5	.6
2975.00	−.067	−.043	.5	.5
2980.00	.412	.290	.6	.4
2985.00	.073	.028	.7	.7
Mean		−.076		
Median	−.353	−.089		
Fluoride				
13-2950.00	−0.706	−0.459	0.3	0.5
2965.00	−.766	−.367	.3	.5
2973.50	−.586	−.234	.1	.2
2973.80	−.909	−.703	.2	.5
2974.00	−.993	−.832	.1	.2
2974.04	−.261	−.168	.1	.1
2974.25	−.691	−.401	.1	.2
2974.40	−.152	−.044	.1	.1
2974.45	−.530	−.290	.1	.1
2974.50	−.754	−.332	.1	.1
2974.80	−.367	−.184	.1	.1
2974.85	−.382	−.313	.1	.1
2975.00	−.444	−.441	.1	.2
2980.00	−.504	−.236	.2	.2
2985.00	−.828	−.475	.2	.5
Mean		−.365		
Median	−.586	−.332		
Nitrite and nitrate as N				
13-2950.00	−0.422	−0.224	0.04	0.05
2965.00	−.545	−1.238	.02	.11
2973.50	−.032	−.016	.02	.03
2973.80	.438	.465	.03	.02
2974.00	.437	.275	.02	.02
2974.04	.207	.141	.02	.02
2974.25	.979	.803	.06	.02
2974.40	−.094	−.093	.05	.06
2974.45	.420	.167	.02	.02
2974.50	.839	.369	.05	.03
2974.80	.937	.871	.18	.05
2974.85	.943	.554	.14	.06
2975.00	−.496	−.899	.01	.04
2980.00	−.495	−.513	.08	.04
2985.00	.056	.051	.05	.04
Mean		.117		
Median	.438	.167		
Orthophosphorus				
13-2950.00	−0.376	−0.205	0.01	0.01
2965.00	.441	.240	.02	.01
2973.50	.106	.061	.04	.03
2973.80	.595	.387	.02	.01
2974.00	.000	.000	.01	.01
2974.04	.607	.359	.02	.02
2974.25	−.417	−.251	.01	.02
2974.40	.000	.000	.01	.01
2974.45	.000	.000	.01	.01
2974.50	.977	.349	.03	.02
2974.80	.892	.296	.02	.02

TABLE 44.—*Summary of regression equation data, miscellaneous water-quality parameters as a function of discharge*—Continued

Orthophosphorus—Continued

U.S. Geological Survey Station No.	Correlation coefficient, *r*	Exponent, or slope of relation	Value of parameter: Bankfull (Q/Q_B=1.0)	Value of parameter: Mean annual (Q/Q_B=0.25)
13–2974.80	−0.511	−0.341	0.01	0.02
2975.00	.729	1.100	.15	.03
2980.00	.547	.297	.02	.02
2985.00	.296	.212	.02	.01
Mean		.167		
Median	.441	.212		

Total phosphorus

U.S. Geological Survey Station No.	Correlation coefficient, *r*	Exponent, or slope of relation	Value of parameter: Bankfull (Q/Q_B=1.0)	Value of parameter: Mean annual (Q/Q_B=0.25)
13–2950.00	−0.522	−0.089	0.03	0.04
2965.00	.211	.086	.04	.04
2973.50	.223	.035	.08	.07
2973.80	.595	.646	.07	.03
2974.00	.037	.019	.02	.02
2974.04	.934	.726	.14	.05
2974.25	−.618	−.135	.03	.04
2974.40	−.825	−.651	.01	.02
2974.45	−.370	−.082	.03	.04
2974.50	.325	.142	.06	.05
2974.80	−.458	−.195	.02	.03
2974.85	.035	.012	.08	.08
2975.00	.600	1.470	.79	.10
2980.00	.663	.698	.17	.06
2985.00	.775	.731	.09	.03
Mean		.228		
Median	.552	.035		

pH

U.S. Geological Survey Station No.	Correlation coefficient, *r*	Exponent, or slope of relation	Value of parameter: Bankfull (Q/Q_B=1.0)	Value of parameter: Mean annual (Q/Q_B=0.25)
13–2950.00	−0.057	−0.002	7.4	7.4
2965.00	−.377	−.016	7.4	7.6
2973.50	−.579	−.014	7.4	7.5
2973.80	−.442	−.020	7.4	7.6
2974.00	.113	.003	7.9	7.8
2974.04	−.128	−.004	7.8	7.9
2974.25	.246	.008	7.9	7.8
2974.40	−.063	−.003	7.1	7.2
2974.45	−.198	−.012	6.9	7.1
2974.50	−.149	−.007	7.2	7.3
2974.80	−.392	−.026	6.9	7.2
2974.85	−.662	−.027	7.1	7.3
2975.00	.105	.003	7.7	7.7
2980.00	−.527	−.020	7.4	7.6
2985.00	−.408	−.015	7.5	7.5
Mean		−.010		
Median	−.246	−.012		

Alkalinity as $CaCO_3$

U.S. Geological Survey Station No.	Correlation coefficient, *r*	Exponent, or slope of relation	Value of parameter: Bankfull (Q/Q_B=1.0)	Value of parameter: Mean annual (Q/Q_B=0.25)
13–2950.00	−0.716	−0.140	22	27
2965.00	−.900	−.333	29	46
2973.50	−.993	−.295	43	65
2973.80	−.912	−.326	37	59
2974.00	−.896	−.246	36	50
2974.04	−.963	−.200	50	66
2974.25	−.945	−.207	47	63
2974.40	−.293	−.034	8.4	8.8
2974.45	−.320	−.115	19	22
2974.50	−.967	−.318	16	25
2974.80	−.968	−.266	16	23
2974.85	−.897	−.174	37	47
2975.00	−.849	−.205	28	37
2980.00	−.882	−.191	57	74
2985.00	−.953	−.260	46	67
Mean		−.221		
Median	−.900	−.207		

TABLE 44.—*Summary of regression equation data, miscellaneous water-quality parameters as a function of discharge*—Continued

Total hardness

U.S. Geological Survey Station No.	Correlation coefficient, *r*	Exponent, or slope of relation	Value of parameter: Bankfull (Q/Q_B=1.0)	Value of parameter: Mean annual (Q/Q_B=0.25)
13–2950.00	−0.833	−0.184	17	22
2965.00	−.951	−.442	22	41
2973.50	−.985	−.356	39	64
2973.80	−.960	−.414	32	57
2974.00	−.935	−.278	35	52
2974.04	−.993	−.216	45	61
2974.25	−.952	−.201	47	62
2974.40	−.618	−.102	6.2	7.1
2974.45	−.954	−.296	13	19
2974.50	−.843	−.246	18	26
2974.80	−.986	−.345	14	23
2974.85	−.977	−.206	39	51
2975.00	−.939	−.287	27	40
2980.00	−.947	−.221	52	71
2985.00	−.968	−.296	42	62
Mean		−.273		
Median	−.952	−.278		

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