Chemical Quality of the Surface Waters of the Snake River Basin

GEOLOGICAL SURVEY PROFESSIONAL PAPER 417-D

Chemical Quality of the Surface Waters of the Snake River Basin

By L. B. LAIRD

CONTRIBUTIONS TO STREAM-BASIN HYDROLOGY

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A description of the water quality patterns in the Snake River basin and a discussion of the geologic, climatic, and water use variations that produce these patterns

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GLOSSARY OF TERMS

Cubic feet per second (cfs): A rate of discharge of a stream whose channel is 1 square foot in cross-sectional area and whose average velocity is 1 foot per second.

Dissolved solids: The reported quantity of dissolved solids—the residue on evaporation—consists mainly of the dissolved mineral constituents in the water. It may also contain some organic matter and water of crystallization. Waters with less than 500 parts per million (ppm) of dissolved solids are usually satisfactory for domestic and some industrial uses (California State Water Pollution Control Board, 1952, p. 244) (U.S. Public Health Service, 1962, p. 2152–2155). Water containing several thousand parts per million of dissolved solids are sometimes successfully used for irrigation where soil conditions permit the removal of soluble salts by the application of large volumes of water.

Equivalents per million (epm): Anionic and cationic constituents of water are sometimes reported in "equivalents per million". One "equivalent per million" of an element or ion is exactly equal in combining power to one "equivalent per million" of another element or ion. Equivalents per million can be calculated by dividing the commonly used parts-per-million values of chemical constituents by the combining weights of the appropriate constituents. (Combining weight=atomic or molecular weight of ion divided by ionic charge.)

Hardness: Hardness of water is caused almost entirely by compounds of calcium and magnesium. Other constituents—such as iron, manganese, aluminum, barium, strontium, and free acid—also cause hardness, although they usually are not present in quantities large enough to have any appreciable effect. Hardness is commonly recognized by the increased quantity of soap required to produce lather. It is also objectionable because it contributes to the formation of scale in boilers, water heaters, radiators, and pipes, with the resultant decrease in rate of heat transfer, possibility of boiler failure, and loss of flow. The classification of adjectives applied to hardness of water by the U.S. Geological Survey is listed as follows:

Hardness range (ppm)	*Adjective rating*
0–60	Soft.
61–120	Moderately hard.
121–180	Hard.
181+	Very hard.

Most probable number (MPN): This unit is the most probable number of coliform bacteria groups per 100 milliliters of water.

Parts per million (ppm): A part per million is a unit weight of a constituent in a million unit weights of water.

Sodium adsorption ratio (SAR): The term "sodium-adsorption-ratio (SAR)" was introduced by the U.S. Salinity Laboratory Staff (1954) and is a ratio expressing the relative activity of sodium ions in exchange reactions with the soil. It is expressed by the equation:

$$SAR = \frac{Na^{+1}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}},$$

where the concentrations of the ions are expressed in milliequivalents per liter (or equivalents per million for most irrigation waters). SAR is used primarily to evaluate the suitability of water for irrigation of crops.

Specific conductance (micromhos per centimeter at 25° C): Specific conductance of water is a measure of the ability of water to conduct a current of electricity. Conductance varies with the concentration and degree of ionization of the different minerals in solution and with the temperature of the water.

CHEMICAL QUALITY OF THE SURFACE WATERS OF THE SNAKE RIVER BASIN

By L. B. Laird

ABSTRACT

The Snake River basin has an area of about 109,000 square miles including almost all Idaho, the eastern part of Oregon, and lesser parts of Washington, Wyoming, Nevada, and Utah. The topography varies from complex mountain ranges and dissected volcanic plateaus to the broad Snake River Plain and other small plains characterized by lava plateaus and alluvial terraces. The rock formations consist principally of volcanic materials and granitic rocks and lesser amounts of consolidated sedimentary rocks and aluvium. Annual precipitation ranges from 8 inches or less in many of the plains to more than 60 inches in the higher mountains.

The quality of surface waters of the Snake River basin ranges from excellent to poor depending on the use for which the water is intended. Dissolved solids range from less than 20 to over 2,000 ppm (parts per million). The water of the Snake River is satisfactory for most industrial, agricultural, and municipal uses throughout most of its length. In the central reaches, a buildup of dissolved solids to an average of about 400 ppm makes the water less desirable as a municipal or industrial supply, but the water can be used satisfactorily after treatment. This water is still usable for irrigation. At times, some reaches of the Snake River are polluted by food-processing and domestic wastes.

Most of the tributary streams from the headwaters through the Henrys Fork basin contain water satisfactory for most uses. From Henrys Fork to the Idaho-Oregon border, the Snake River flows across the Snake River Plain. A relatively small volume of surface flow enters the Snake River throughout this semiarid segment of the basin. Headwaters of most of the central Snake River tributaries are reasonably dilute (dissolved solids: 50–160 ppm) and are predominately of the calcium bicarbonate type. However, as these streams approach their confluences with the Snake River, their sodium and dissolved-solids contents increase by as much as sevenfold, and the sodium content equals or exceeds that of calcium. The increase in dissolved solids and sodium can be attributed primarily to the application of water for irrigation, but the increase in mineralization is rarely sufficient to prohibit the use of the water for further irrigation. Pollution, particularly wastes from municipalities and the food-processing industry, is a problem in some of these streams. The problem is local, however, and is limited to specific reaches of a few streams.

The streams draining the mountainous areas in central and northeastern Idaho and northeastern Oregon are of excellent quality with few exceptions. This excellence is due to moderate to high precipitation, rock materials resistant to solution, and relatively low water use. The dissolved-solids content of most of these streams does not exceed 100 ppm. A few segments of some streams may be subject to pollution from organic and domestic wastes; however, pollution does not often seriously impair the quality of the water.

In the lower part of the Snake River basin, the quality of the tributary streams is affected primarily by sediment content, rather than by chemical content. The chemical quality of the streams is fairly good; the water from these streams contains from 50 to 250 ppm of dissolved solids, which are predominantly calcium bicarbonate. However, turbidity and disposition of the sediment loads carried are problems in the use of water from these streams.

PURPOSE AND SCOPE

The purpose of this report is to describe the chemical and physical properties of the surface waters of the Snake River basin, the relation of these waters to geologic environment and the climatic patterns of the basin, together with the effects of water use on water quality. The study has been, of necessity, a reconnaissance. The size of the area involved, combined with a multitude of factors affecting water quality, required the omission of some details; however, the general water-quality patterns and features that should be considered in the development of water resources of the basin have been discussed.

The steadily increasing demand for water of good quality has focused attention on the importance of water as a critical resource. A knowledge of the quality characteristics of water has become essential in developing water resources from which maximum benefit can be derived for all uses.

ACKNOWLEDGMENTS

Several agencies supplied data that were used in this report. The Bureau of Reclamation furnished analyses of surface-water samples collected from many streams throughout the Snake River basin. Data also were obtained for the Snake River basin in Washington under the cooperative program supported by the Washington Department of Conservation, Washington Pollution Control Commission, and the U.S. Geological Survey. The Idaho State Board of Health furnished information on water quality and pollution problems in much of the Snake River basin. The Oregon State Sanitary Authority supplied information on industrial wastes discharged into the Snake River and tributaries in Oregon.

The Agriculture Experiment Station of the University of Idaho furnished data collected in 1948 and 1949 on the surface waters of Idaho. Most of these data are applicable to the 1958–60 collection of data for this report. The runoff conditions for the two periods were similar, and the analysis of periodic samples collected during 1958–60 at the 1948–49 sampling sites indicated, at most places, very little change in chemical quality or dissolved-solids loads.

LOCATION AND EXTENT OF SNAKE RIVER BASIN

The Snake River drains all of Idaho except the north end and the extreme southeast corner, eastern Oregon, the southeast corner of Washington, and smaller parts of western Wyoming, northern Nevada, and Utah (pl. 1). From its origin in Yellowstone National Park to its confluence with the Columbia River near Pasco, Washington, the river flows slightly more than 1,000 miles. It is the largest tributary to the Columbia River, as it comprises about 42 percent of the drainage area and contributes about 18 percent of the flow of this river system.

The Snake River basin consists of about 109,000 square miles of variable topography. About one-third of the basin is mountainous, one-half consists of foothills and intermontane basins, and the remainder is made up of plains. The basin is largely bounded by mountain ranges, and the drainage divide is sharp in most areas. At some places along the south and west margins of the basin, however, the drainage divide crosses high desert areas, and the delineation is somewhat indeterminate. Mountain spurs extend out from many of the encircling ranges, and these spurs form the basin boundaries of many of the tributary streams of the Snake River.

The Bitterroot Range and Centennial Mountains form the north boundary of the basin except for a small part of the basin that extends over the plateaus of southeastern Washington. The crest of the Bitterroot and Centennial Mountains is the State boundary between Montana and Idaho and also the Continental Divide. Through Yellowstone National Park and southward for about 100 miles, the Continental Divide forms the basin boundary separating the Snake River drainage from the Missouri River drainage to the east. Farther south the Gros Ventre Range and the Wyoming Range separate the basins of the Snake River and the Green River, tributary of the Colorado River. The south boundary of the Snake River basin extends generally westward from Cougar Peak in Wyoming through a series of mountain ranges in southeastern Idaho, northwestern Utah, and northeastern Nevada to near the southeast corner of Oregon. The south boundary is at a somewhat lower elevation than the east boundary. From east to west the southern ranges gradually decline to hills and then lose their identity in the high plateau area of northern Nevada and eastern Oregon, where no distinctive topographic features mark the exact boundary. The southwest edge of the basin is a high, flat desert containing few prominent land features. The west boundary of the basin follows the summit of the Blue Mountains in Oregon and Washington. Near the mouth of the Snake River, the basin boundaries are traceable through the low hills and flatlands that characterize the boundary section of the Columbia River Plateau. Plate 1 is a map of the Snake River basin showing the boundaries, relief, and general stream patterns of the basin.

The headwaters section of the basin is characterized by wide valleys and steeply rising mountain ranges. The Teton Mountains in this area rise to an elevation of 13,766 feet, which is the highest point in the Snake River basin. Shortly after entering the State of Idaho, the Snake River enters the Snake River Plain and flows in a broad, sweeping arc across Idaho. This long, broad plain of low relief is bordered by largely unforested mountains and hills on the south and somewhat higher partly forested mountains on the north. On this plain, between Heise and Milner, Idaho, the principal diversions for irrigation are made from the Snake River. The northern and the central parts of the Snake River basin are mountainous and heavily forested areas of moderate to rugged relief. These areas include all the Clearwater River and Salmon River drainage areas and the headwater areas and upper parts of the Weiser, Payette, Boise, Big Wood, Big Lost, and Little Lost Rivers and Henrys Fork.

The principal characteristics of the climate of the Snake River basin are a wide range in precipitation (from less than 6 to more than 60 inches), wide range in temperature (from below 0° to more than 100°F), and generally low humidity and high evaporation. In the plains area, the summers are hot and dry. In the timbered mountain areas, the temperatures are lower and the precipitation, in general, is much greater than on the plains. In the lower elevations of the basin, snow rarely remains long on the ground; however, much of the mountainous area has large accumulations of snow that melt in the spring and furnish a very large percentage of the total runoff.

FACTORS THAT AFFECT THE CHEMICAL QUALITY OF WATER IN THE SNAKE RIVER BASIN

All natural water contains dissolved mineral matter. Water in contact with soils or rocks, even for a few hours, will dissolve some minerals. The quantity of the dissolved mineral matter depends primarily on the type of rocks or soils and the length of contact time. Carbon dioxide and acids from decaying vegetation dissolve in water and greatly enhance the solution of certain rock or soil materials. Thus, the type of rocks that make up a particular basin are important in determining the quality of water found in that basin.

Precipitation also influences water-quality patterns. The amount and intensity of precipitation can noticeably affect the water quality. This is especially notable in the Snake River basin, where the differences in relief cause appreciable variations in precipitation.

Man may use water without changing its quality appreciably; but he may make noticeable changes in quality by the addition of waste products from municipalities, industries, and agriculture. Changes in runoff and solution patterns, caused by development of watersheds and specific land areas for particular uses, may also cause noticeable changes in quality. Changes induced by man do not always derogate water quality; for example man may improve water quality by the construction of reservoirs and the augmentation of normal low flows by the release of stored water. Thus, three factors—geology, precipitation, and water and land use by man—have the greatest effect on water quality in the Snake River basin. The factors and their effects on water quality are discussed in the following sections.

GEOLOGY

Most of the rocks in the Snake River basin are of igneous origin (pl. 2) and are predominantly volcanic flows of diverse kinds and related breccia and tuff. In Yellowstone National Park, in the Snake River Plain, and in several other parts of the basin the previous topography has been obscured by volcanic flows, some of which reach a thickness of several thousand feet. These formations are predominant in an arc that is about 100 miles wide along the south and west edges of the basin. This band is narrowed in the east end of the basin, where sedimentary formations infringe from the south. It is also somewhat discontinuous in the western part, where sedimentary formations occur in eastern Oregon and extend into western Idaho. Granitic rocks do not underlie as large an area as those of the volcanic type; however, granitic rocks cover a large area in central and northern Idaho and are part of the extensive mountainous uplift in this area. Smaller areas of granitic rocks also occur in western Wyoming and eastern Oregon. The sedimentary rocks were formed from sediments deposited in lakes and marine environment that covered all or part of the Snake River basin in the geologic past. Significant areas of these rocks occur in the southeastern, east-central, west-central, and northern parts of the basin. Alluvium occurs throughout the basin, often in sizable deposits.

The minerals in the rocks and their susceptibility to weathering and solvent action have a direct bearing on the chemical quality of the water of the area. Surface water that traverses areas of volcanic rocks has certain distinct patterns of chemical quality. Where precipitation occurs in moderate amounts, the surface water is usually of a calcium bicarbonate type and sometimes contains appreciable quantities of magnesium but generally less than 100 ppm of dissolved solids. Where rainfall is low, the sodium concentrations are much higher and sometimes equal or even exceed the calcium concentrations. Silica is also a notable constituent of many of the streams that drain volcanic rocks because of the silicic nature of these rocks.

Granitic rocks are generally resistant to solution; thus water of streams flowing in areas underlain by these rocks usually has a very low dissolved-solids content. In some areas of high precipitation, the granitic rocks have become deeply weathered through exposure over a long period of time; however, the water of the streams in these areas is still very dilute. Water in most of the streams draining granitic rocks is principally of the calcium bicarbonate type; however, in a few streams the sodium content equals or exceeds the calcium concentration. This predominance of sodium in some streams may be caused by local variations in the composition and weathering of the quartz monzonite, which makes up a sizable percentage of these granitic rocks.

The chemical quality of water flowing through areas of sedimentary rocks is variable. Well-consolidated sedimentary rocks, such as those of the Belt Series in the northern and northeastern parts of the basin, are resistant to solution. The water traversing these areas is low in dissolved solids and normally is a calcium bicarbonate type. Water traversing areas of poorly consolidated sedimentary rocks and alluvium is variable in chemical type. This water is usually much higher in dissolved-solids content because such rock materials are much more susceptible to weathering and solvent action.

PRECIPITATION AND STREAMFLOW

Precipitation in the Snake River basin is characterized by wide geographic variations. The normal annual precipitation, shown on the isohyetal map (pl. 3), generally ranges from 6 inches on the arid plains of southeastern Idaho to 60 inches in the headwaters of the Snake River and in the Sawtooth Mountains of Idaho. The precipitation pattern is largely determined by topography. Eastward-moving Pacific maritime airmasses, though modified by intervening topographic barriers to the west, have a moisture content that is sufficient to produce considerable precipitation when these airmasses are lifted over the mountains within the area. The greatest amounts of precipitation occur on the western slopes of the highest mountains. In the dry areas of the basin, precipitation is, with some exceptions, fairly evenly distributed throughout the year. It is slightly greater than average during the winter and spring and somewhat less during July and August. In areas of higher elevation, where the normal annual precipitation is greater than average, the distribution is uneven. More than half the annual precipitation falls during the winter. In the spring it decreases, reaching a minimum during July and August; then it gradually increases during the autumn.

Plate 3 illustrates the relationship between precipitation and annual runoff. Mountainous areas of the northeastern and central parts of the basin receive 40–60 inches of precipitation. The streams originating in these areas and flowing through them are the largest tributaries to the Snake River. The annual flow of the streams in the central part of the basin is low and correlates directly with the low rainfall.

Precipitation is directly related to chemical quality of the streams in at least two ways. In humid areas of the Snake River basin, surface runoff usually dissolves only small amounts of minerals. Thus, storm runoff from these areas almost always has a low dissolved-solids content. A similar situation exists when the precipitation occurs as snow on mountainous areas. When the snow melts in the spring, runoff is generally rather rapid and dissolves only small amounts of minerals.

Precipitation affects stream quality in another way. Over long periods of geologic time, the moderate to high precipitation in humid areas will dissolve most of the readily soluble materials in the surface rocks and soils and leave behind those materials more resistant to water's solvent action. Precipitation on this type of an area produces runoff that is characteristically very dilute. In contrast, the arid and semiarid areas, where the most readily soluble salts and minerals have not been completely removed by continuous solvent action of precipitation and resulting runoff, produce runoff having a much higher dissolved-solids content. In some streams the concentration may even be greater during storm runoff than during periods of moderate and low flows. Large areas of arid and semiarid land occur in the Snake River basin, and the availability of these readily soluble salts and minerals have a pronounced effect on the water quality of the streams in these areas.

WATER USE

Changes of water quality brought about naturally by changes in geology or precipitation patterns usually take place slowly. However, the use of surface water by man as a supply and a means of waste disposal for domestic, industrial, and agricultural purposes can have a pronounced effect on the chemical quality of the surface water of a specific area or region over a relatively short period of time. The effects of some of these water uses on water quality in the Snake River basin are discussed in the following section.

DOMESTIC USE

The population of the Snake River basin is slightly less than 700,000 people (1960 census). This population is divided almost equally between rural and urban areas by the Bureau of Census' definition of urban places as "incorporated and unincorporated places of 2,500 inhabitants or more, and the towns, townships, and counties classified as urban." The population density is less than 6½ people per square mile. The largest city in the basin, Boise, Idaho, has a population of less than 35,000. Plate 4 is an illustration of the population densities in the Snake River basin. The greatest concentrations of population are in Idaho and along the main stem of the Snake River and in the lower part of the tributary streams. Except in three or four general areas of population concentration, the Snake River basin is very sparsely populated. The aridity of the country in the south and southwest and the rugged, mountainous terrain in the central and northern part of the basin have been major factors in restricting population growth.

Surface water use in connection with population has two primary functions: one is as a source of domestic supply; the second is as a carrier and dilutant for domestic sewage and associated waste products. Cities and communities in the Snake River basin use only a very moderate amount of surface water for domestic supply. The average daily pumpage is about 22 million gallons. Twin Falls, Idaho, the major user of surface water for municipal supply in the basin, pumps an average of about 6 million gallons per day.

Domestic use of water has only an indirect effect on the quality of the water. If the flow is small and most of it is used as a source of supply, then the reduced flow below the point of intake may be more highly contaminated by waste products added to the stream because less water is available for dilution of these products.

Surface water of the Snake River basin also is used for the disposal of domestic waste products. Most of the urban areas in the basin dispose of these waste products to some surface drainage. About 80–90 percent of such releases are processed through either primary or primary and secondary sewage-waste treatment plants before their release. These releases are obviously greater in the areas of population concentration, along the Snake River itself and in the lower part of many of the tributary valleys. Because of controlled streamflow in these irrigated valleys, in certain periods of the year the quantity of water available is inadequate to provide dilution and natural purification of the municipal waste discharged to the waters. A higher degree of waste treatment is needed than is now being furnished in some areas.

Disposal of domestic wastes in surface water normally brings about minor changes in the chemical character of the water. Some increase in chloride, nitrate, and phosphate contents of the water usually is noted, and detergents and various types of organic materials may be added to the water. However, these additions are only part of the picture. The most serious aspect is the bacterial pollution resulting from the discharge of raw and inadequately treated sewage. In the highly developed irrigated valleys of the upper and central Snake River basin, unusually high rates of enteric diseases have occurred in past years. Health officials believe that a contributing factor to these outbreaks is the discharge of raw and inadequately treated domestic sewage into streams from which water is diverted for irrigation (Federal Security Agency, 1951, p. 8).

IRRIGATION USE

Irrigation agriculture is the greatest user of surface water in the Snake River basin. More than 2,800,000 acres is under irrigation. Irrigation agriculture is by far the largest segment of economic activity in the basin. The availability of sufficient water of satisfactory quality affects the economic status of hundreds of thousands of people.

The concentration of dissolved constituents in the water determines its suitability for irrigation use. The characteristics that appear to be most important in determining this quality are: (1) total concentration of soluble salts, (2) relative proportion of sodium to other cations, (3) concentration of boron or other elements that may be toxic to plants, and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium. According to classifications formulated by the United States Department of Agriculture (U.S. Salinity Laboratory Staff, 1954, p. 69–82) most of the surface water of the Snake River basin is suitable for irrigation. Water in a very few tributaries has undesirable characteristics, such as high salinity or high sodium content; however, by far the greatest volume of the water is classed as excellent or satisfactory.

Irrigation also is a source of stream pollution. Use of water for irrigation definitely decreases the volume available in the river basin. Infiltration losses and evapotranspiration reduce the volume of irrigation water from 40–80 percent, but 67 percent is generally accepted as an average (Haney and Bendixen, 1953, p. 1161). This volume is not available for downstream dilution; moreover, the dissolved-solids residue from this "lost" water is usually picked up by the drainage water. In addition, water applied for irrigation, because of leaching of minerals from the soils, has a greater opportunity to increase in mineral content than the water does from continuous flow through natural drainage channels. Soluble fertilizers also contribute to the dissolved-solids increase. Thus, the use of surface water for irrigation, and a subsequent return of drainage water to the stream, does in many places cause an increase in dissolved-solids content of the river water. Most streams thus affected show a progressive increase in dissolved solids in a downstream direction. Marked increases in sodium, bicarbonate, sulfate, and chloride concentrations commonly occur. The use of water for irrigation in the upper part of a river basin can be of considerable concern to users in the lower basin.

INDUSTRIAL USE

Many industrial plants using relatively small quantities of water depend on public water systems to supply their needs. Others, particularly those requiring large quantities of water or those outside the area served by public system, have developed their own supplies. In the Snake River basin such supplies have been mostly developed from underground sources; however, some industries use adjacent surface water as a source of supply. Industrial water supplies are adequate throughout most of the populated areas, although some surface-water supplies require treatment to provide water of a satisfactory quality for some industrial uses.

Some industries use surface water not only as a source of supply but also as a means of waste disposal. Industrial waste problems in the basin have been growing rapidly more serious and will probably continue to do so in the future. Untreated or partially treated industrial wastes can bring about appreciable changes in the chemical quality of the surface water. For example, many oxygen-depleting type wastes are discharged, and if present in sufficient concentration make the water undesirable for many uses. This type of waste discharge has been increasing rapidly and constitutes the greatest problems in quality of water management in the Snake River basin at the present time (1962).

Although pulp mills contribute some oxygen-depleting wastes to streams in the Snake River basin, food-processing plants are the chief source of these wastes. A recent increase in waste problems has been caused by the rapid growth of the potato-processing industry. At present (1962) more than 20 such plants in the basin convert potatoes into potato starch or food products, and collectively, these plants are the largest source of

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oxygen-depleting wastes. The plants processing sugar beets are the second largest source of these organic wastes. Plants processing wood pulp are the third largest, followed by miscellaneous sources such as canneries, slaughter houses, and milk-processing plants. The relative population equivalents of the oxygen-depleting power of industrial organic wastes and domestic sewage illustrate the magnitude of the organic-waste problem in the basin. The wastes from the potato, sugar, wood-pulp, and miscellaneous food-processing plants in the basin exceed many times the waste discharges of domestic sewage to surface drainage. When these waste discharges and those from domestic sources are added to normal low flows and (or) diversions of streamflow for irrigation, pollution is greatly intensified.

Reductions in industrial-waste discharges can sometimes be achieved more economically by changes in plant processes than by changes in actual treatment facilities. For example, the sugar-beet-processing industry has significantly reduced its wastes, largely by the substitution of pulp drying for silo storage. The sugar-beet industry, the potato industry, and similar industries in the basin are working with pollution-control officials to decrease the amount of these oxygen-depleting wastes discharged into streams of the basin. The discharge of such wastes, however, probably will continue to be a water-quality problem for many years to come.

CHEMICAL QUALITY OF SURFACE WATER BY GEOGRAPHIC REGION

Many of the subbasins of the Snake River drainage basin contain surface water that is similar in quality to water in adjacent subbasins. This similarity is usually produced by congruencies in geology, precipitation, and(or) water use, as discussed in the previous section. For discussion, the basin has been divided into geographic areas of similar water quality. Representative analyses of water from the larger streams and from some of their more important tributaries are given in table 1.

HEADWATERS REGION

The Snake River and its tributaries in the headwaters region (fig. 1) drain a segment of the Middle Rocky Mountains physiographic province. The major relief consists of the Teton Mountains on the west and the Gros Ventre Range in the southeast. The Teton Mountains and part of the Gros Ventre Range are hard, resistant granitic rock. The remainder of the Gros Ventre Range is composed largely of folded sedimentary rocks. The drainage area in Yellowstone National Park is underlain by volcanic and sedimentary formations. South of Jackson Lake the Snake River flows

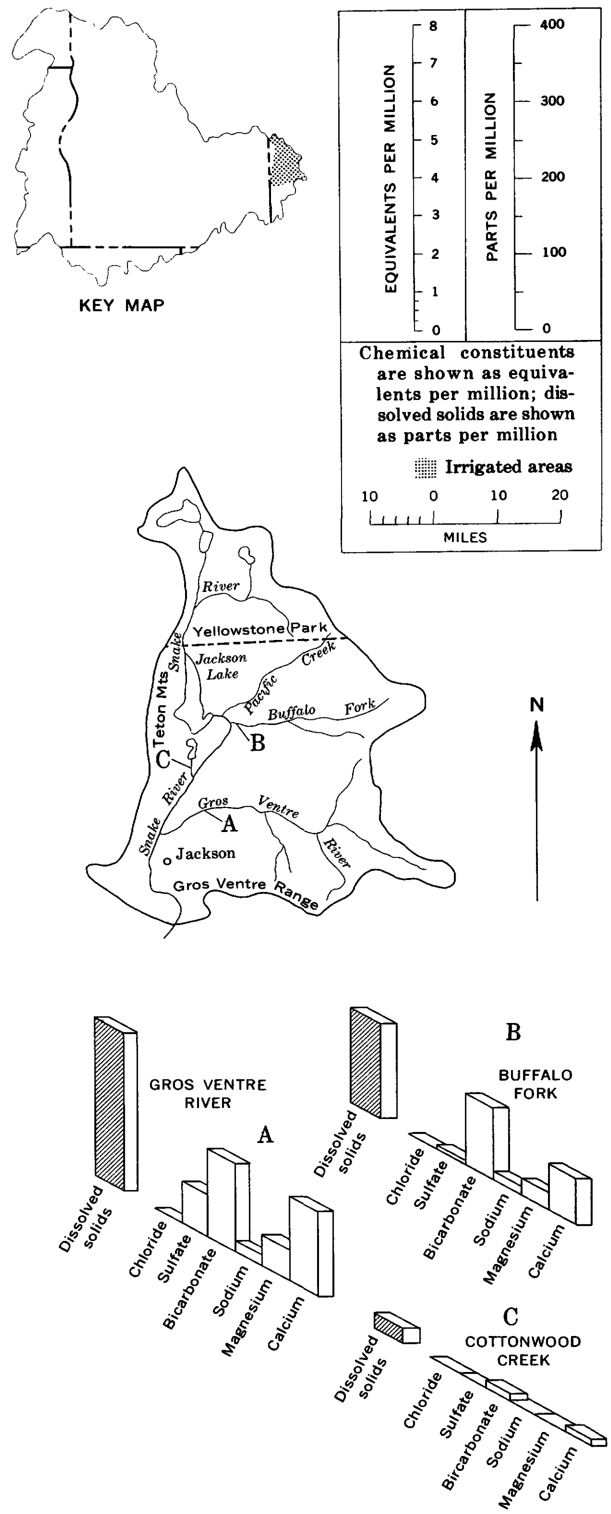

FIGURE 1.—Physical features and representative chemical quality of water in the headwaters region, 1959–60.

through a broad alluvial valley which narrows south of Jackson, Wyo.

The principal tributaries of the Snake River in this part of its drainage basin are Pacific Creek, Buffalo

Fork, and the Gros Ventre River. All three tributaries drain largely sedimentary rocks and have a calcium bicarbonate water whose dissolved solids range from about 200 ppm for the Gros Ventre River near Kelly, Wyo., to about 125 ppm for both Buffalo Fork and Pacific Creek near their mouths. The sulfate content of the Gros Ventre River exceeds the sulfate content of the other two streams. This sulfate and the higher dissolved-solids contents probably come from the weathering of the soft shales that occur in the Gros Ventre River basin and from the inflow of spring water high in calcium sulfate. The streams tributary to the Snake River from the west drain the Teton Mountains, whose higher elevations receive almost 60 inches of precipitation. This high precipitation together with the rocks of low solubility produces stream runoff that has a low dissolved-solids content. For example, Cottonwood Creek near Jenny Lake, Wyo., in July 1960, had a dissolved-solids content of 22 ppm and a calcium bicarbonate type of water. The chemical quality of this stream is similar to the other east-slope drainage from the Teton Mountains.

The acreage under irrigation in the headwaters region is relatively small; much of it is centered around Jackson and the lower part of the Gros Ventre River. A smaller irrigated area is located on the lower part of Buffalo Fork. The return drainage from this irrigation appears to have very little effect on the water quality in the subbasin

Very little industry has settled in the area; the largest activity consists of lumber or wood-processing plants in and around Jackson, and they seem to have very little effect on the water quality.

HOBACK RIVER BASIN

The Hoback River drains 572 square miles of folded sedimentary rocks associated with the Southern Rocky Mountain province (fig. 2). These rocks extend northward and also underlie part of the drainage area of the Gros Ventre River. The Hoback River is of interest because of the higher dissolved-solids and sulfate contents of the water in this basin as compared with water in the surrounding basins. The other streams of the upper Snake River basin have calcium bicarbonate type water and dissolved-solids contents ranging from about 20 to 230 ppm. However, dissolved-solids concentrations found in many of the tributaries to the Hoback River exceed 250 ppm, and in a few they exceed 500 ppm. Sulfate is the predominant anion in many of these tributary streams, and this constituent slightly exceeds the bicarbonate concentration at the mouth of the Hoback River during most of the year. Water of the Hoback River has only a moderate effect on the chemical quality of the Snake River. Below the confluence of these two streams, the dissolved-solids content of the Snake River water increases about 35 ppm, and the sulfate content increases moderately. At this point the Snake River is still predominantly a calcium bicarbonate water.

The fact that the dissolved-solids and sulfate concentrations in the water of the Hoback River basin are greater than those in adjoining basins can probably be traced to the shales and related sedimentary deposits, which are predominant in the Hoback River basin. These strata extend to the north into the Gros Ventre basin and bring about a similar but less pronounced effect, as has already been noted. Most of the increased mineralization probably comes from ground-water inflow to these rivers. An estimated flow of 3–4 cfs from a spring on the Hoback River a few miles above the mouth had a dissolved-solids content of 1,200 ppm, which consisted predominantly of calcium and sulfate ions.

Irrigation use of water in the Hoback River basin is very small and would have practically no bearing on surface-water quality. The basin has no industry at present (1962).

SOUTHEASTERN REGION

The southeastern region (fig. 3) includes the Snake River tributaries south of the Snake River from Greys River through the Blackfoot River and the small creeks that enter the Snake River from the north from below the Hoback River northwest to the mouth of Henrys Fork.

The Greys River drains about 154 square miles lying between the Wyoming Range on the east and the Salt River Range on the west. In the upper half of the basin the river drains rocks that are volcanic and sedimentary in origin; in the lower half of the basin, the river drains an area of sediments that are susceptible to weathering and solvent action and has cut a narrow canyon through the northern tip of the Salt River Range to the Snake River near Alpine, Wyo. The lower part of this canyon has been cut in limestone. Very little irrigation and no industrial activity is carried on in the basin. Water in the basin is a calcium bicarbonate type, and several samples collected near the mouth show average dissolved-solids content of about 175 ppm; the extremes were 165 and 212 ppm.

The Salt River rises at the south end of the Salt River Range and drains the western slopes of this range and the eastern slopes of the southern extension of the Caribou Range in Idaho. It has a drainage area of about 890 square miles, slightly more than half of which is in the State of Wyoming. From its headwaters, the Salt River flows almost due north through Star Valley and enters the Snake River just west of the Idaho border.

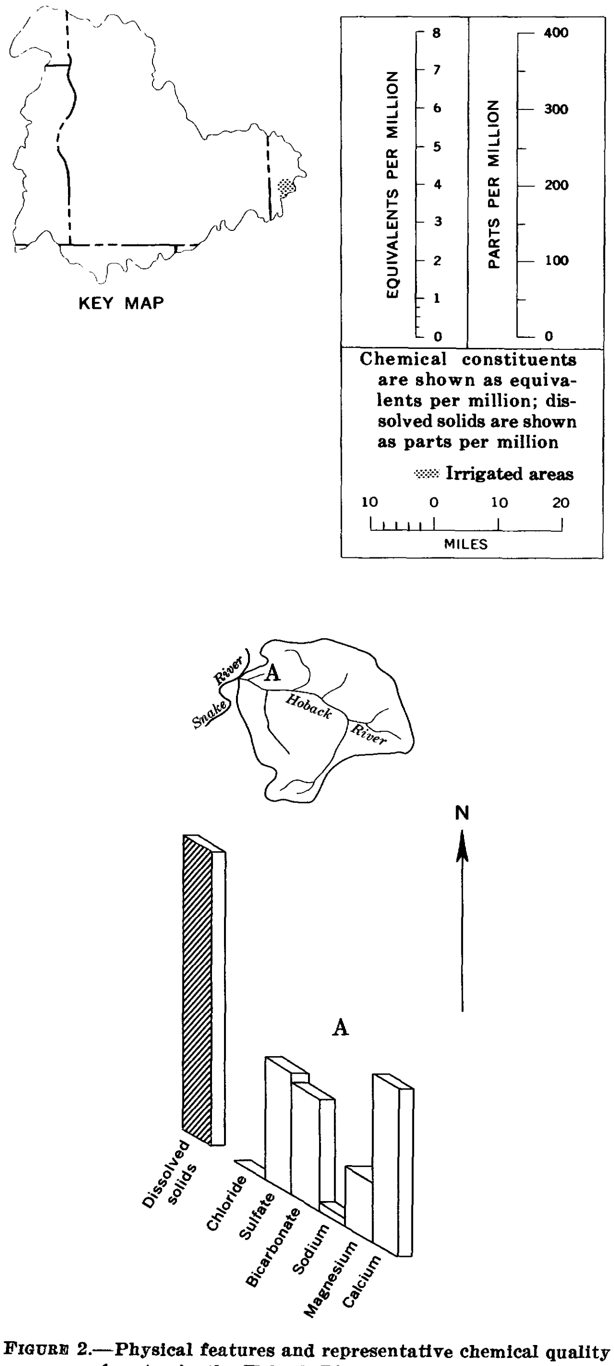

FIGURE 2.—Physical features and representative chemical quality of water in the Hoback River basin, 1959–60.

Unregulated flows of the Salt River and its tributaries furnish water to irrigate about 66,000 acres of land in Star Valley. The area has a few food-processing plants, but these have little influence on water quality in the basin. Water throughout the basin is a calcium bicarbonate type; however, samples collected near the mouth of Salt River also contained more magnesium than adjacent streams. The dissolved-solids content of the stream increases somewhat from the headwaters to the mouth. Dissolved-solids content of high- and low-flow samples collected from the Salt River in headwaters area near Smoot, Idaho, ranged from 174 to 211 ppm, and for similar samples collected at the mouth dissolved solids ranged from 247 to 271 ppm. Although this increase could be partly due to return flows from irrigation, it is probably due to natural causes because much of the water of the main stem and tributaries flows through alluvial materials.

Willow Creek drains about 700 square miles lying between the Caribou Range and the Blackfoot Mountains. The upper part of the basin is characterized by wide valleys; many of the hills and ridges are capped by basalt. Below its confluence with the Grays Lake outlet, Willow Creek has cut a canyon through lava fields. In some reaches the stream flows on the remnants of the basaltic rocks of Pliocene or Pleistocene age, but in most places it has cut entirely through the basalt and entrenched itself in sedimentary rocks of Triassic or older ages. Where Willow Creek emerges from the canyon onto the Snake River Plain, its gradient becomes much flatter. On the plain, Willow Creek divides and forms North and South Willow Creeks. North Willow Creek flows to the southwest and joins the Snake River just upstream from Idaho Falls. South Willow Creek divides several times further downstream, and these flows, together with diverted Snake River waters, are used to irrigate lands along the east edge of the Snake River Plain upstream from the Blackfoot River. Samples taken from Willow Creek near Ririe indicate the water has a calcium bicarbonate chemical character and average dissolved-solids content of about 200 ppm.

Little water is used for irrigation in the basin above the point where Willow Creek enters the Snake River Plain. Below this point, however, a large segment of the basin is under irrigation. This irrigation probably has little effect on the quality of the water in Willow Creek; however, much of the water from Willow Creek is used for irrigation and eventually finds its way back to the Snake River in the area between Idaho Falls and Blackfoot.

Only a few food-processing plants operate in this basin, and they probably have little effect on the chemical quality of the water in Willow Creek.

The Blackfoot River drains an area of about 1,100 square miles consisting of the west slope of the Blackfoot Mountains and the northeast slope of the Aspen Range. In addition, some water from the Willow Creek basin is diverted into the Blackfoot River basin during the irrigation season. The basin consists of folded and thrust-faulted marine sedimentary rocks of Triassic and Jurassic age; between the uplifts are areas filled with deposits of the Salt Lake Formation and basalt of the Snake River Group.

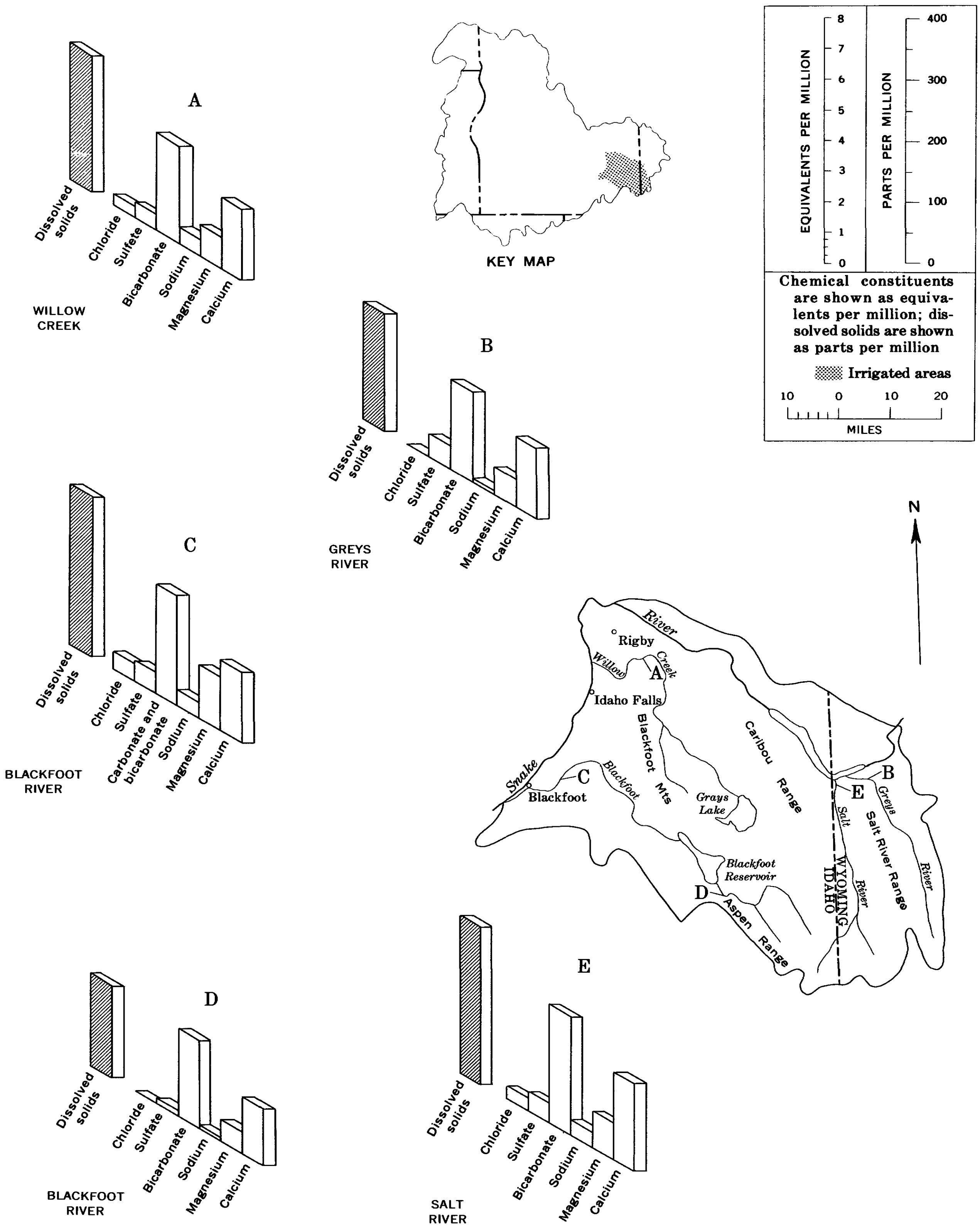

Figure 3.—Physical features and representative chemical quality of water in the southeastern region, 1948–49 and 1958–60.

From the headwaters to the mouth, the water of the Blackfoot River is predominantly of the calcium bicarbonate type. Magnesium content increases in the reaches of the river below Blackfoot Reservoir. Water above the reservoir near Soda Springs has a dissolved-solids content of about 150 ppm and below the reservoir, of about 250 ppm. Part of this increase may be due to evaporation of the water and to subsequent concentration of the dissolved material in the reservoir. Average annual evaporation in this area, measured by use of class A pans, amounts to about 50 inches, and average annual lake evaporation is 36 inches (Kohler and others, 1959, pls. 1, 2). From the reservoir to the mouth, the Blackfoot River is relatively uniform in chemical quality and maintains an average dissolved-solids content of about 250 ppm; a daily sampling station above the town of Blackfoot had an average dissolved-solids content of 251 ppm, and a corresponding range of 181–276 ppm (1948–49). (A study of flow data and 1958–60 chemical analyses show that the 1948–49 data are comparable to those of the 1958–60 period.) Part of the flow in the lower part of the river is actually Snake River water. Much of the flow during the nonirrigating season and a smaller part during irrigation season is water wasted from the Snake River canals.

A small acreage is irrigated in the headwaters of this basin and a large acreage, in the lower part of the basin where the river flows on the Snake River Plain. The irrigation in the lower part of the basin, however, has little effect on the water quality of the Blackfoot River.

Several food-processing plants are operated in and around Blackfoot. The waste products from these plants and the sewage wastes from the town of Blackfoot are discharged indirectly into the Snake River (via Jackson Creek) and only a small volume of waste products is discharged into the Blackfoot River.

AMERICAN FALLS REGION

The water of the streams in the American Falls region (fig. 4) contains a greater amount of dissolved minerals than the water of the streams of the southeastern region. A definite trend of increasing dissolved-solids content is evident in the streams from north to south throughout the southeastern and American Falls regions. It has been traced from Willow Creek, which has an average dissolved-solids content of about 200 ppm, through Blackfoot River, Portneuf River, Bannock Creek, and Rock Creek to the Raft River, where it reaches a maximum. Dissolved solids average almost 900 ppm near the mouth of the Raft River. The trend is not completely uniform, but it has few exceptions. The reason for this progressive increase in dissolved-solids content is probably twofold: (1) a trend of decreasing precipitation from north to south, and (2) a difference in the rock formations. The headwaters of the Willow Creek basin receive an average of more than 20 inches of rainfall per year, but the Raft River basin receives only about 12 inches average annual rainfall. Therefore, in the southern part of the basin there is less runoff, less dilution by the runoff, and probably a greater proportion of soluble constituents remaining in the soils and rocks because the lower precipitation has removed less of the soluble materials previously. Also, the nature of the rocks changes from north to south throughout this area. The northern part of the area consists largely of consolidated marine sedimentary rocks and some Snake River basalts. From Willow Creek southward, the percentage of basalt decreases, and the sediments become more poorly consolidated. In place of the basalt, sizable deposits of alluvium are found in many of the valleys. These poorly consolidated sediments and alluvium are fairly susceptible to solvent action and are the source of much of the dissolved mineral matter found in the streams of this area.

The Portneuf River originates in the barren hilly country on the Fort Hall Indian Reservation. This drainage basin has an area of about 1,350 square miles between the Blackfoot River on the east and the Bannock Range on the west. Most of the upper tributaries are intermittent streams. The only large tributary is Marsh Creek, which joins the Portneuf River from the south at Inkom, Idaho. The upper and middle parts of the Portneuf Valley consist largely of moderately to poorly consolidated sedimentary rocks. However, some basalts of the Snake River Group also exist in this area. Marsh Creek valley was probably one of the outlets for Pleistocene Lake Bonneville. Large deposits of alluvium in the upper and lower reaches of the Portneuf Valley are attributed to this source (U.S. Congress, 1952, p. 1222).

The water throughout the Portneuf basin is uniformly calcium bicarbonate in type. However, sodium content increases from the headwaters to the mouth. This increase may be due to application of irrigation water, to natural solvent action of the water on the alluvium that is predominant in much of this area, or to a combination of these two factors. Dissolved solids in water of Portneuf River below Portneuf Reservoir at Chesterfield annually average more than 300 ppm. At the daily sampling station downstream near McCammon, the dissolved solids content averaged 413 ppm and ranged from 322 to 442 ppm in 1948–49. Sampling in 1959 and 1960 indicated that the 1948–49 range was still reliable. Dempsey Creek, an intermittent stream that enters the river near the town of Lava Hot Springs (above the sampling station near McCammon) was sampled during high flow in

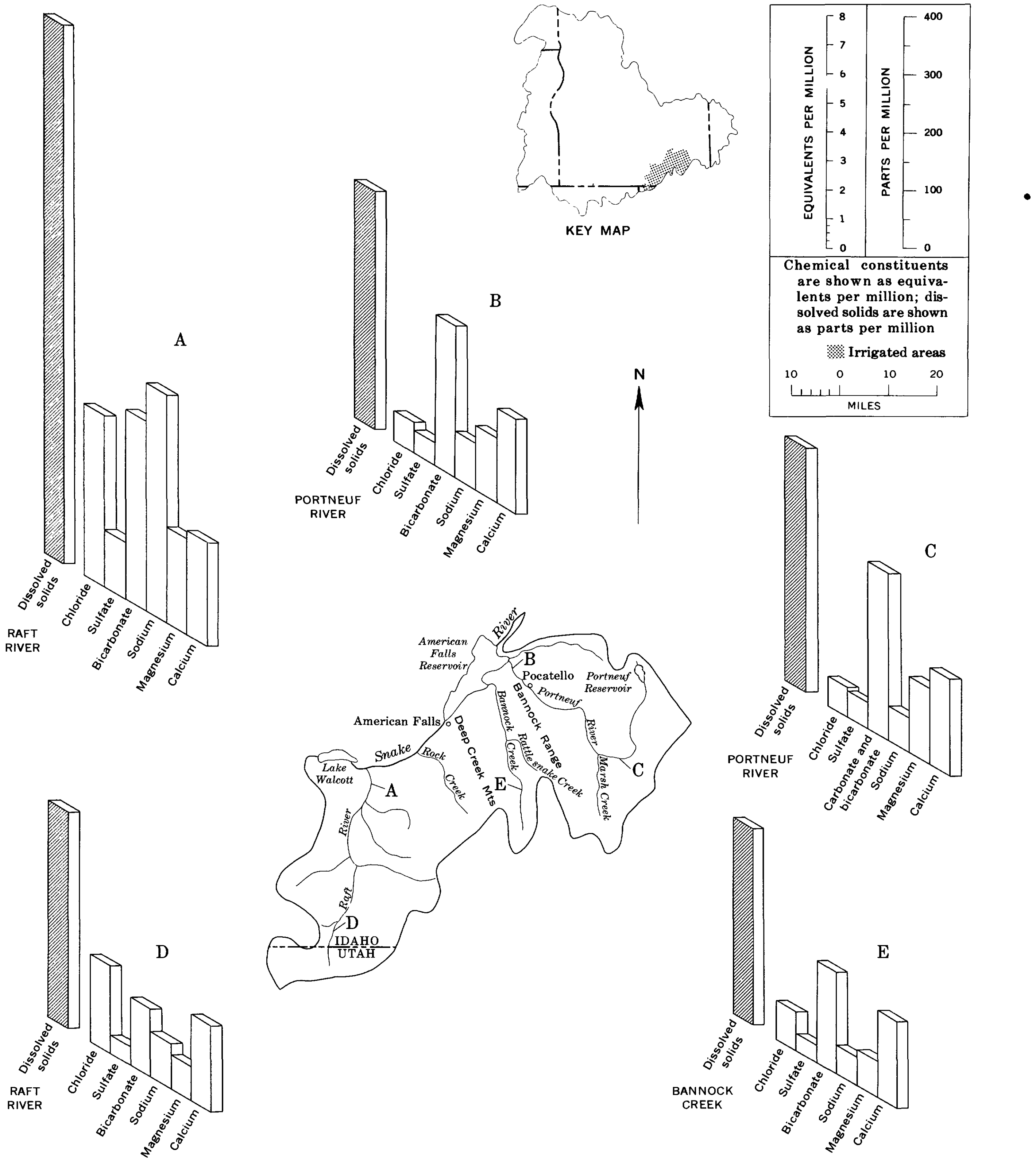

FIGURE 4.—Physical characteristics and representative chemical quality of water in the American Falls region, 1948–49 and 1958–60.

the spring of 1959. It had a dissolved-solids content of 475 ppm. Dempsey Creek is expected to have a greater dissolved-solids content than the Portneuf River because of the alluvial character of the Dempsey Creek Valley. Marsh Creek also has a basin that is largely alluvial. This stream had a dissolved-solids content of 560 ppm during low flow in August 1959 and of 440 ppm during high flow in April 1960. At the same times Portneuf River near Portneuf (above Pocatello) contained about 360 ppm and 473 ppm dissolved solids during high and low flows, respectively, and the average dissolved-solids contents of intermittent samples collected below Pocatello was 380 ppm.

The basin contains about 40,000 acres of irrigated land. This acreage lies in two general areas: one area lies immediately below Portneuf Reservoir and the other, a larger area, lies in the middle part of the basin, including most of the east side of Marsh Creek valley. Many smaller isolated tracts are irrigated. Return flows from this irrigation bring about little change in the water quality of the Portneuf River.

Industry in the Portneuf basin centers mostly around the city of Pocatello. The principal industries are food processing, lumber and wood products, and mineral processing. Waste discharges from these plants are not serious, but they do have some effect on the quality of the water in the lower Portneuf River. Oxygen-depleting wastes and sludge together with the sewage from Portneuf and Alameda cause the greatest water-quality problem. The stream in its lower part is meandering and sluggish and has very little gradient. The slow flow aggravates the problem of these organic wastes. The flow in the river is reduced by irrigation diversions and also by losses to ground water throughout a sizable reach of the channel above Pocatello. The average daily flow at Pocatello is about 250 cfs; however, the daily flow during the summer is much lower, less than 50 cfs most days. Downstream from Pocatello, springs discharge about 180 cfs to the river. A large part of this flow is from previous surface-water infiltration in the Portneuf basin. Thus, the low flow past Pocatello produces higher waste concentrations than might normally be expected, and below the city the spring flow has a diluting effect and improves the quality of the water that is discharged by the Portneuf River into American Falls Reservoir. The pollution levels have been reduced significantly in recent years owing to action taken by the cities of Pocatello and Alameda and the Idaho Department of Health. Action to further reduce volumes and levels of waste discharge promises greater improvement in Portneuf River water quality.

Bannock Creek has a drainage area of about 430 square miles, most of which is a fairly flat valley between the Bannock Range on the east and the Deep Creek Mountains on the west. The main channel of the creek lies almost entirely in alluvium from its headwaters to the mouth where it enters American Falls Reservoir. The tributary streams drain alluvium and moderately to poorly consolidated sedimentary rocks. Precipitation averages about 16 inches, but runoff is low. Much of the water in the stream channel is lost to ground water, and only a small percentage ever reaches the Snake River as surface flow.

The chemical quality of the stream is fairly consistent throughout its length; normally the water is of a calcium bicarbonate type and contains smaller amounts of magnesium chloride. Dissolved solids range from about 300 ppm in the headwaters to about 500 ppm at the mouth. Rattlesnake Creek, the principal tributary to Bannock Creek, was sampled during high runoff in August 1960; it had a dissolved-solids content of 460 ppm. The increase in dissolved solids from the headwaters to the mouth of Bannock Creek is undoubtedly due to the natural solvent action of the water as it flows through the alluvium and poorly consolidated sedimentary rocks. Very little irrigation has been developed in the basin; most of the irrigated land is in small isolated areas in the headwaters region. There is virtually no industry in this basin. Water usage has practically no effect on water quality in this drainage.

From its origin, Rock Creek (Power County) flows northwestward for about 30 miles to enter the Snake River about 12 miles downstream from American Falls Dam. The valley floor along the streambed is made up of alluvium; the remainder of the valley floor and the higher benches consist of poorly consolidated sedimentary rocks. Very little acreage is irrigated in the basin except the areas immediately adjacent to the stream and some of the larger tributaries. The flow is diverted directly from the streams to irrigate these fields. Most of the flow of Rock Creek is diverted for irrigation, and very little of it actually reaches the Snake River via the stream channel.

Only one sample of Rock Creek water was obtained. This sample was collected at Rockland, Idaho, after a summer rain storm. The water was a calcium bicarbonate type containing 489 ppm of dissolved solids.

The Raft River drains an area of about 1,400 square miles from its source in the Raft River Mountains in northwestern Utah to its mouth where the stream enters Lake Walcott (Snake River), about 14 miles above Minidoka Dam. From its source, the Raft River flows north into Idaho and east to the foothills of the Raft

River Mountains to enter the Raft River valley. This valley is made up almost entirely of alluvial material. Cassia Creek, Clear Creek, and many of the headwaters tributaries also drain alluvial material. Annual runoff for the Raft River basin is estimated to be about 50,000 acre-feet; however, only about 8,000 acre-feet are discharged into Lake Walcott. Part of this loss can be attributed to the diversion of water for irrigation; however, the largest part of this loss can be attributed to the infiltration of the surface flow into the ground.

The dissolved-solids content increases noticeably from the headwaters to the mouth of the river; this increase is accompanied by a change in chemical type of the water. A sample of Raft River water in the headwaters, near Almo, Idaho, collected during low flow had a dissolved-solids content of 367 ppm, which included a predominance of calcium, chloride, and bicarbonate ions and lesser amounts of sodium and magnesium. Further downstream, near Bridge, four samples collected during high and low flows ranged in dissolved-solids content from 569 to 900 ppm; no change in chemical type was noted. Near its mouth, the Raft River had an average dissolved-solids content of 890 ppm; an increase in sodium was very noticeable when compared with water from the upstream sampling points.

About 60,000 acres is irrigated in this basin, mostly with ground water. The surface water used is diverted directly from the stream for irrigation of adjacent areas. However, irrigation probably has no appreciable effect on the surface-water quality in the basin because there is very little return flow to the stream. Very little industry is located in this basin; however, on two occasions Cassia Creek was observed to be highly polluted by organic wastes from a food-processing plant. Most of the high mineral concentrations in the Raft River and the variations in chemical type are probably due to the variations in the alluvium through which the stream flows for almost its entire length.

HENRYS FORK BASIN

Henrys Fork rises in Henrys Lake near the crest of the Centennial Mountains. The rugged Teton Mountains form the east boundary of the basin, and the Big Hole Mountains form the south boundary, separating Henrys Fork basin and the Snake River (fig. 5). All the major tributaries to Henrys Fork enter from the east. These consist of Big Springs Creek and Buffalo, Warm, Falls, and Teton Rivers. The Teton River receives its flow from runoff from the western slopes of the Teton Mountains, and it is the only sizable tributary that is not largely spring fed.

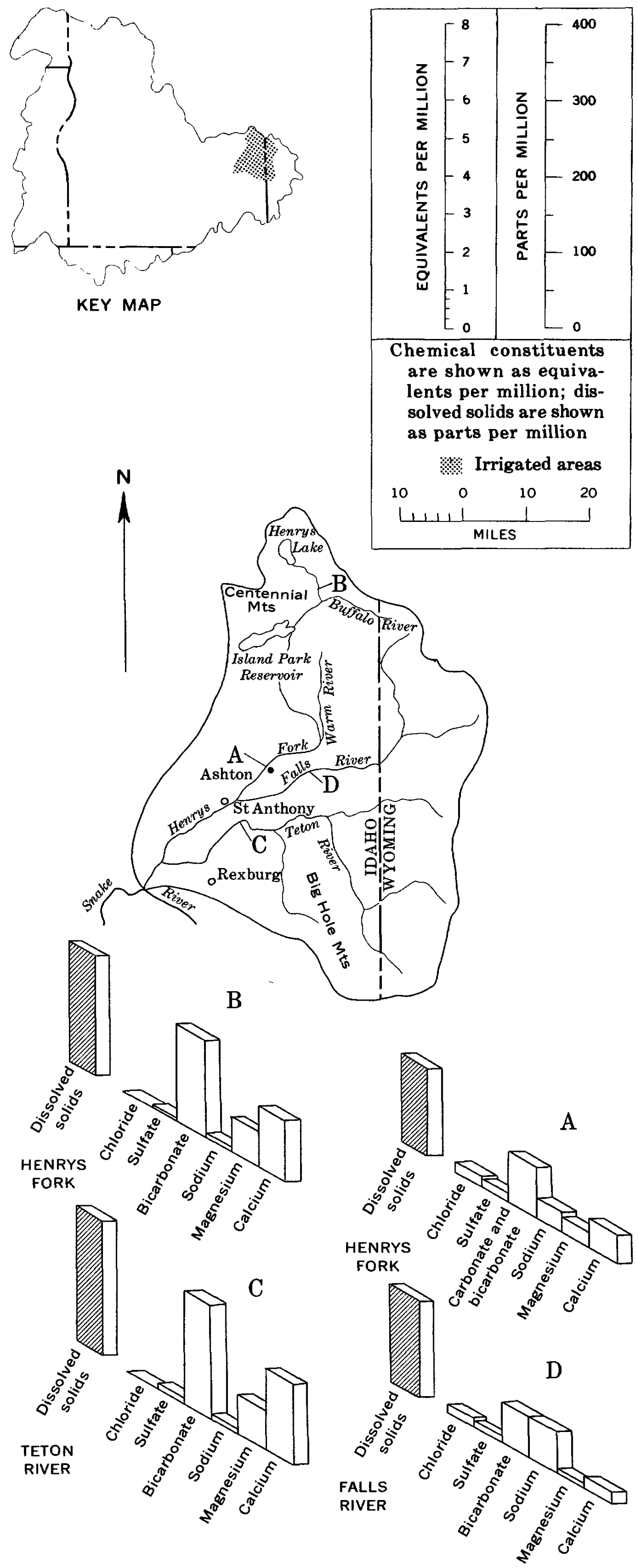

FIGURE 5.—Physical characteristics and representative chemical quality of water in the Henrys Fork basin, 1948–49 and 1959–60.

The other four principal tributaries receive the greatest part of their flow from springs discharging water collected by the very porous surface layers of ash, cinders, and fragmental lavas that make up the northeastern part of the basin. Large deposits of alluvium surround Henrys Lake and Island Park Reservoir and the intervening area. Another large deposit of alluvium extends from a point north of St. Anthony southwestward to the mouth of the Henrys Fork and beyond. This deposit is part of the Snake River Plain.

Upstream from the Snake River Plain, loss of water from the streams to ground-water bodies is not perceptible. Upon entering the plain, however, all the streams are subject to such loss. The situation is complex, but the U.S. Army Corps of Engineers has determined that the Henrys Fork Channel, from the mouth of the Warm River down to the diversion point near St. Anthony, loses more than 300,000 acre-feet of water annually to the ground-water reservoir (U.S. Congress, 1952, p. 1210). The average discharge of Henrys Fork near Rexburg, Idaho, is 1,383,000 acre-feet per year (1909–59). The channels of the Warm, Falls, and lower Teton Rivers probably have similar losses. Henrys Fork receives ground-water inflow near its mouth, but this inflow is probably a return from application of water for irrigation on the bench west of St. Anthony and is not part of a water loss from the channels above.

The chemical quality of surface water varies throughout the basin. The dissolved-solids content of Henrys Fork undergoes a slight "reversal" from the headwaters to the mouth. Below Henrys Lake near Macks Inn, the dissolved-solids content of the river was about 150 ppm. Downstream, below Island Park Reservoir, the dissolved solids was about 100 ppm. Farther south, at Ashton, the average dissolved-solids content of composites of daily samples was 126 ppm, and samples taken farther down the river toward the mouth showed a progressive increase to about 150 ppm at the mouth, similar to the content in headwaters. The decrease in dissolved-solids content in the upper part of the basin is brought about by tributary inflow of streams draining the volcanic rocks from the east. These streams are relatively low in dissolved-solids content. Big Springs Creek and Buffalo River had dissolved solids of about 100 ppm, and Warm River averaged about 70 ppm. The slight increase in dissolved solids in the lower reaches of Henrys Fork probably comes from a combination of three factors: the alluvium over which the river and its tributaries flow, irrigation return flows, and wastes from industrial operations. The range in dissolved solids throughout the basin is generally low; at Ashton dissolved solids ranged from 105 to 141 ppm during 1½ years of daily sampling (1948–49). Sampling in 1959–60 indicated that the 1948–49 data were still reliable.

In its headwaters Henrys Fork has a calcium bicarbonate type of water, but in its southward flow it picks up increasing quantities of sodium. At the mouth of Henrys Fork, sodium and calcium represent virtually equal chemical equivalents. Several of the tributary streams draining the volcanic rocks in the northern and eastern parts of the basin contain water of a sodium bicarbonate type. Waters of Big Springs Creek and Falls and Buffalo Rivers are of this type. The principal constituents of the water of the Teton and Warm Rivers are calcium and bicarbonate.

One of the notable features of the surface waters in the Henrys Fork basin is the appreciable fluoride concentrations, in places exceeding 4 ppm. A survey of fluoride concentrations in the surface waters during August 1960 indicated that much of this constituent comes from the volcanic formations in the northern and eastern parts of the basin. In the headwaters, at Henrys Lake and immediately below, the fluoride concentrations are low, about 0.1 ppm; however, farther south, Big Springs Creek and Buffalo River entering from the east had concentrations of 4.0 and 2.8 ppm respectively. Henrys Fork below Island Park Reservoir had a concentration of 1.8 ppm showing the effect of the contribution of these tributaries. The fluoride content of Henrys Fork from Island Park Reservoir to the mouth remained fairly consistent at the time of this survey, and ranged from 1.4 to 1.8 ppm. Warm River and Falls River, also draining some of the volcanic regions, had fluoride concentrations of 2.3 and 2.4 ppm respectively near their mouths. The Teton River was found to contain much lower concentrations. A measurement of 0.7 ppm was the maximum found in this basin, and the water near the mouth of the Teton River had a fluoride content of about 0.2 ppm. The Teton River, however, does not receive the spring flow from the volcanic rocks of Pliocene and Pleistocene ages which are probably the source of the fluoride.

About 180,000 acres of land is irrigated in the Henrys Fork basin. Most of this acreage lies in the lower valley contiguous to the Snake River lands; a much smaller amount is in the headwater valleys. Irrigation return flows do contribute some additional minerals to the streams in the basin, especially the lower part of Henrys Fork and the Teton River drainages. However, these areas are alluvial, and the difference between the amount of natural increase in mineralization and that from irrigation has not been distinguished.

Most of the industry in the area is concentrated in the lower part of the basin, where some food-processing plants add wastes to Henrys Fork and some of its tributaries. These wastes and those from municipal sewage plants cause a pollution problem in Henrys Fork. This problem is most noticeable during the summer when a large part of the flows are diverted for irrigation.

SNAKE RIVER PLAIN—EASTERN PART

The Snake River Plain is a structural downwarp filled with permeable basalts and kindred rocks. Successive eruptions of basalt have repeatedly dammed and shifted the course of the Snake River. In the lakes behind the dams, sediments were deposited and were in turn covered by additional basaltic flows. These alternating permeable flows and impermeable lake beds form an immense underground reservoir. Streams entering the plain from the north lose their entire flow into the permeable basalt and gravel. The underground water flows generally southwestward and emerges through springs in the Snake River canyon, principally between Milner and King Hill, Idaho. These springs have a relatively uniform flow and contribute about 6,500 cfs to the Snake River in this reach (Mundorff and others, 1960, p. 11).

All the streams in the area rise in the northern part, on the south slope of the Bitterroot and Centennial Mountains (fig. 6). These slopes receive 12–20 inches of precipitation annually, depending on elevation. The mountainous area, which makes up the headwaters of these streams, consists largely of consolidated sedimentary rocks. In the eastern part of the area these rocks are more poorly consolidated; westward, the sedimentary rocks are more highly consolidated, and volcanic rocks also occur. Almost all the valleys are made up of alluvial material, from near the headwaters to the terminus of each stream.

The chemical quality of the streams is uniform throughout the subbasin. The water of all the streams is of the calcium magnesium bicarbonate type. A general progressive decrease in dissolved-solids content from east to west correlates with the degree of consolidation of the sedimentary rocks, the less consolidated rocks in the east being more susceptible to solvent action. Dissolved-solids content of streams in the basin ranged from about 80 ppm for a sample collected in the headwaters of the Big Lost River to more than 200 ppm for Beaver and Medicine Lodge Creeks. Composites of daily samples of the Big Lost River near Mackay in 1948 had an average dissolved-solids content of 179 ppm and ranged from 158 to 186 ppm. (This range is representative of 1960 concentrations.) Most of the downstream increase in dissolved solids can probably be attributed to the alluvial formations through which the river flows. Only a moderate amount of water is used for irrigation in the northern stream valleys, and very little irrigation return flow enters the streams. Most of the excess irrigation water percolates into the ground and is transmitted underground into the Snake River Plain aquifer.

Water from the springs in the Snake River canyon wall comes partly from the Big Lost and Little Lost Rivers and similar streams in the northern part of the Snake River Plain. The chemical quality of these springs is considerably different than that of the calcium bicarbonate waters which infiltrate the Snake River Plain to the north. The spring waters have dissolved solids generally ranging from 200 to 450 ppm, and the principal chemical constituents consist primarily of equal amounts of calcium, magnesium, and sodium bicarbonates. The change in chemical quality can readily be explained. The long passage of the water through the basalts of the Snake River Group would explain a slight increase in dissolved-solids content; however, a much greater increase and the change in chemical quality are due to infiltration of irrigation waters applied in the eastern and southern parts of this area. Part of the Snake River Plain is irrigated with water diverted from the Snake River. A sizable part of the water applied infiltrates into the ground, joins the flow to the southwest and finally emerges as part of the spring flow in the Snake River canyon. Snake River water is higher in dissolved-solids, sodium, and magnesium contents than the natural ground water. The irrigation waters also leach additional minerals from the soils to which they are applied. This leaching is probably the source of much of the increase in sodium content of the waters emerging from the springs in the Snake River canyon.

Industrial activity in this subbasin does not affect the water quality of the "tributary" streams. However, waste products of a few industrial plants along the main stem of the Snake River may find their way directly into the river. Several potato-processing plants and a sugar refinery are in this area. Wastes from these plants and treated sewage from the city of Rupert are discharged to the Snake River.

SNAKE RIVER PLAIN—WESTERN PART

The western part of the Snake River Plain (fig. 7) is similar to the eastern part. It differs principally in that the strip of porous gravel and basalts of the plain, lying between the mountains to the north and the Snake River to the south, is much narrower here than in the eastern part. The Big Wood River is the principal tributary to the Snake River in this subbasin. A definite drainage pattern has been formed by this stream and its tributaries; however, it is not continuous. Much of the surface water infiltrates to the ground-water body of the Snake River Plain, and only during flood periods does

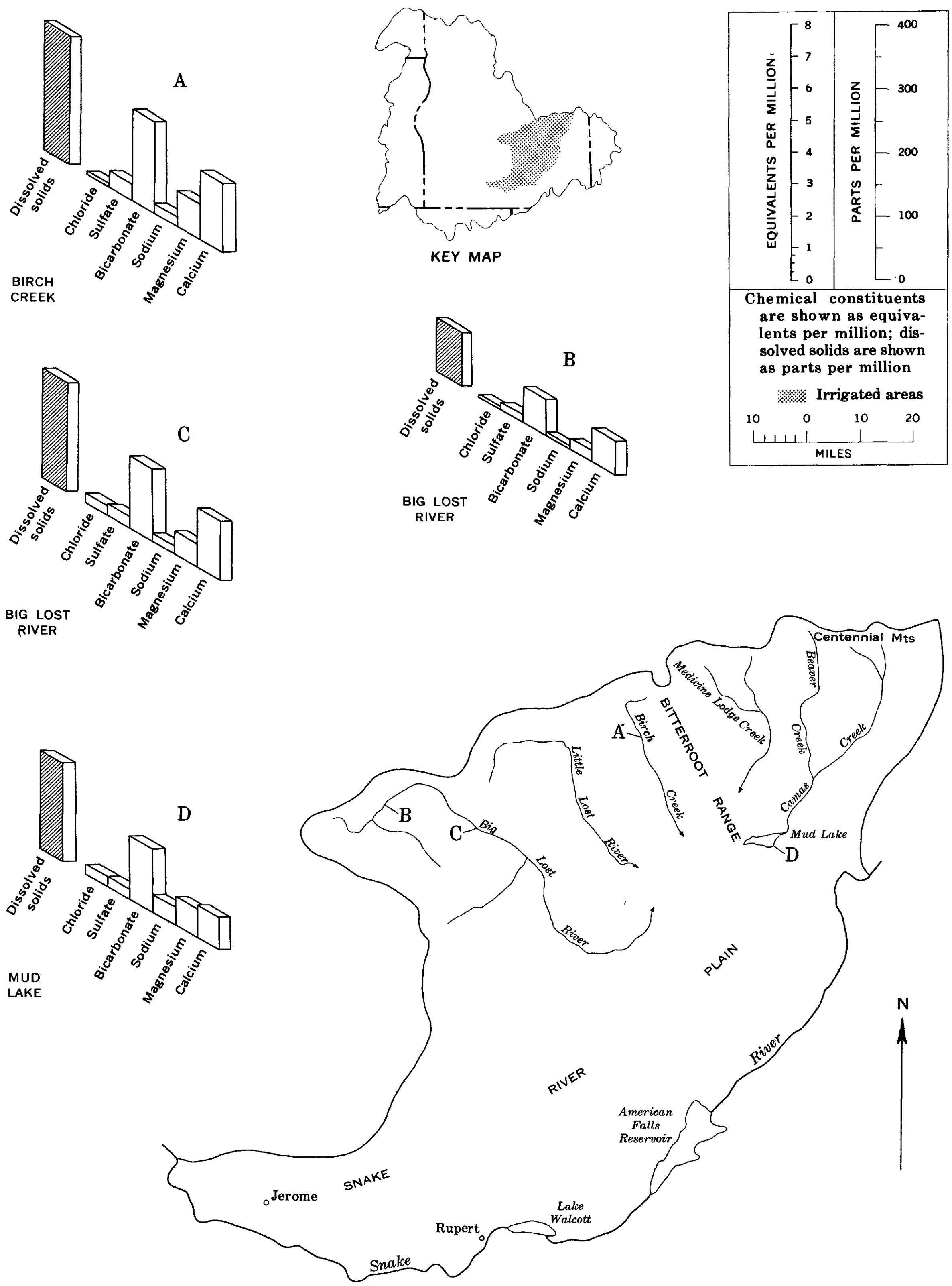

FIGURE 6.—Physical characteristics and representative chemical quality of water in the Snake River Plain, eastern part, 1948–49 and 1959–60.

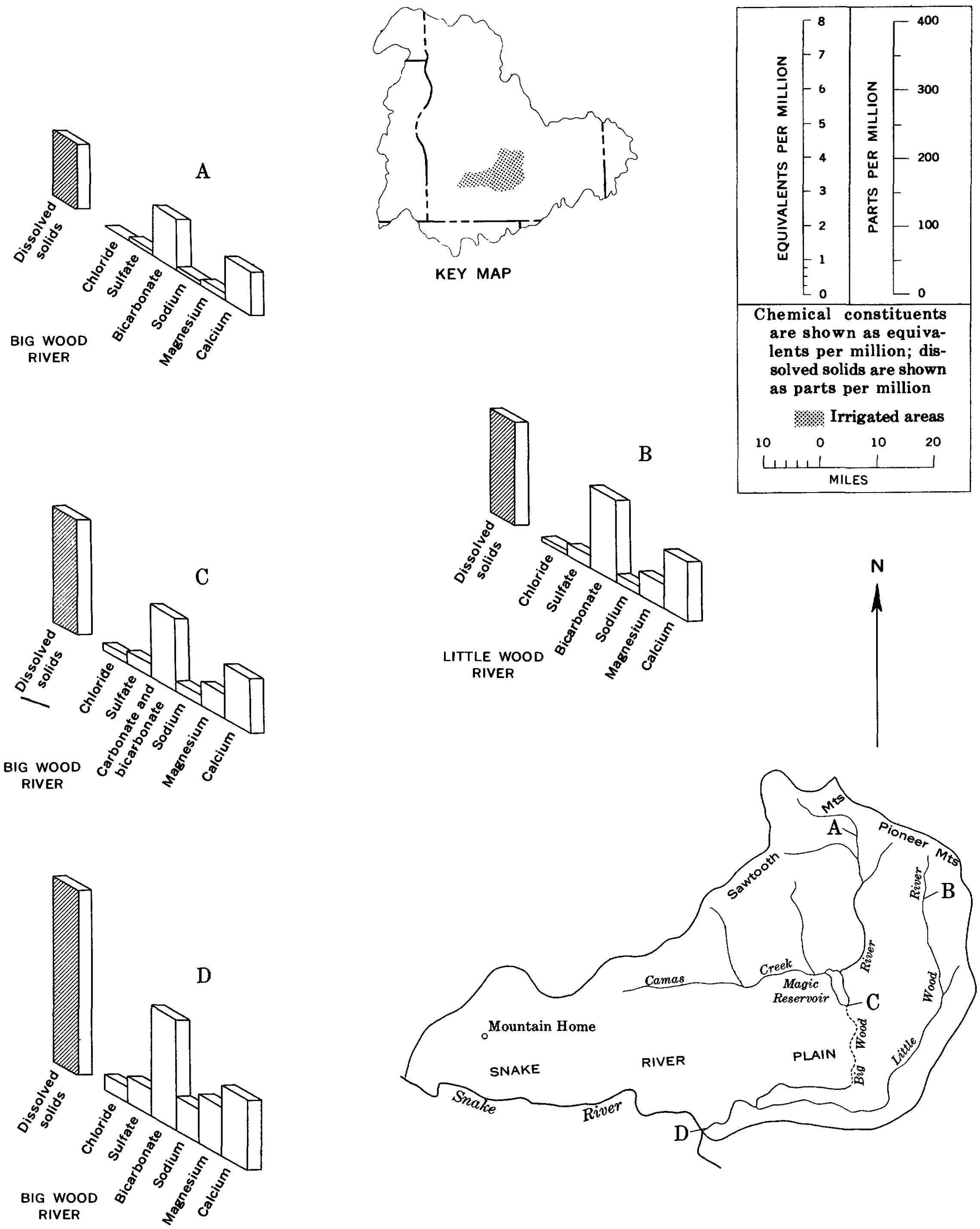

Figure 7.—Physical characteristics and representative chemical quality of water in the Snake River Plain, western part, 1948–49 and 1959–60.

the flow from the upper Big Wood River actually reach the Snake River via stream channels. Flow from the Little Wood River is small, most of it being diverted for irrigation or lost through percolation to the ground water. The flow of the lower Big Wood River entering the Snake River comes largely from Malad Springs and other springs in the Big Wood River canyon.

The Big Wood River originates on the south slope of the rugged Sawtooth Mountains, and the Little Wood River originates on the slopes of the Pioneer Mountains. These areas consist principally of volcanic and well-consolidated sedimentary rocks that are resistant to the solvent action of water; thus the drainage from these areas is rather low in dissolved-solids content, normally less than 100 ppm, which consists primarily of calcium and bicarbonate ions. The dissolved-solids contents of the headwaters of both the North and East Forks of the Big Wood River exceed 100 ppm. This higher concentration of dissolved solids can be attributed to the calcareous rocks which form a large part of the drainage basin of these forks. Below the headwaters areas dissolved-solids content of the water of the streams increases. Most of this increase can be attributed to the alluvial materials that make up a large part of the stream valleys. Composites of daily samples of the Big Wood River at the outlet of Magic Reservoir had an average dissolved-solids content of 167 ppm and ranged from 139 to 190 ppm during 1948–49. (Data are representative of 1960 concentrations.) This calcium bicarbonate water is representative of the water used for irrigation in the Big Wood River basin.

The large spring flow into the lower Big Wood River tends to make the chemical quality relatively consistent. The Big Wood River discharge to the Snake River is a calcium bicarbonate water, containing about 265 ppm of dissolved solids.

Water from the Big Wood River, Little Wood River, and Camas Creek is used to irrigate an area of about 165,000 acres. The soil is very porous, and the required diversion per acre is very high. Much of the applied water infiltrates to the ground water body and becomes part of the southward flow to the Snake River. Some irrigation water drains into the lower Big Wood and Little Wood Rivers. This return flow constitutes most of the flow in the lower Big Wood and Little Wood Rivers through the irrigated area during much of the year; however, these surface flows are only a small part of the discharge of the Big Wood River to the Snake River, as most of the discharge comes from the spring inflow in the Big Wood River canyon.

TWIN FALLS REGION

The Twin Falls region consists of the southern part of the Snake River Plain, which is bordered on the south by low mountains and hills that make up part of the Snake River basin boundary (fig. 8). Principal streams in this area are the Bruneau River, Salmon Falls Creek, Rock Creek, and Goose Creek. This area, south of the Snake River, is noticeably different geologically from the area lying immediately east of it. The American Falls region is one of consolidated sedimentary rocks and large areas of alluvial materials. The Twin Falls region consists principally of basalt of the Snake River Group and associated silicic volcanic rocks. Streams draining these harder, more resistant rocks are normally of moderate dissolved-solids content in which calcium bicarbonate predominates.

Goose Creek was sampled above the reservoir at both high and low flow in 1960. Dissolved-solids content was 165 ppm at high flow and 296 ppm at low flow, and calcium bicarbonate was the principal constituent in each sample. All the flow of Goose Creek is diverted for irrigation, and none of this flow reaches the Snake River directly.

Rock Creek in Twin Falls County rises in the mountainous country southeast of the city of Twin Falls. As the stream leaves the mountains and enters the Snake River Plain, it is diverted for irrigation. Parts of this basin are also irrigated with water diverted from the Snake River. Near Twin Falls and downstream, the flow in the Rock Creek channel is primarily from irrigation return. The water used for irrigation in the upper part of the basin is of low mineral content. At Twin Falls the water is still predominately of a calcium bicarbonate type, but the irrigation use of the Rock Creek water and more mineralized Snake River water has brought about increases in sodium and magnesium contents and has increased the dissolved solids by several hundred parts per million.

From about 1 mile upstream from the city of Twin Falls to its mouth, Rock Creek is often polluted. Oxygen-depleting wastes from domestic and industrial sources foul the stream, which makes a noticeable contribution of wastes and sludge to the Snake River.

The area immediately southeast of the city of Twin Falls has a fairly high average precipitation, exceeding 40 inches at the higher elevations. West of this area the precipitation declines rapidly to an average of less than 7 inches. This dry western part of the Twin Falls area makes up the drainage of the Bruneau River and Salmon Falls Creek basins.

Salmon Falls Creek rises in Nevada and drains about 1,000 square miles of that State and about 900 square miles in Idaho before entering the Snake River. In southern Idaho the Salmon Dam creates a reservoir, the water from which is used to irrigate about 19,000 acres. The water upstream from this reservoir is of a calcium bicarbonate type having a dissolved-solids content normally ranging between 100 and 200 ppm. Sodium concentrations are slightly higher in waters of the upper Salmon Falls Creek basin than those found in waters of the upper part of Goose and Rock Creek basins. Salmon Dam diverts all flow at that point for irrigation. A large part of the flow at the mouth of Salmon Falls Creek consists of drainage from irrigation projects. The irrigation waters leach appreciable quantities of minerals from the soils of this semiarid region. A progressive increase in mineralization was noted in Salmon Falls Creek from the dam to the mouth. Six samples periodically collected near the

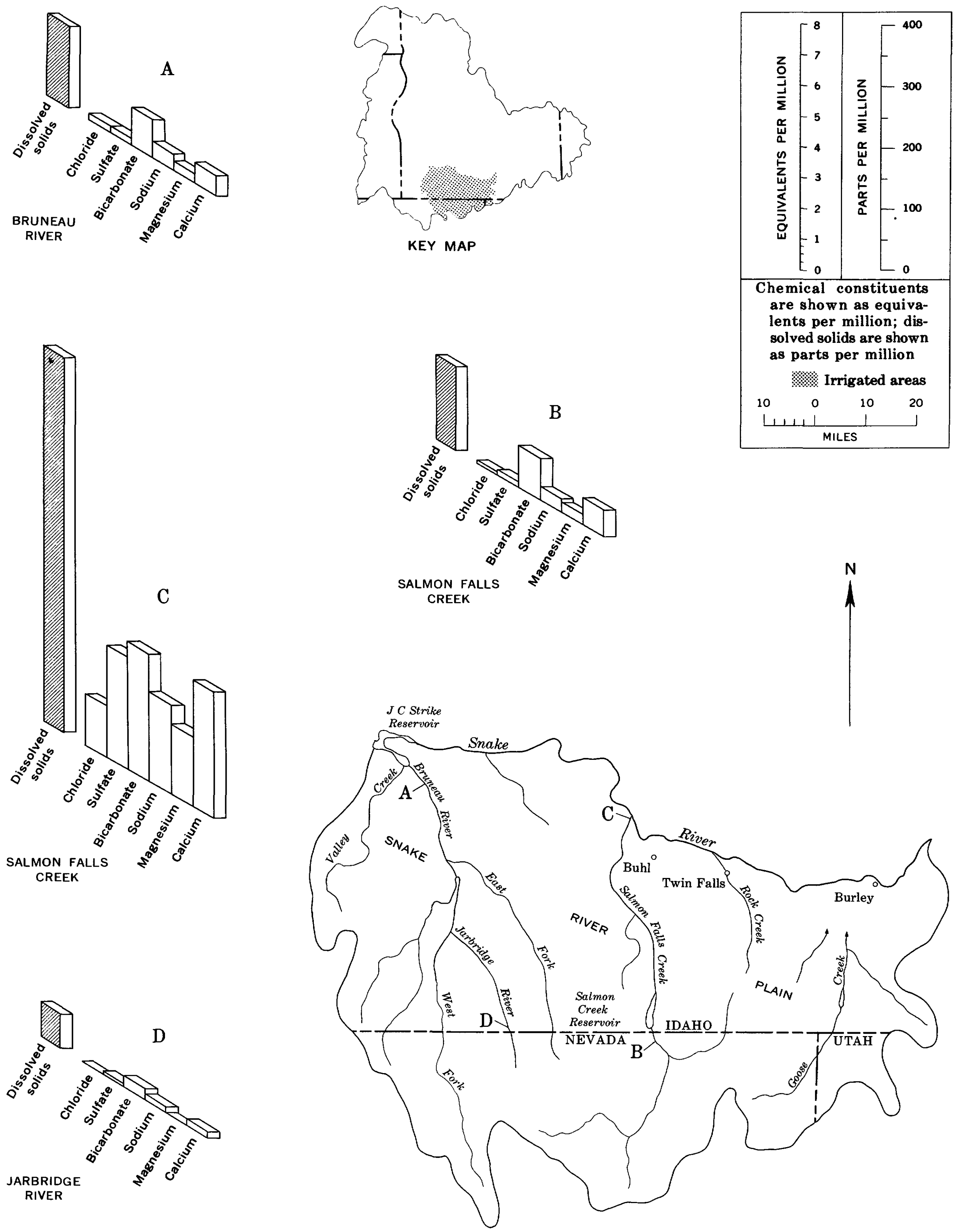

Figure 8.—Physical characteristics and representative chemical quality of water in the Twin Falls region, 1958–60.

mouth near Buhl had an average dissolved-solids content of about 600 ppm. At the time of sampling, calcium bicarbonate still predominated in the water at this point; however, the sodium, magnesium, sulfate, and chloride contents were much higher than those in the water in the upper part of the basin. Domestic and industrial surface-water uses are practically nonexistent in this watershed and make no changes in the water quality.

The Bruneau River basin consists of more than 3,300 square miles of sparsely populated area in southern Idaho and northern Nevada. The stream rises in the untimbered mountainous area in northern Nevada. The rocks here consist primarily of volcanic materials of low solubility; thus the amount of dissolved minerals in the Bruneau River and its upper tributaries is very low. Samples collected during low flow—normally the most mineralized—of the Jarbridge River at Murphy Hot Springs, Idaho, in 1959, contained only 61 ppm dissolved solids. The increase in mineralization from the headwaters to the mouth was much less than might be expected for a stream draining a semiarid area. The dissolved-solids content of composites of daily samples of the Bruneau River at Hot Spring, Idaho, averaged 130 ppm and ranged from 80 to 185 ppm, 1948–49. (Data are representative of 1960 concentrations.) The fact that the downstream increase in mineralization is very moderate can be attributed to two factors: first, the resistant volcanic rocks, which make up almost all the drainage basin; and second, the almost negligible use of the water for irrigation.

The Bruneau River and its tributaries drain an area in southwestern Idaho noted for its high fluoride concentrations in both surface and ground waters. Ten samples collected from the Bruneau River at Hot Spring had an average fluoride content of 2.7 ppm, and six samples collected from Little Valley Creek near Bruneau had an average fluoride concentration of 9.5 ppm. The water of Little Valley Creek is moderately mineralized (dissolved-solids content usually more than 2,000 ppm) and is of the sodium bicarbonate type, which is commonly associated with high fluoride concentrations.

CENTRAL AND SOUTHEASTERN OREGON TRIBUTARIES

The area drained by the central and southeastern Oregon streams extends northward from the mountains of northern Nevada, through the high, flat desert that is included in the drainage of the Owyhee and Malheur Rivers, through the Burnt and Powder River basins (fig. 9). The Blue Mountains form the western boundary of the area in the northern part of this region. The slopes of these mountains form the headwaters area of the northern streams.

The Owyhee River drains an area of about 11,340 square miles. Its principal tributaries are North Fork, South Fork, Middle Fork, and Jordan Creek. Many of the minor tributaries are intermittent streams. Much of the basin is a high plateau having broken or rolling topography. Beyond its headwaters in the mountains of northern Nevada, the South Fork Owyhee River flows through a structual basin that is partly filled with alluvial deposits of Pleistocene and Recent ages. The other major segments of this river drain areas that are principally composed of volcanic rocks. Near the Idaho-Oregon border, the Owyhee River enters a deep canyon cut in lavas and pyroclastic rocks of Tertiary age, and in the lower part of the basin it leaves the canyon and flows across a western segment of the Snake River Plain.

Average annual precipitation over the Owyhee River basin ranges from 8 to 20 inches and occurs largely as snow during the winter. The greatest precipitation occurs only in very small areas of high elevation. The Owyhee River has a lower unit runoff than most of the principal tributaries of the Snake River. The mean annual flow at Owyhee Dam is over 700,000 acre-feet, which includes about 450,000 acre-feet diverted annually from Lake Owyhee for irrigation of lands in the lower part of the basin and outside of the basin. The Owyhee River basin contains several widely separated irrigated areas totaling approximately 150,000 acres; the largest of these areas is in the lower part of the basin.

The chemical quality of the water in the Owyhee basin is typical of that in many of the semiarid tributary basins of the Snake River. The waters are generally of a sodium bicarbonate type having varying amounts of calcium. In the areas of higher precipitation, the calcium equals or exceeds the sodium content during periods of high runoff. During most of the year, however, sodium is the predominant cation. The Owyhee River receives a sizable irrigation return flow from the large irrigated area below Owyhee Reservoir. These return flows have a marked effect on the quality of the water in the lower part of the river. The water discharged from Owyhee Reservoir is a sodium calcium bicarbonate type containing an average dissolved-solids content of about 193 ppm. At the mouth of the river near Adrian, the average dissolved-solids content of four samples collected periodically was almost 800 ppm, consisting primarily of sodium sulfate and lesser amounts of calcium bicarbonate. Industrial activity in the Owyhee basin is nil, and has no influence on water quality.

The Malheur River rises in the Strawberry Mountains, a southern spur of the Blue Mountains of Oregon. Its headwaters area is covered by pine, fir, and tamarack forests. Beyond this mountainous area the stream flows through rolling sagebrush land, where the precipitation averages about 8 inches per year. The drainage area of the Malheur River is 4,610 square miles, consisting of several types of rock. The headwaters area consists of lava, which is an extension of the high lava plains of the Columbia Plateau; the northern part of the basin consists of metamorphosed volcanic and sedimentary rocks of the south edge of the Blue Mountains; and the lower part of the basin is poorly consolidated lake-bed sediments associated with the western part of the Snake River Plain.

About 75,000 acres of land is irrigated with water from streams in the Malheur River basin. By far the largest part of this acreage lies in the lower part of the basin encompassing the lower parts of Bully Creek and Willow Creek valleys as well as the lower part of the Malheur valley.

The geology, topography, and precipitation of the Malheur River basin are similar to those in the Owyhee River basin. Thus, it is not surprising that the water quality also is similar. In the headwaters areas, the chemical type of the water varies between sodium bicarbonate and calcium bicarbonate waters. The calcium bicarbonate type predominates during high-flow periods, and sodium bicarbonate predominates during moderate- and low-flow periods. In the lower reaches of the Malheur River and many of the tributary streams, the influence of irrigation is readily apparent in the quality of the water. Several samples of Bully Creek water collected periodically near Vale in 1958–60 had dissolved-solids contents ranging from 179 to about 670 ppm. The water was primarily of the calcium bicarbonate type during high flows and of the sodium bicarbonate type during moderate and low flows. Willow Creek, draining an area of greater irrigation, has even greater changes in water quality from the upper to the lower drainage. A sample collected at Ironside in the headwaters of Willow Creek had a dissolved-solids content of about 290 ppm, which was predominantly calcium bicarbonate. Near Vale, near the mouth of Willow Creek, the observed dissolved-solids contents for high- and low-flow samples were 807 and 1,000 ppm respectively (table 1), and the chemical type was consistently sodium bicarbonate. Samples taken near the mouth of the Malheur River near Ontario show the cumulative effect of these irrigation drainages. At this point, high-flow samples contained about 400 ppm dissolved solids, and low-flow samples contained more than 1,000 ppm; sodium, bicarbonate, and sulfate were the principal mineral constituents (table 1). Some of the surface waters are mineralized naturally by their contact with the poorly consolidated lake-bed sediments that make up a large part of the lower Malheur basin. However, this source is probably responsible for a smaller percentage of the total increase in mineralization observed than the increase attributable to return flows from irrigated lands.

The Burnt and Powder River basins, in the northern part of this subbasin, differ somewhat in geology, precipitation, topography, and water quality from the Malheur and Owyhee basins lying to the south. These northern basins are a transition zone between the more highly mineralized streams of the semiarid area to the south and the less mineralized streams of the more humid Grande Ronde area to the north.

The Burnt River drains about 1,100 square miles in Oregon. The western part of its basin lies almost entirely in the Blue Mountains; in the central part the river has cut a narrow canyon through rolling grassy hills; and the lower part of the basin is a wider valley containing cultivated and irrigated areas surrounded by rolling hills covered with sagebrush and grass. The rocks of the upper part of the basin consist largely of volcanic materials of various geologic ages. The middle and lower part of the basin consists of several complex rock types including metamorphosed sedimentary and volcanic rocks of Paleozoic age intruded by many igneous bodies and overlain unconformably by volcanic rocks of Tertiary age.

Samples collected in 1958–60 in the headwaters of the Burnt River generally had dissolved-solids contents of less than 100 ppm during high-flow periods and less than 200 ppm during low-flow periods (table 1). Water was generally of a calcium bicarbonate type except for a few tributaries whose water contained appreciable sodium concentrations during low-flow periods.

About 23,000 acres of land is irrigated in the Burnt River basin. Water is supplied by gravity diversions from the stream channel, and low flows are augmented by releases from several small reservoirs. The largest of these reservoirs is Unity Reservoir which has a capacity of 25,000 acre-feet. In the lower reaches of the Burnt River the nature of the dissolved solids has been changed somewhat by return flow from irrigation; however, these changes are not as marked as those in the Malheur and Owyhee Rivers. Dissolved-solids content increased from an average of about 100 ppm in the headwaters to about 350 ppm at Huntington, near the mouth of the Burnt River. The chemical quality was still predominately calcium bicarbonate.

The Burnt River basin has very little industrial activity. A large cement plant at Lime utilizes part of

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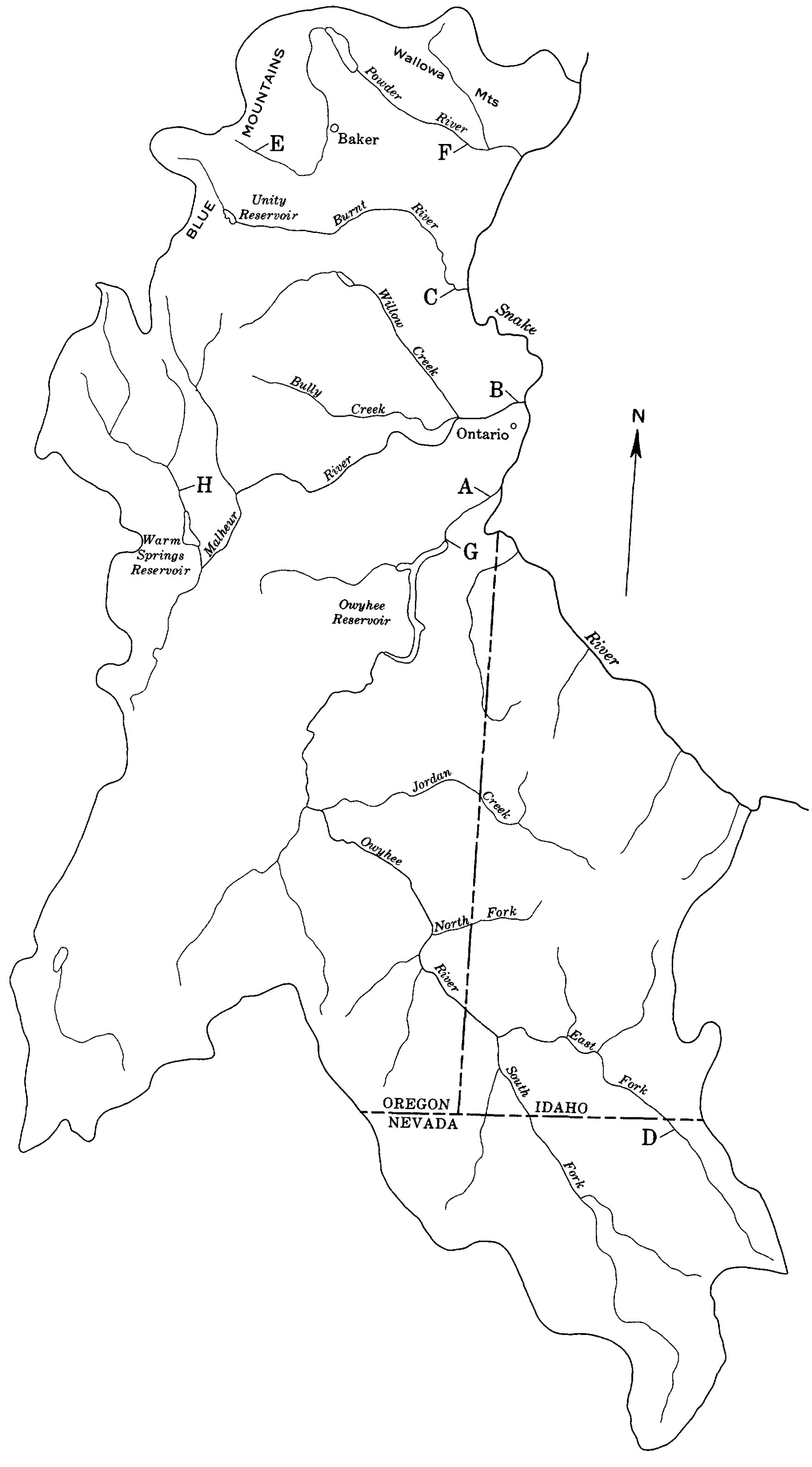

FIGURE 9.—Physical characteristics and representative chemical quality of water in the central and southeast Oregon tributaries, 1948–49 and 1959–60.

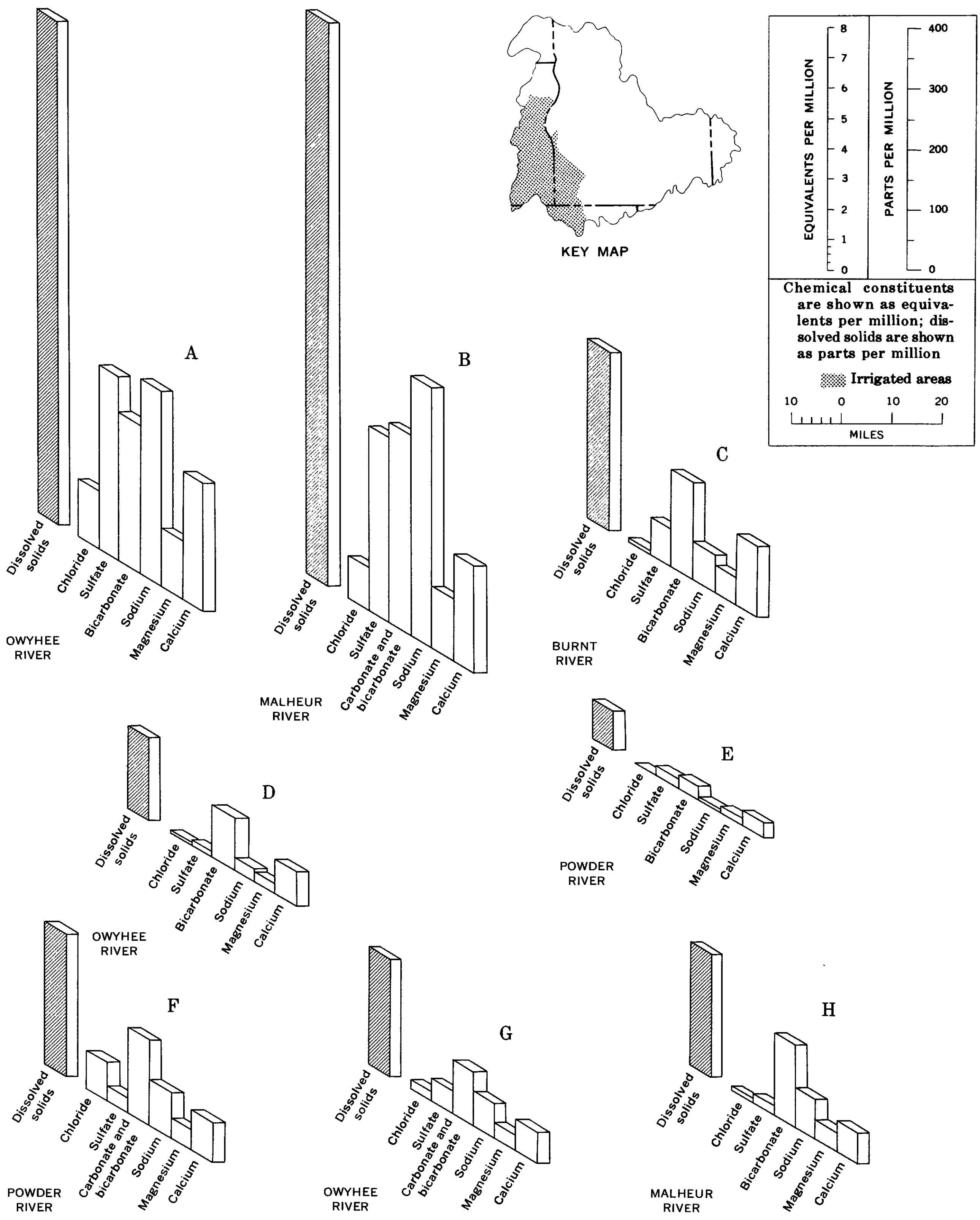

FIGURE 9.—Continued

the sizable deposit of limestone of Triassic age, which lies in the lower part of the basin. Waste products from this plant seem to have very little effect on the chemical quality of the Burnt River.

The Powder River drains an area of 1,700 square miles, the topography of which ranges from high, rugged peaks of the Blue Mountains to rolling hills and flat valleys. The rocks of the Powder River basin are very similar to those of the Burnt River basin to the south. In addition, many of the valleys are structural depressions filled by several hundred feet of glacial outwash and Recent alluvium. The climate of the Powder River basin is generally semiarid but varies widely with altitude. The annual precipitation ranges from less than 12 inches in the valley to more than 24 inches in the mountain areas.

In the headwaters area the quality of the Powder River is very similar to that of the Burnt River. The water is of a dilute calcium bicarbonate type. The mineral content of the Powder River water increases in the central reaches of the stream and then decreases toward the mouth. The average dissolved-solids content upstream from Baker, Oreg., was about 127 ppm; and at Hanes, at the lower part of the Powder River valley irrigation development, the average content was 206 ppm. The water at Hanes has increased in sodium content and shows the influence of return flows from this irrigation project on the water quality of the Powder River. Downstream from this point, however, the Powder River receives water from tributaries rising in the Wallowa Mountains to the north. Such streams as Big Creek, Goose Creek, and Eagle Creek are low in dissolved solids, averaging less than 100 ppm. These tributaries dilute the flow of the Powder River so that the discharge-weighted average dissolved-solids content at a monthly sampling station at Richland, Oreg., near the mouth was 152 ppm—predominantly calcium, sodium, and bicarbonate.

Domestic and industrial wastes are discharged to the Powder River at Baker. These wastes are most noticeable at periods of low flow when maximum irrigation diversions occur; however, the wastes have not yet reached a concentration that is high enough to preclude the use of the water for irrigation.

THE HEARTLAND

The heartland consists of the Boise, Payette, and Weiser River basins as well as a small segment of the western part of the Snake River Plain lying north of the Snake River (fig. 10). This region is so called because it lies in the center of the Snake River basin, includes 30 percent of the population of the basin, and contains one of the most highly developed and productive areas of irrigation agriculture in the Snake River basin. It also contains Boise, the capital of Idaho, which serves as a marketing and trading center for a large segment of the basin.

The Boise River heads in the Sawtooth Mountains, flows west, and joins the Snake River. The drainage area consists of about 4,130 square miles. The headwaters area is mountainous and includes many peaks more than 10,000 feet in elevation. About 20 percent of the basin is more than 7,000 feet in elevation, and 70 percent is more than 5,000 feet in elevation. About 8 miles upstream from Boise the river emerges from the mountains and meanders for about 60 miles through a large, flat alluvial valley bordered by the benchlands of the Snake River Plain.

The Boise River drains the south edge of the Northern Rocky Mountain physiographic province, an area in which granitic rocks and older basalt flows with associated pyroclastic rocks have been dissected into mountainous terrain. A large part of the drainage pattern of the Boise River is formed by the southern part of the Idaho batholith. The lower reach of the river flows entirely in the softer lake-bed deposits of the Idaho Group. In this reach, the land surface south of the river gradually rises and is underlain by large gravel deposits. To the north, the rise is abrupt, and in a short distance the truncated edges of various rock formations underlying the Snake River Plain are successively exposed.

Irrigation was started in the Boise River valley in 1864 by direct diversions from the river. At the present time (1962) approximately 340,000 acres is supplied with waters from the Boise River. Additional lands in the basin are irrigated with water from the Payette River. Reservoirs having a total usable storage of almost 1,235,000 acre-feet have been constructed.

Some of the land along the Boise River has been affected by excess drainage water and seepage from higher irrigated lands. These bottom lands were once irrigated directly from the river and had no drainage or alkali problems; however, extensive development of the irrigable lands on the bench above the valley floor, and subsequent increase in waste water coming onto the valley floor late in the season have caused the soils to become waterlogged and alkali to appear. Extensive drainage works have been constructed and others are contemplated in an effort to alleviate this situation (Nace, West, and Mower, 1957, p. 9).

The Boise River valley, from the city of Boise to the mouth of the river, is one of the most highly industrialized areas in the basin. At times, wastes from food-processing plants in particular cause a noticeable deterioration of water quality in the lower Boise River. Sewage wastes from Boise and surrounding areas, as

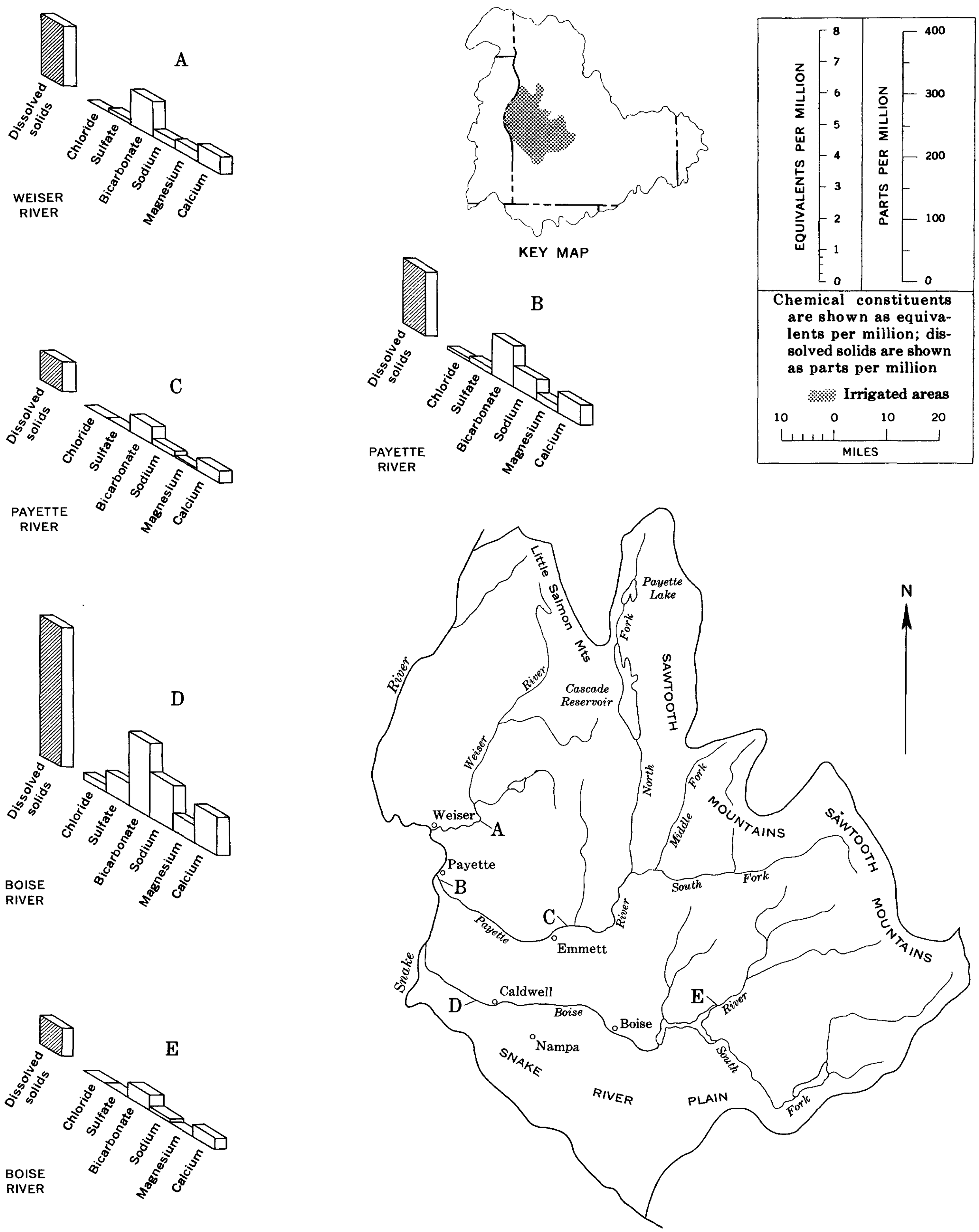

FIGURE 10.—Physical characteristics and representative chemical quality of water in the heartland, 1958–60.

well as from towns downstream, add to this problem. Pollution is particularly acute during periods of low flow, when most of the natural flow is being stored or diverted for irrigation. Irrigation users have a pre-emptive right to divert the water; thus, at times, low flows will persist in the stream channel and accentuate the pollution problem. Many of the industrial and municipal wastes are treated prior to discharge. Although some improvement in the quality of the waste discharged can be made, a point is being approached where further treatment becomes economically impracticable. Thus it seems that the pollution problem in the lower Boise River will continue and probably become more acute through population and industrial growth until better methods of waste treatment that are economically feasible are developed and (or) a system of low flow augmentation is developed.

Quality of water in the Boise River basin varies with the geology and the water use. The mountainous headwaters receive about 40 inches of precipitation a year. The granitic rocks that make up this area are resistant to solution, and the dissolved-solids content in the streams is low; calcium and bicarbonate are the principal constituents. This low concentration is typical of all the headwater streams in the Boise River basin. Samples taken in the Moore Creek basin in 1959 had a dissolved-solids content of less than 80 ppm, and samples of the Boise River near Twin Springs averaged 46 ppm for the 1959 water year. At Boise, four samples collected in 1959–60 ranged in dissolved-solids content from 57 to 88 ppm (table 1). From Boise to the mouth, however, the concentrations increase. This increase can be attributed primarily to return flows of irrigation water that is entering the river in increasing amounts in a downstream direction. Some increase in mineral content can be attributed to the alluvial materials that make up the valley bottom, as well as to pollution from industrial and domestic wastes; however, by far the greater part of the increase is caused by the return flows from irrigation and drainage from the waterlogged areas. The dissolved-solids content at Notus, Idaho, based on daily sampling for a period of 11 years, averaged 203 ppm. A series of samples show that the dissolved-solids content increases by about 45–50 ppm between Notus and the mouth of the river, a distance of about 14 miles. The water in the lower part of the river was a sodium calcium bicarbonate type.

Although the 11-year average of dissolved-solids content of the Boise River water at Notus was 203 ppm (table 1), the annual average concentration varied considerably owing to differences in runoff and diversion. For example, during the 1955 water year when the runoff from the basin was about 86 percent of normal and the flow at Notus was about 36 percent of normal, the average dissolved-solids content at Notus was 427 ppm.

Annual precipitation in the Boise valley averages 12 inches or less, and the streams that enter the river in the lower part of the basin are all intermittent. The water in these streams is generally of a calcium sodium bicarbonate type, and dissolved solids exceed 200 ppm.

The North Fork Payette River rises on the south slope of the sharp divide between the Salmon River and Payette River basins. It flows southward through Payette Lakes and Cascade Reservoir, joins the South Fork, and forms the main stem of the Payette River. The South and Middle Forks Payette River rise on the west slope of the Sawtooth Mountains and drain an area that is almost exclusively underlain by intrusive granitic rocks. The headwaters area of the North Fork is underlain principally by the same kind of rocks. However, the North Fork flows through a broad alluvial valley from the Payette Lakes to a point south of the Cascade Reservoir, where it reenters an area of intrusive rocks. Below the confluence of the North and South Forks, the Payette flows generally southward, then westward to Emmett, Idaho, where it enters the broad plain of the fertile Payette Valley. This valley and most of the hills south of the valley are built up sedimentary deposits of the Payette Formation.

The chemical quality of the surface waters of the Payette River basin is almost uniformly excellent. The upper parts of the basin, draining largely intrusive granitic rocks, have surface waters of very low dissolved-solids content. This is true even for the North Fork Payette River beyond the upper alluvial valleys. Intermittent samples of water collected at the outlet of Cascade Reservoir had a maximum dissolved-solids content of only 29 ppm. Daily samples of the Payette River at Black Canyon Dam near Emmett, for two individual periods of record (1948–49, 1958–59), had an average dissolved-solids contents of 68 and 49 ppm. The water at this sampling station, as well as at all the points sampled in the headwaters area, was of a calcium bicarbonate type. Samples taken at the mouth of the Payette River at Payette indicated that the dissolved-solids content increased slightly as one progressed from the headwaters; the sodium also increased and became equivalent to the calcium in content. However, the average dissolved-solids content was still less than 100 ppm. The increase in the sodium is probably attributable in part to return flows of irrigation waters that enter the lower part of the Payette River in moderate amounts and in part to natural pickup from the sedimentary materials that make up the Payette valley. About 188,000 acres of land is irrigated in the Payette River basin; almost all this land lies in the lower part of the valley. A drainage problem exists in part of the basin similar to that in the Boise River basin. Drainage from these waterlogged areas probably contributes to the increased mineral content of the irrigation water returned to the river.

Food-processing plants in the Payette valley discharge some wastes to the river. In addition, the river receives domestic wastes from the towns along its course. These wastes produce some deterioration in water quality. However, the influence of these waste products is principally local, and these wastes do not have a serious deleterious effect on the water quality in the Payette River. The flows of the river remain moderate even during the summer. These flows dilute the waste products below critical levels. The diversions for irrigation and other water uses have not yet (1962) reached the point where the waste products added to the reduced flows bring about a pollution problem. The generally excellent quality of water in the Payette River basin can be attributed to the resistant granitic rocks which make up a large part of the basin, to the very moderate diversions for irrigation, and to only moderate use for waste disposal.

The Weiser River rises in the metamorphosed lava and pyroclastic rocks of the Little Salmon mountains, and throughout most of its course flows through an area underlain by basalt of Miocene age. The lower part of the basin consists of sedimentary lake-bed deposits alternating with lenses of thin layers of basaltic lava of the Payette Formation. Annual precipitation ranges from about 12 inches at Weiser to more than 40 inches in the headwaters area.

The quality of the water of the Weiser River reflects the volcanic rocks that underlie much of the drainage of this river. Samples taken in the upper part of the river were all less than 100 ppm in dissolved solids and all of a calcium bicarbonate type. The dissolved-solids content of samples of the Weiser River near Weiser, near the mouth, averaged only slightly more than 100 ppm (1948–49, 1958–59), and the water was of the calcium magnesium bicarbonate type.

The Weiser River supplies water to irrigate several small projects totaling about 41,000 acres of land. The greatest amount of this irrigated acreage is in the lower part of the basin. The small amount of industrial activity in the basin is carried on mostly in or around Weiser at the mouth of the river. Disposal of waste products and diversion of water for irrigation use seem to have little influence on the quality of water of the Weiser River.

SALMON-CLEARWATER RIVER BASINS

The Salmon and Clearwater Rivers drain the large sparsely populated mountainous area of central and north-central Idaho (fig. 11). A sizable part of these basins consists of isolated areas of limited access. Precipitation is high over much of these basins, runoff is largely uncontrolled, and these two streams furnish more than half the flow of the Snake River at its mouth.

The Salmon River drains an area of about 14,100 square miles and is the largest tributary of the Snake River on the basis of drainage area. The stream rises in the Sawtooth Mountains in central Idaho. It flows generally north and west for about 400 miles to enter the Snake River. The mountain valleys of the upper Salmon, Pahsimeroi, Lemhi, and lower Salmon Rivers are several miles wide in places; however, the general topography of the basin is one of rugged relief and narrow valleys. The basin is underlain almost entirely by volcanic and intrusive rocks. Only minor amounts of consolidated sedimentary rocks occur, and these are principally in the upper part of the basin. Small amounts of alluvium also occur; the largest amounts are in the valleys of the Pahsimeroi and Lemhi Rivers. The average precipitation in the basin ranges generally from 20 inches to 60 inches. This relatively high average precipitation, compared to the rest of the Snake River basin, brings about an average annual runoff of almost 7½ million acre-feet.

Man's activities have little effect on the water quality in the Salmon River basin. The population density in this basin is much less than the average of 6.5 people per square mile for the Snake River basin. Most of the population is in the headwaters area or in the lower part of the basin. The small amount of industrial activity in the basin and domestic waste disposal have no known affect on the water quality in this basin.

Only a relatively small area (about 106,000 acres) is irrigated in the Salmon River basin. More than one-third of this acreage is in the Lemhi River basin. This irrigation produces only minor changes in the chemical quality of the water. However, in some areas overgrazing has led to erosion, and objectionable turbidity levels have been reported for several streams.

Surface waters of the Salmon River basin are almost uniformly excellent in quality because of heavy precipitation and high runoff, the high resistance of the widespread volcanic and intrusive rocks to solvent action, and the low water diversion and use of water in the basin. The dissolved-solids content of almost all the streams sampled in the basin was less than 100 ppm (table 1). Two exceptions to this were the Pahsimeroi and the Lemhi Rivers, where the average concentrations

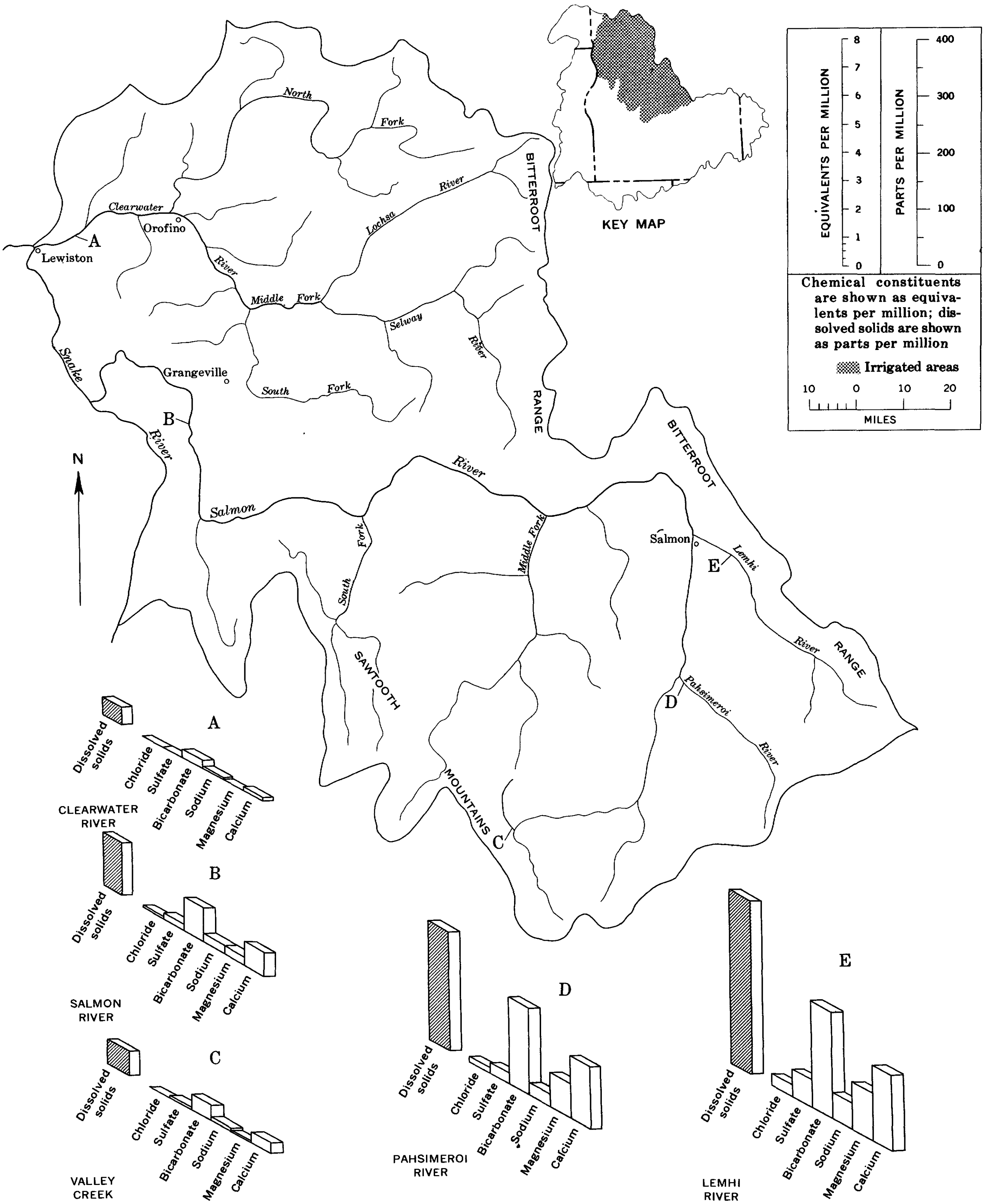

FIGURE 11.—Physical characteristics and representative chemical quality of water in the Salmon-Clearwater River basins, 1958–60.

of spring and fall samples were more than 200 and 300 ppm, respectively. This higher dissolved-solids content can probably be attributed to the alluvial nature of these valleys. The alluvium is much more susceptible to solvent action of the water than the volcanic and intrusive rocks that predominate in the rest of the basin. The dissolved-solids content for the 1959 water year for daily samples taken from Valley Creek, a small stream whose quality is typical of quality in the headwaters of the basin, averaged 43 ppm and ranged from 30 to 57 ppm. Monthly samples of the Salmon River, collected near White Bird in the lower part of the basin during the 1959 water year, contained an average dissolved-solids content of 91 ppm, illustrating a very moderate increase of about 50 ppm of dissolved solids from the headwaters to the mouth.

Calcium bicarbonate was the principal constituent of almost all the streams of the basin. A few streams have sodium concentrations equal to or slightly in excess of the calcium content. Because irrigation is not a factor here, the sodium content in the water may have been caused by differences in the sodium content of the monzonite, which is a principal constituent of many of the intrusive rocks or to differential weathering.

The Clearwater River drains about 9,600 square miles and is third in the order of magnitude of drainage areas of the Snake River tributaries. The average discharge of the Clearwater River, however, is more than 11 million acre-feet per year, which makes the Clearwater River first in the order of magnitude of actual water volume. The headwaters of the Clearwater River are in the Bitterroot Range, in an area underlain by the metamorphosed rocks of the Belt Series. These rocks, together with those of the Idaho batholith and associated rocks, make up the headwaters area of the Clearwater River and its tributaries. The lower parts of the Middle and South Forks Clearwater River, as well as the lower Clearwater River itself, flow over the basalt of an eastern extension of the Columbia Plateau.

The drainage basin has a rugged topography. The streams flow generally in steep-sided, narrow canyons, and at only a few places do the valleys widen and the stream grades flatten. Almost all the headwaters areas are heavily timbered. The western part of the drainage basin consists generally of barren, untimbered hills. The valleys are cultivated where suitable land exists, and some land is irrigated by diversion from tributary creeks or by pumping from the river. Irrigation use of water in the basin is diminutive, however, primarily because the areas suitable for irrigation are extremely small.

Annual precipitation is normally about 15 inches on the lower, west side of the basin and increases to more than 70 inches in the headwater areas to the east. Warm moisture-laden air moving eastward from the Pacific Ocean becomes subject to orographic lifting as it passes over the basin and thus is the cause of the heavy precipitation. The average annual precipitation for the basin is about 40 inches.

The population of the Clearwater basin is very small and is principally in the agricultural areas along the main stream and at the mouth of the basin in and around Lewiston. The headwaters areas of the basin are isolated and of limited access.

Most of the present (1962) industrial activity in the basin is associated with the production of timber and wood products. A large pulp mill located just above the mouth of the Clearwater River at Lewiston discharges wastes to the Clearwater River and hence to the Snake River.

The quality of water in the Clearwater River basin is very similar to that in the Salmon River basin. Throughout both basins, the resistant rocks, the high precipitation, and the small water use result in very low concentrations of dissolved solids. All samples taken in the Clearwater River basin had a dissolved-solids content of less than 100 ppm. The highest dissolved-solids content determined was 77 ppm for a sample of the Clearwater River at Lewiston. The average for a monthly sampling station on the Clearwater River at Spalding, 12 miles above the mouth, was 33 ppm. Calcium bicarbonate was the predominant constituent in the water throughout the basin. A slight increase in sodium content was apparent in the lower reaches of the Clearwater River (table 1).

GRANDE RONDE RIVER AND ADJACENT BASINS

The drainage from the basins of the Grande Ronde River, Imnaha River, and Asotin Creek (fig. 12) enters the Snake River in northeastern Oregon or southeastern Washington. The main part of this region is generally a rough, wooded mountainous area containing two large valleys drained by the Grande Ronde River and its tributary, the Wallowa River. The precipitation in the basin ranges from about 12 inches in parts of the Grande Ronde Valley to more than 40 inches in the mountainous areas. The abundant precipitation in the mountainous areas is undoubtedly a factor in the occurrence of the relatively dilute waters of this area.

The Grande Ronde River rises in an area of volcanic, granitic, and metamorphic rocks on the north edge of the Elkhorn section of the Blue Mountains. However, most of the drainage area in the headwaters, as well as most of the drainage area in the middle and lower parts of the basin, is underlain by the Columbia River Basalt and other volcanic rocks. The broad Grande Ronde

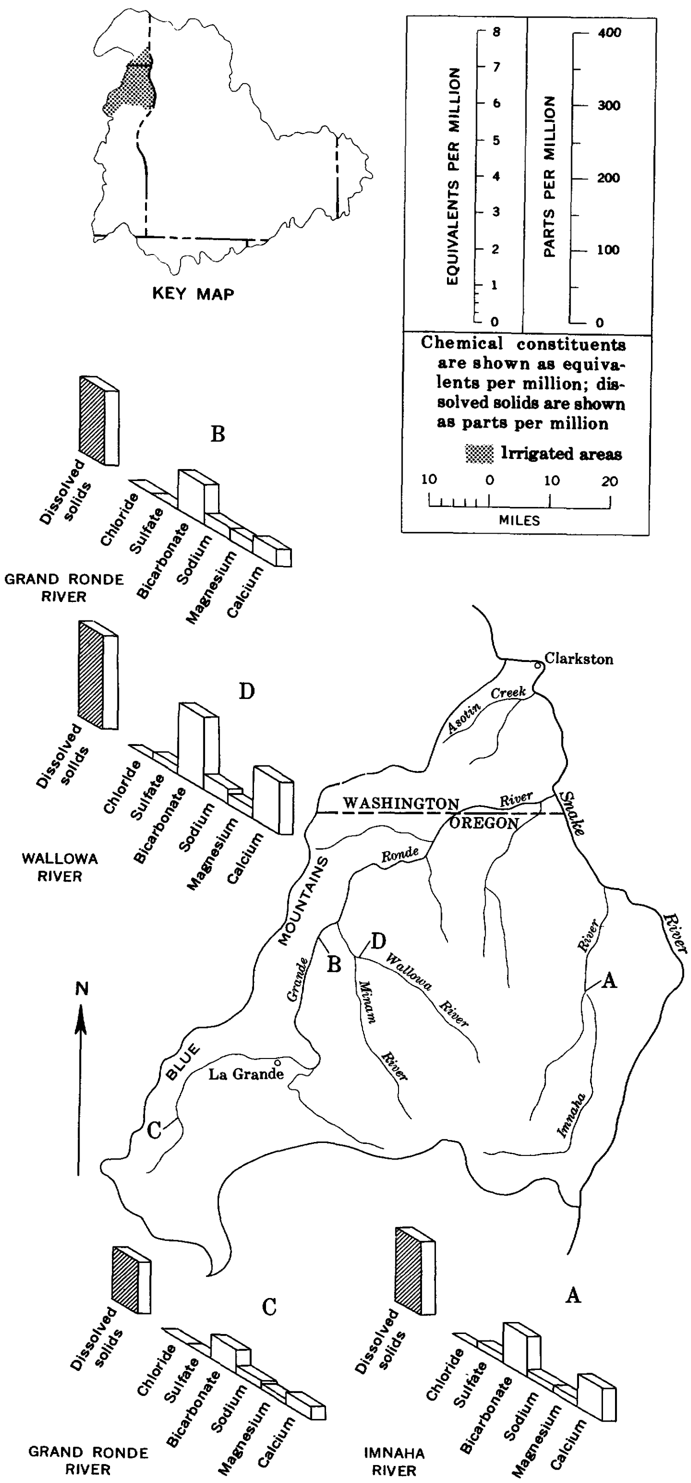

FIGURE 12.—Physical characteristics and representative chemical quality of water in the Grande Ronde River and adjacent basins, 1959–60.

River valley contains lake sediments and alluvial materials, and the river flows over these materials in its course through this valley. The tributary Wallowa and Minam Rivers rise in the Wallowa Mountains in areas underlain by volcanic, granitic, and metamorphic rocks. Below the headwaters areas, these rivers flow over the Columbia River Basalt and other volcanic rocks. Above Wallowa Lake, the Wallowa River flows through a canyon blanketed by glacial debris. The Imnaha River also heads in the Wallowa Mountains. Below its headwaters areas, the Imnaha River flows through volcanic materials before joining the Snake River. Asotin Creek drains an area composed entirely of the Columbia River Basalt.

The chemical quality of the surface waters of the Grande Ronde River and adjacent basins is similar to that of the Clearwater-Salmon region and other volcanic and intrusive rock terrains in the Snake River basin. All waters in the streams in the Grande Ronde and adjacent basins are of the calcium bicarbonate type. In a few places, there is an increase in the sodium content, attributable to use of the water for irrigation; however, sodium in no place exceeds calcium in contration. The dissolved-solids content of the water is relatively low. The dissolved solids exceed 100 ppm in only a few samples, and these occurrences were samples collected during a low-flow period. The average dissolved-solids content of samples collected monthly from the Grande Ronde River near Elgin during the 1960 water year was 103 ppm; the maximum was 119 ppm.

Water from the Grande Ronde River and its tributaries is used to irrigate more than 95,000 acres, principally in the Wallowa and Grande Ronde River valleys. This diversion and the subsequent partial return of the water cause a slight change in the chemical type of the water in both the Grande Ronde and the Wallowa Rivers. The sodium and the dissolved-solids contents were slightly greater in the lower parts of these valleys than in the upper drainage areas.

Most of the small amount of industrial activity in this area is associated with the production of lumber and wood products. Some food-processing plants are located in and around La Grande. Wastes added to the Grande Ronde River in this area can cause pollution because the gradient of the stream is gentle throughout most of the valley, and the flow is sluggish. Organic and sewage wastes discharged to the stream in only moderate proportions can therefore cause a high level of pollution in this reach.

THE LOWER BASIN

The lower basin consists of the drainage area extending from below the Clearwater River to the mouth of the Snake River (fig. 13). The principal tributaries to the Snake River in this region are the Palouse River and the Tucannon River. Several other small streams enter the Snake River in this area; however, their dis-

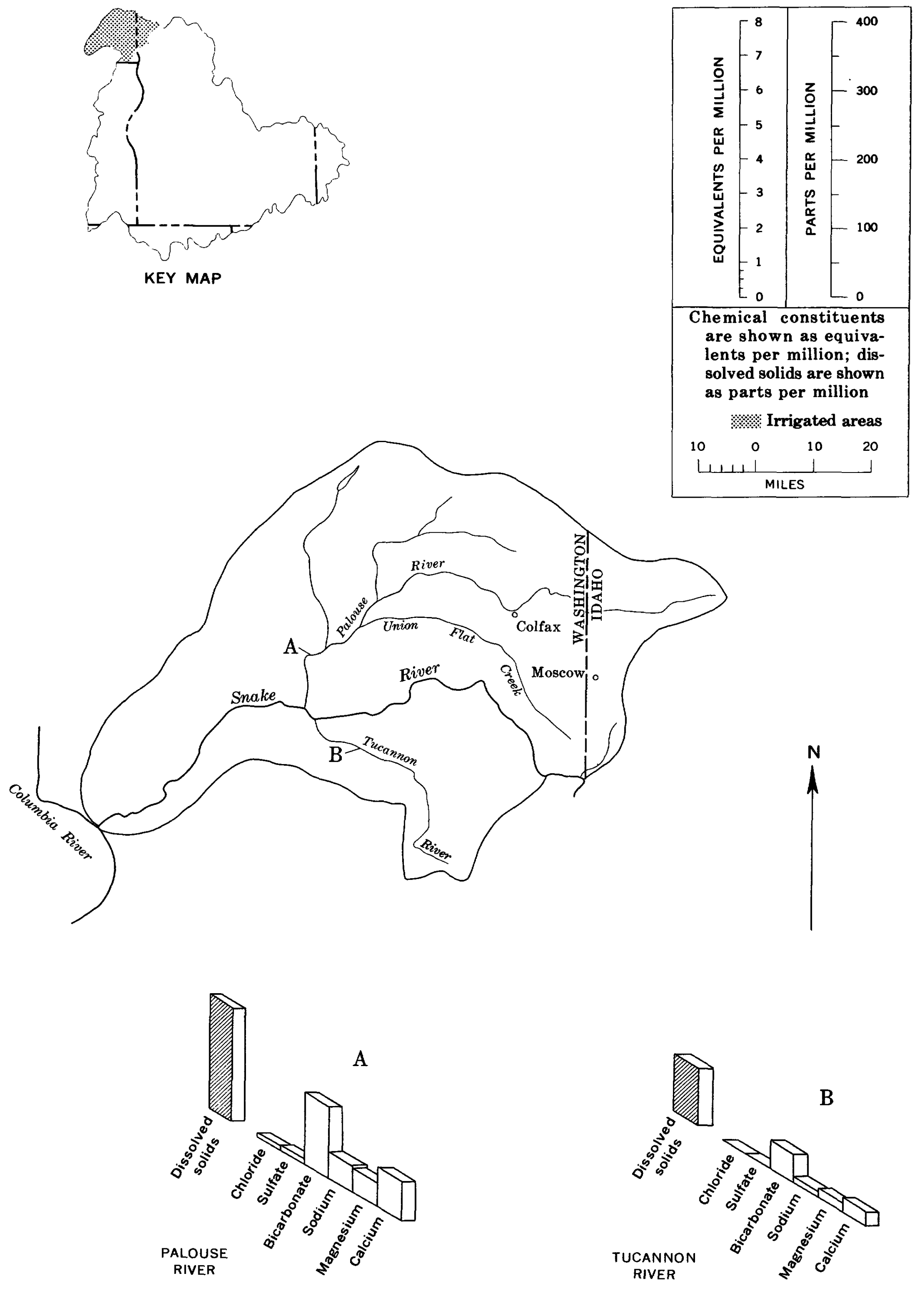

FIGURE 13.—Physical characteristics and representative chemical quality of water in the lower basin.

charge is intermittent and their contribution to the flow of the Snake River is negligible. Many of the tributaries of the Palouse and Tucannon Rivers are also intermittent streams. Because of orographic influences, precipitation in the lower basin increases from about 8 inches at the mouth of the Snake River to about 30 inches in the headwaters of the Palouse River.

The Palouse River drains an area of slightly less than 3,000 square miles, most of which is in the State of Washington. It rises in the Moscow Mountains in northwestern Idaho and flows from the headwaters to a point near the Washington-Idaho border in a canyon that is cut in metamorphosed rocks. From this canyon to the mouth, the river flows over the basalt of the Columbia Plateau.

In its headwaters the Palouse River is relatively low in dissolved solids. The dissolved-solids content of samples collected near Princeton, Idaho, ranged from 51 to 84 ppm; the water was calcium bicarbonate in type. As the water flows downstream, however, its concentration of dissolved solids increases from the natural inflow it receives. Samples collected monthly from the Palouse River below the confluence with Cow Creek near Hooper, Wash., had an average dissolved-solids content of about 135 ppm for the period November 1959 to June 1960 and about 215 ppm for the period July to October 1960. For the period November to June, water was of the calcium bicarbonate type and contained lesser amounts of magesium and sodium. During the low-flow period July to October, however, both magnesium and sodium equaled calcium in concentration.

The small amount of industrial activity in the Palouse basin has little effect on the water quality of the streams. However, towns use this river and its tributaries to dispose of domestic wastes, and some high MPN coliform counts have been observed at the sampling point near Hooper; a maximum of 240,000 was observed on two occasions in 1960. Paradoxically, the higher coliform concentrations occurred during high-flow periods.

Surface water of the Palouse River basin is not utilized to any appreciable extent for irrigation. All diversions are made directly from the river but include only a low percentage of the flow. A considerable part of the basin consists of the Palouse wheatlands, where dry farming is highly successful.

The type of soil found in this region has an appreciable bearing on the quality of the waters in the streams. The soil, in many places, is a loess, which is highly susceptible to erosion. This soil is usually very thick and highly productive. Attempts are being made to control the erosion; however, it continues at an appreciable rate. Not only does this erosion produce a high sediment load in most of the streams throughout this area, but it increases the solution of minerals by the water and produces concentrations of dissolved constituents greater than would normally be expected in an area underlain by basalt.

Although the source of the Tucannon River is in the foothills of the Blue Mountains, the river lies almost entirely on the Columbia Plateau in southeastern Washington. The principal geologic formation of the entire Tucannon River basin is Columbia River Basalt. The river has a drainage area of about 500 square miles.

The Tucannon River is similar to the Palouse River in that its water increases in dissolved-solids content from the headwaters to the mouth. However, this increase is much less than that of the Palouse River. Samples collected monthly from Tucannon River near Delany during the 1960 water year had an average dissolved-solids content of 82 ppm, which consisted principally of calcium and bicarbonate ions. The dissolved-solids content is relatively stable, ranging annually from 72 to 93 ppm. The Tucannon River has a much smaller basin than the Palouse River, and it does not receive as much drainage from the loess soils of the Palouse Formation. Its water quality is therefore probably more representative of the drainage of basalt rocks, and is much less influenced by the drainage of fine soils of the Palouse Formation than the Palouse River.

Farming is intensive in the Tucannon River basin. The major products are wheat and barley produced by dryfarming methods. Little of the water of the river and its tributaries is used for irrigation. Industrial water use has little or no effect on the chemical quality. The stream does receive domestic wastes, and the coliform concentration of monthly samples collected near Delaney had MPN coliform counts of 46,000 on two occasions during 1960.

SNAKE RIVER MAIN STEM

The Snake River is formed by the junction of several small creeks just inside the south boundary of Yellowstone National Park. At the south boundary of the park, the water of the Snake River is of a sodium calcium bicarbonate type, and dissolved solids average about 200 ppm. Below the park boundary, the Snake enters Jackson Lake—a reservoir having a storage capacity of 847,000 acre-feet. This reservoir compounds the flows, and many of the fluctuations in water quality are "smoothed out." Jackson Lake also receives tributary flow from the Teton Mountains, a large granitic mass lying immediately west of the lake. This inflow is very low in dissolved solids and dilutes the Snake River water stored in the reservoir. The net result is that the flow from Jackson Lake is very uniform in quality, the dissolved-solids content being about 100 ppm—principally calcium and bicarbonate.

The water in the Hoback River is more mineralized than the water in the other streams in the upper Snake River basin. It contains greater quantities of calcium, sulfate, and bicarbonate than the adjacent tributaries. This influx of more mineralized water increases the dissolved-solids content of the Snake River by approximately 35 ppm.

From the confluence of the Snake River and Hoback River to Heise, Idaho, the dissolved-solids content of the Snake River increases 25–50 ppm but the chemical type remains principally calcium bicarbonate. This increase in dissolved solids is probably brought about by the inflow from the Greys and Salt Rivers and from smaller creeks entering the Snake River from the north. All these stream waters are of the calcium bicarbonate type but normally have dissolved-solids contents greater than those of the Snake River.

Daily samples collected from 1953 to 1960 from the Snake River at Heise, where it enters the Snake River Plain, had an average dissolved-solids content of 215 ppm which was comprised largely of calcium bicarbonate and of lesser amounts of sodium sulfate (pl. 5). Below Heise, the Snake River receives the flow of Henrys Fork. This water is more dilute and has a somewhat higher calcium concentration than that of the Snake River. However, throughout the reach from Heise to Lake Walcott (Minidoka Dam) the Snake River receives a large amount of return flow from irrigation. This inflow is from a large irrigated area contiguous to the Snake River as well as from the Blackfoot River, Portneuf River, and other smaller streams. In addition, the Snake River probably increases somewhat in mineral content from the alluvial materials in the area. Daily samples collected at Minidoka Dam during 1948–49 had a discharge-weighted average dissolved-solids content of 262 ppm, an increase of about 50 ppm over the average at Heise. The increment is composed principally of increases in the sodium, magnesium, chloride, and carbonate-bicarbonate concentrations. (Annual discharge-weighted averages of dissolved solids in the Snake River vary less than 10 percent from year to year for a given point; see table 1. Thus, the averages for Minidoka Dam for the period 1948–49 are comparable to those for later periods.)

Varying degrees of pollution occur in the reach of the Snake River from Heise to Minidoka Dam. Oxygen-depleting wastes are received from Henrys Fork, Blackfoot, and Portneuf Rivers as well as by direct discharge to the Snake River itself. The pollution is usually not excessive, but the intensive use of the water for irrigation could have undesirable effects. Phosphates from domestic wastes, fertilizers, and the mineral-processing industry occur in noticeable concentrations in the Snake River at times. These phosphates are linked to the appreciable algal bloom which occurs in this reach and farther downstream in the summer. The algal bloom reaches sizeable proportions and reduces the suitability of the water for some uses.

From Minidoka Dam to the Oregon-Idaho border, the Snake River receives only a small amount of inflow from surface streams. The country is semiarid, and most of the available streamflow is diverted for irrigation or other uses. The very moderate streamflows that enter this part of the Snake River usually contain more than 400 ppm of dissolved solids. In this reach, spring flow contributes more water to the Snake River than surface flow. About 6,500 cfs enters the river from the Snake River Plain aquifer between Milner and King Hill. The dissolved-solids content of the spring water ranges from about 200 to more than 450 ppm, depending on the location of the outflow. Calcium and bicarbonate usually predominate, but sodium, magnesium, sulfate, and chloride ions are also present in appreciable percentages.

A combination of spring inflow and surface flows, having less volume but higher concentrations of dissolved solids, increases the mineral content of the Snake River. The average dissolved-solids content of daily samples collected at King Hill from 1951 to 1960 was about 325 ppm, an increase of some 60 ppm over the average content at Minidoka Dam. Increases in the sodium and bicarbonate concentrations made up the largest part of this increment. The Snake River receives little inflow between King Hill and the Oregon border, and its chemical quality changes very little. At a daily-sampling station at Marsing, Idaho, the water quality was almost identical with that at King Hill (table 1).

Noticeable pollution of the oxygen-depleting type occurs at times in parts of this reach of the Snake River. Wastes from Twin Falls, Burley, Rupert, and other smaller towns are discharged into the Snake River. The food-processing industry contributes wastes having an even greater oxygen demand. In addition, large amounts of organic sludge have been discharged, and large beds of this material have formed in the Snake River below Twin Falls. State Health Department officials are working with the towns and the food-processing industry to rectify this situation; however, the current increase in food processing, especially by plants dealing with potatoes, may cause waste disposal and pollution problems to continue in this reach of the Snake River for some time.

North of Marsing the Owyhee River, Malheur River, and Boise River enter the Snake River within a distance of 24 miles. Each of these tributaries contributes sodium bicarbonate or sulfate water having greater dissolved-solids content than that of the Snake River. In the reach below the Malheur River, the Snake River reaches its maximum dissolved-solids content, averaging about 400 ppm. About 3 miles below the confluence of the Snake and the Malheur Rivers, the Payette River delivers its contribution of relatively dilute water. This water, averaging less than 100 ppm dissolved solids, has a markedly diluting effect on the Snake River water. The Weiser River enters downstream from the Payette River, and like the Payette its water has a diluting effect on the Snake River. Below the Weiser River, the Snake River contains about equal quantities of calcium and sodium, and bicarbonate is the principal anion. The average dissolved-solids content of the Snake River at Weiser, Idaho, is about 335 ppm.

Northward from Weiser there is a progressive decline in the amount of semiarid drainage areas and a corresponding sharp increase in average runoff. A combination of higher precipitation and the large areas of resistant volcanic, granitic, and well-consolidated sedimentary rocks produce a large volume of very dilute runoff into the Snake River. The Salmon, Grande Ronde, and Clearwater Rivers are large tributaries of this type. All these waters are of a calcium bicarbonate type. The Clearwater River is the last major tributary to contribute to the dilution of the Snake River water. The Snake River below this point, sampled daily at Central Ferry, Wash. (1955–58), had a dissolved-solids content of 130 ppm and a calcium bicarbonate character. This is the quality of the water as it enters the Columbia River near Pasco. Thus, the average flow at the mouth (48,600 cfs) is 2½ times the flow at Weiser (19,450 cfs), and the dissolved-solids content is less than half.

Figure 14 illustrates the dissolved-solids load carried by the Snake River. At Heise the load reaches a maximum in May during the period of peak runoff of snowmelt from the headwaters region. At Minidoka Dam the Snake River shows a slight increase in dissolved-solids load; here also, the maximum load occurs in May at the time of high water runoff. At King Hill the load has increased appreciably owing to the return flows from irrigation and to spring inflows that enter the Snake River in the reach between Minidoka Dam and King Hill. The dissolved-solids load is uniform at King Hill because much of the upstream flow is diverted for irrigation and most of the flow at this point originates from the steady spring outflow in the canyon walls between Milner and King Hill. At Central Ferry the

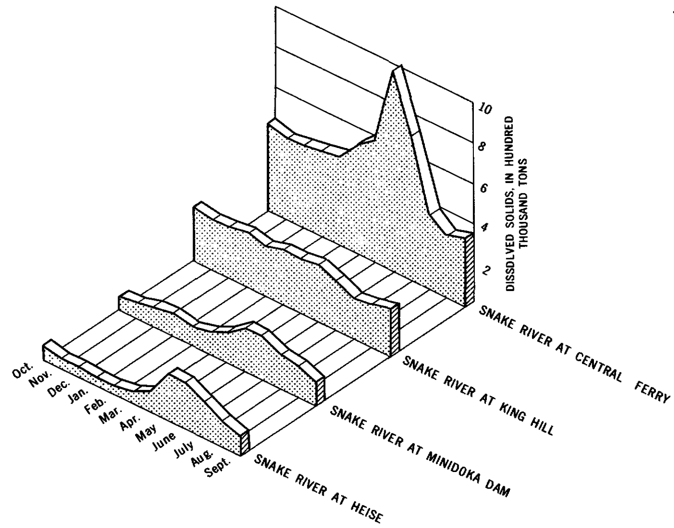

FIGURE 14.—Average monthly dissolved-solids loads transported by the Snake River at four sampling points, 1955–58.

load has increased greatly. This marked increase is in part due to the contribution of highly mineralized water from the Boise, Malheur, and Owyhee Rivers; however, the principal cause of the increase is the large volume of flow from the Clearwater and Salmon River basins. The snowmelt runoff from these mountainous basins also brings about a sharp peak in the dissolved-solids load during May.

SUMMARY

The quality of surface water of the Snake River basin ranges from excellent to poor, depending on the use for which the water is intended. The water samples analyzed were predominantly of a calcium bicarbonate type, and their dissolved-solids contents ranged from 18 to 2,340 ppm.

Water of the Snake River is satisfactory for most uses throughout most of its length. In the central reaches of the river, the average dissolved-solids content increases to about 400 ppm, the sodium content and hardness of water increasing correspondingly. However, the water is still satisfactory for irrigation. It is less desirable as a municipal or industrial supply but can be used satisfactorily after treatment. Below the Malheur River, the tributary inflow is dilute, and the chemical quality of the Snake River becomes progressively better. The Snake River is polluted at times in some reaches by food-processing and domestic wastes. These wastes make the water undesirable for many uses and require the installation of treatment facilities before the water can be used for some purposes.

From the headwaters through Henrys Fork basin, all the tributaries sampled had a dissolved-solids content of 271 ppm or less, except the Hoback River—one sample of which had dissolved solids of 458 ppm. Three of the streams had a hardness of water of more than 180 ppm (table 1). Although the water of all these tributaries could probably be used for irrigation, some of it would require softening and other treatment to meet domestic and industrial standards of quality.

From Henrys Fork to the Idaho-Oregon border and beyond, the Snake River flows across the Snake River Plain. Very little surface water flows into the river throughout this semiarid part of the basin. Much of the flow is ground-water inflow; part of this flow is natural and part comes from infiltration of irrigation water. In the headwaters areas most of the surface streams in the semiarid part of the basin are fairly dilute (dissolved-solids content less than 100 ppm) and are predominantly calcium bicarbonate water. However, before these streams flow into the Snake River their dissolved-solids and sodium contents increase to several times what they were in the headwaters.

South of the Snake River, in the general area between Idaho Falls and the Malheur River basin, the sodium content of the streams increases westward. The waters of the Owyhee, Malheur, and Raft Rivers increase in sodium content throughout their course. At their mouths, the Owyhee and Raft Rivers average about 160 ppm sodium and the Malheur River, about 230 ppm. North of the Snake River, the dissolved-solids and sodium contents of the Big Wood and the Boise Rivers also increase noticeably as these streams flow toward the Snake River.

The marked increases in dissolved-solids and sodium contents of the Snake River and its tributaries in the middle section of the basin can be attributed largely to irrigation. However, these increases are rarely sufficient to prohibit reuse of the water for more irrigation. Wastes from municipalities and food-processing plants cause pollution in some of the streams of the middle section of the Snake River basin.

With few exceptions, the streams draining the mountainous areas in central and northeastern Idaho and northeastern Oregon are of excellent quality. The average precipitation in these areas is moderate to high, as compared with the rest of the basin, and at some places exceeds 60 inches. The rocks making up the basin are resistant to solvent action, and the water use is small. Because of these conditions, the water is of a calcium bicarbonate type and low in dissolved solids, usually less than 100 ppm. Hardness of the water does not generally exceed 90 ppm. Segments of some streams may be subject to pollution from organic and domestic wastes; however, these segments are few, and pollution usually does not seriously impair the quality of the water.

In the lower part of the Snake River basin, the problem is less one of chemical quality than of physical quality—the sediment content. The chemical quality of the Palouse and Tucannon Rivers in this area is fairly good; the dissolved-solids content generally is only slightly more than 200 ppm even during low flow in the summer. However, these streams remain very turbid throughout the year and transport huge quantities of sediment. Turbidity and disposition of sediment loads are problems to be considered in any use of water from these streams.

TABLE 1.—*Representative analyses of surface waters of the Snake River basin*

[Sampling frequency: D, daily; M, monthly; P, periodic; H, high flow; L, low flow. Number of samples: Analyses by U.S. Geol. Survey except as indicated by asterisk (U.S. Bur. Reclamation) and by dagger (Idaho Univ. Agr. Expt. Sta.)]

Location	Sampling period	Sampling frequency	Number of samples	Discharge (cfs)	Silica (SiO_2) (ppm)	Equivalents per million: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180° C) (parts per million)	Hardness as $CaCO_3$: Calcium, magnesium (parts per million)	Hardness as $CaCO_3$: Noncarbonate (parts per million)	Specific conductance (micromhos at 25° C)	pH
ASOTIN CREEK BASIN																			
Asotin Creek at Asotine, Wash	8/26/59	L	1	37				0.35		1.54		0.06				65	0	164	7.5
Do	4/5/60	H	1	167	35	0.42	0.21	.16	0.04	.79	0.02	.01	0.01	0.01	91	32	0	86	7.1
BANNOCK CREEK BASIN																			
Bannock Creek at Pauline, Idaho	8/3/60		1		22	2.99	1.20	.96	.49	3.51	.58	1.35	.02	.01	334	210	34	540	7.6
Bannock Creek near Pocatello, Idaho	7/23/58		1		26	4.49	2.60	1.70	.14	5.05	.96	2.82	.01	.01	518	355	102	828	7.9
Do	9/1/59		1					1.65		5.18		2.17				355	96	854	7.6
Rattlesnake Creek at Crystal, Idaho	8/3/60	H	1			3.89				4.80	.40				460			704	8.0
BIG WOOD RIVER BASIN																			
Big Wood River near Gooding, Idaho	8/21/49		1	26	13					2.79	.81	.34	.03	.03		166	26	391	
Do	7/25/58		1	78	8.6	2.59	1.32	.87	.11	3.31	1.00	.54	.05	.01	268	196	30	443	8.2
Do	9/2/59		1	71				1.09		3.21		.68				178	17	475	7.8
Do	4/20/60		1	45	13	2.74	1.35	1.13	.11	3.51	.96	.73	.06	.00	300	204	29	505	8.2
Big Wood River near Hagerman, Idaho	9/2/59		1		31	2.05	1.49	1.00	.09	[1] 3.34	.77	.45	.02	.06	276	177	10	435	8.3
Do	4/20/60		1		33	1.90	1.42	1.00	.09	[1] 3.18	.69	.39	.02	.06	256	166	7	410	8.4
Big Wood River near Ketchum, Idaho	9/2/59		1	63	13	1.30	.15	.14	.01	1.48	.12	.01	.02	.00	95	72	0	158	8.0
Do	4/21/60	H	1	155	11	1.15	.15	.13	.01	1.28	.13	.01	.01	.00	85	65	1	144	7.9
Do	8/31/60	L	1	51	11	1.30	.20	.15	.01	1.49	.10	.02	.02	.00	97	75	0	160	8.2
Big Wood River below Magic Reservoir	3/31/48–9/30/49	D	†24	692		1.58	.69	.30	.24	[2] 2.18	.36	.22			[3] 167	114	0		
Do	9/2/59		1	611			.30			2.46		.06				119	0	257	7.8
Do	4/20/60		1	12	21	1.60	.66	.52	.05	[4] 2.39	.27	.10	.02	.00	160	113	0	261	8.4
Camas Creek near Fairfield, Idaho	7/30/57		1	8.2	24	1.15	.72	1.00	.14	2.62	.10	.17	.03	.02	176	94	0	280	7.3
Do	4/20/60		1	532	17	.50	.23	.38	.04	.95	.09	.03	.02	.01	90	36	0	111	7.2
EF Big Wood River near Gimlet, Idaho	4/21/60	H	1		6.2	1.90	.88	.07	.02	2.36	.44	.03	.01	.01	152	139	21	269	8.1
Do	8/30/60	L	1		9.0	2.40	1.06	.08	.03	3.02	.44	.04	.01	.01	194	173	22	330	8.1
Little Wood River near Bellevue, Idaho	9/2/59		1		12	2.10	.97	.15	.03	[4] 2.87	.33	.04	.01	.00	176	154	10	295	8.3
Little Wood River at Little Wood River Dam	8/30/57		1		14	1.70	.72	.18	.03	2.28	.25	.10	.01	.02	144	121	7	247	7.7
NF Big Wood River near Ketchum, Idaho	4/21/60		1		7.4	1.85	.51	.06	.01	2.08	.31	.02	.01	.01	134	118	14	230	8.0
Soldier Creek near Fairfield, Idaho	9/18/57		1		16	.60	.16	.16	.02	.90	.02	.01	.01	.01	65	38	0	92	7.8
BLACKFOOT RIVER BASIN																			
Blackfoot River at Blackfoot, Idaho	11/17/51		1	662	18	2.89	1.81			3.67	1.04	.45		.04		235	52	452	
Do	7/23/58	P	1	18	13	2.50	1.66	.44	.07	3.72	.46	.27	.02	.02		208	22	408	
Do	8/29/59	P	1	2	13	2.05	.98	.44	.07	[5] 2.67	.62	.24	.03	.00	205	152	18	332	8.3
Do	4/24/60	P	1	142	19	2.15	.92	.65	.07	2.82	.65	.34	.05	.00	229	154	12	368	8.0
Blackfoot River at Presto, Idaho	4/5/48–9/16/49	D	†25	386		2.26	1.66	.47	.22	[6] 3.51	.59	.51			[3] 251	196	8		
Blackfoot River below Blackfoot Resevoir near Soda Springs, Idaho	8/29/59	L	1					.52		3.84		.34				207	15	440	7.9
Do	4/24/60	H	1		23	2.79	1.40	.61	.05	4.16	.33	.37	.02	.00	258	210	2	446	8.1
Blackfoot River near Soda Springs, Idaho	8/29/59	L	1		6.5	2.50	1.33	.18	.04	3.67	.25	.08	.01	.00	204	192	8	364	8.0
Do	4/24/60	H	1		7.7	1.50	.42	.10	.05	1.88	.10	.04	.01	.00	120	96	2	195	7.7
BOISE RIVER BASIN																			
Bannock Creek near Idaho City, Idaho	2/12/59	L	1	1.0	25	.80	.14	.30	.04	1.16	.04	.02	.01	.00	88	47	0	109	7.7
Do	4/28/59	H	1	4.1	24	.50	.08	.23	.02	.80	.04	.01	.01	.00	83	29	0	83	7.1
Boise River near Arrowrock, Idaho	4/1/39–1/17/40	D	29	2,580		.62	.13			.89	.09	.02		.01	72	38	0	98	
Boise River at Boise, Idaho	2/12/59	L	1	28	16	.75	.21	.40	.03	[7] 1.16	.12	.06	.03	.01	88	48	0	133	8.4
Do	4/28/59	H	1	1,610	14	.60	.03	.20	.02	.79	.07	.01	.03	.01	65	32	0	89	7.1
Do	8/30/60		1	926	11	.50	.12	.18	.02	.75	.05	.00	.02	.01	57	31	0	85	8.0

Boise River at Notus, Idaho	1/13/39–1/17/40	D	36	497	------	2.52	1.34	------	------	[8] 3.84	3.11	1.41	------	.04	531	193	14	------	------
Do	11/20/50–9/30/51	D	33	1,924	21	.95	.40	.91	.10	1.59	.54	.18	.02	.05	154	67	0	226	------
Do	10/1/51–9/30/52	D	39	2,525	20	.90	.41	.82	.05	1.47	.46	.16	.02	.04	142	65	0	206	------
Do	10/1/52–9/30/53	D	39	1,402	21	1.15	.53	1.26	.06	1.93	.75	.26	------	.04	190	83	0	285	------
Do	10/1/53–9/30/54	D	39	1,104	23	1.40	.61	1.48	.06	2.31	.87	.28	------	.04	221	100	0	336	------
Do	10/1/54–9/30/55	D	36	386	36	2.45	1.15	3.26	.12	4.34	1.94	.62	------	.06	427	180	0	655	------
Do	10/1/55–9/30/56	D	36	2,173	------	.95	.35	.87	------	1.54	.48	.16	------	.03	147	65	0	218	------
Do	10/1/56–9/30/57	D	22	1,948	------	1.10	.40	1.00	------	1.79	.58	.18	------	.03	166	75	0	249	------
Do	10/1/57–9/30/58	D	25	1,775	------	1.25	.42	1.09	------	1.95	.60	.20	------	.04	178	84	0	270	------
Do	10/1/58–9/30/59	D	34	546	------	------	------	2.70	------	4.15	------	------	------	------	386	177	0	592	------
Do	10/1/59–9/30/60	D	33	805	------	------	------	2.13	------	3.13	------	------	------	------	289	124	0	448	------
Boise River near Twin Springs, Idaho	1/21/39–3/31/39	D	7	608	------	.57	.10	------	------	.80	.09	.02	------	.01	71	34	0	96	------
Do	10/1/58–9/30/59	D	26	1,074	12	.41	.03	.13	.01	.54	.05	.01	.03	.00	46	22	0	60	------
Dry Creek near Eagle, Idaho	2/12/59	H	1	5.7	31	1.65	.46	.61	.06	2.20	.35	.06	.04	.04	178	106	0	257	7.8
Do	4/28/59	L	1	2.9	35	2.25	.70	.96	.16	3.21	.52	.09	.11	.03	254	148	0	373	7.6
Mores Creek near Arrowrock, Idaho	2/12/59	L	1	124	18	.75	.15	.23	.03	.97	.12	.01	.02	.01	76	45	0	110	7.7
Do	4/28/59	H	1	572	18	.47	.09	.16	.03	.66	.07	.02	.02	.01	62	28	0	73	7.2
Robie Creek near Arrowrock, Idaho	2/12/59	L	1	4.3	24	.80	.24	.27	.03	1.13	.09	.02	.01	.04	93	52	0	126	7.8
Do	4/28/59	H	1	9.8	23	.70	.08	.24	.03	.95	.06	.00	.01	.01	85	39	0	106	7.6
BRUNEAU RIVER BASIN																			
Bruneau River below Hot Spring, Idaho	3/30/48–10/7/49	D	†27	472	------	.68	.27	.58	.21	[9] 1.26	.26	.22	------	------	[3] 130	52	0	------	------
Bruneau River near Hot Spring, Idaho	12/5/58–10/8/59	M	10	------	36	.60	.18	.90	.09	1.24	.22	.12	.14	.01	133	39	0	171	------
EF Bruneau River near Three Creek, Idaho	9/1/59	L	1	3.8	34	.55	.20	.37	.11	1.07	.06	.06	.02	.00	100	38	0	121	7.5
Do	4/25/60	H	1	74	36	.60	.20	.37	.11	1.07	.13	.08	.02	.01	115	40	0	125	8.1
EF Jarbridge River at Murphy Hot Springs, Idaho	9/1/59	L	1	8.1	26	.25	.03	.23	.06	.44	.09	.04	.02	.00	61	14	0	64	7.3
Do	4/25/60	H	1	79	23	.22	.01	.13	.04	.31	.05	.02	.02	.00	56	12	0	57	7.3
Little Valley Creek near Bruneau, Idaho	7/22/58	------	1	------	------	------	------	28.28	------	8.15	------	------	------	------	------	385	0	3,360	7.7
Do	9/3/59	------	1	------	------	------	------	29.93	------	8.41	20.59	5.50	.47	------	------	385	0	3,490	8.0
Do	4/26/60	------	1	------	38	7.48	1.67	24.53	.41	6.72	21.65	4.94	.53	.06	2,340	458	122	3,180	8.0
BUFFALO FORK BASIN																			
Buffalo Fork near Moran, Wyo	8/30/59	------	1	343	23	1.10	.43	.22	.06	1.66	.11	.06	.01	.00	116	76	0	175	7.8
Do	4/22/60	------	1	256	18	1.35	.44	.29	.05	1.88	.17	.11	.03	.00	129	90	0	211	7.8
BURNT RIVER BASIN																			
Burnt River at Durkee, Oreg	4/6/60	H	1	173	32	1.40	.66	.70	.09	2.05	.65	.06	.02	.02	188	103	0	274	7.6
Do	9/29/60	L	1	43	43	2.74	1.63	1.70	.20	[7] 4.54	1.54	.14	.02	.00	386	218	0	558	8.4
Burnt River below Unity Reservoir near Hereford, Oreg	9/17/59	------	1	41	------	------	------	1.00	------	2.34	------	.10	------	------	------	132	15	368	7.6
Do	9/2/60	------	1	82	36	1.15	.74	.70	.10	1.84	.69	.06	.02	.02	191	94	2	255	7.5
Burnt River near Huntington, Oreg	7/25/58	------	1	------	42	2.99	1.40	1.65	.18	4.11	1.81	.13	.02	.02	384	220	14	548	8.0
Do	9/17/59	L	1	------	42	3.74	1.31	2.18	.23	[10] 5.09	2.29	.17	.03	.01	471	252	0	677	8.5
Do	4/6/60	H	1	------	32	1.60	.64	.70	.10	2.15	.71	.06	.02	.03	200	112	0	289	7.6
NF Burnt River near Whitney, Oreg	9/17/59	L	1	------	------	------	------	.57	------	[11] 2.65	------	.03	------	------	------	106	0	254	8.5
Do	4/6/60	H	1	------	28	.40	.32	.16	.03	.85	.05	.00	.01	.00	86	36	0	89	7.4
SF Burnt River near Unity, Oreg	4/6/60	------	1	------	33	.55	.34	.27	.07	1.07	.13	.00	.01	.00	103	44	0	119	7.5
CLEARWATER RIVER BASIN																			
Clearwater River at Kamiah, Idaho	7/21/58	------	1	3,240	12	.19	.03	.08	.02	.33	.02	.00	.01	.00	31	11	0	31	7.3
Clearwater River at Spaulding, Idaho	8/26/59–10/2/60	M	10	------	13	.20	.05	.08	.02	.32	.02	.01	.01	.00	35	12	0	39	------
Little NF Clearwater River near Headquarters, Idaho.	8/26/59	------	1	------	------	------	------	.08	------	.33	------	.01	------	------	------	10	0	34	6.9
Lochsa River at Lowell, Idaho	8/27/59	L	1	545	12	.25	.02	.10	.03	.39	.02	.01	.01	.00	34	14	0	40	7.1
Do	4/19/60	H	1	5,120	12	.15	.03	.07	.01	.25	.00	.00	.01	.00	26	9	0	26	7.7
NF Clearwater River near Headquarters, Idaho.	8/26/59	------	1	------	12	.30	.06	.08	.03	.46	.02	.01	.01	.00	39	18	0	51	7.4
Potlatch Creek near Kendrick, Idaho	8/26/59	L	1	14	------	------	------	.15	------	.69	------	.02	------	------	------	26	0	74	7.6
Do	4/18/60	H	1	1,100	23	.17	.09	.10	.03	.38	.04	.01	.01	.00	57	13	0	41	7.7

See footnotes at end of table.

TABLE 1.—*Representative analyses of surface waters of the Snake River Basin*—Continued

[Sampling frequency: D, daily; M, monthly; P, periodic; H, high flow; L, low flow. Number of samples: Analyses by U.S. Geol. Survey except as indicated by asterisk (U.S. Bur. Reclamation) and by dagger (Idaho Univ. Agr. Expt. Sta.)]

Location	Sampling period	Sampling frequency	Number of samples	Discharge (cfs)	Silica (SiO_2) (ppm)	Equivalents per million: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180° C) (Parts per million)	Hardness as $CaCO_3$: Calcium, magnesium (Parts per million)	Hardness as $CaCO_3$: Noncarbonate (Parts per million)	Specific conductance (micromhos at 25° C)	pH
CLEARWATER RIVER BASIN—Con.																			
Selway River near Lowell, Idaho	8/27/59	L	1	763	13	0.20	0.03	0.09	0.04	0.33	0.02	0.01	0.01	0.00	33	12	0	34	7.2
Do	4/19/60	H	1	6,190	12	.15	.01	.07	.01	.20	.02	.00	.01	.00	26	8	0	26	7.1
SF Clearwater River near Elk City, Idaho	8/27/59	L	1	43	14	.25	.09	.13	.04	.44	.03	.01	.03	.00	39	17	0	50	7.2
Do	4/19/60	H	1	768	17	.12	.04	.10	.02	.25	.03	.00	.01	.00	39	8	0	------	7.1
SF Clearwater River at Kooskia, Idaho	4/19/60	------	1	------	19	.17	.10	.13	.02	.41	.04	.01	.01	.00	55	14	0	48	7.1
COTTONWOOD CREEK BASIN																			
Cottonwood Creek near Jenny Lake, Wyo	8/ 4/60	------	1	------	1.7	.12	.05	.03	.03	.20	.05	.01	.00	.00	22	8	0	27	6.9
GOOSE CREEK BASIN																			
Goose Creek above Reservoir near Oakley, Idaho.	4/25/60	H	1	75	32	1.40	.39	.42	.11	1.84	.25	.25	.01	.01	165	90	0	230	7.9
Do	8/ 2/60	L	1	7.9	34	2.74	.83	.87	.31	3.43	.77	.56	.02	.01	296	178	7	461	7.7
GRANDE RONDE RIVER BASIN																			
Grande Ronde River near Anatone, Wash	8/26/59	L	1	------	------	------	------	.34	------	1.66	------	.03	------	------	------	70	0	175	7.6
Do	4/ 5/60	H	1	------	29	.32	.14	.13	.04	.59	.04	.01	.01	.01	70	23	0	62	7.6
Grande Ronde River near Elgin, Oreg	9/19/59–9/26/60	M	13	------	32	.51	.34	.35	.06	1.12	.06	.05	.01	.01	103	42	0	122	------
Grande Ronde River at Island City, Oreg	9/19/59	L	1	------	------	------	------	.30	------	1.15	------	.04	------	------	------	45	0	120	7.5
Do	4/ 5/60	H	1	------	31	.25	.13	.13	.03	.52	.02	.01	.01	.01	73	19	0	56	7.3
Grande Ronde River near Starkey, Oreg	9/19/59	L	1	------	24	.45	.17	.21	.05	.84	.04	.01	.01	.00	74	31	0	89	7.5
Do	4/ 5/60	H	1	------	30	.30	.14	.17	.04	.61	.06	.01	.01	.01	74	22	0	64	7.3
Lostine River at Lostine, Oreg	4/ 5/60	------	1	198	12	.55	.06	.07	.03	.66	.08	.00	.01	.00	51	30	0	75	7.9
Minam River at Minam, Oreg	9/18/59	------	1	------	15	.30	.06	.08	.03	.49	.02	.01	.00	.00	43	18	0	49	7.2
Do	4/ 5/60	------	1	------	21	.27	.08	.10	.02	.49	.01	.03	.01	.00	51	18	0	51	7.7
Wallowa River at Minam, Oreg	9/18/59	------	1	31	24	1.85	.29	.44	.08	2.43	.25	.03	.01	.01	165	107	0	254	8.0
Do	4/ 5/60	------	1	23	25	.80	.17	.23	.05	1.08	.12	.03	.01	.01	96	48	0	123	7.5
Wallowa River above Wallowa Lake, Oreg	9/18/59	------	1	------	------	------	------	.07	------	.79	------	------	------	------	------	38	0	89	7.4
Do	4/ 5/60	------	1	------	11	.75	.05	.09	.02	.79	.13	.01	.01	.00	57	40	0	94	7.5
GREYS RIVER BASIN																			
Greys River near Alpine, Wyo	8/29/59	L	1	331	5.3	2.50	1.15	.11	.03	2.77	1.02	.02	.01	.00	212	182	44	349	8.2
Do	4/22/60	H	1	820	6.0	2.05	.73	.14	.01	2.41	.50	.01	.01	.00	165	139	18	278	7.9
GROS VENTRE RIVER BASIN																			
Gros Ventre River near Kelley, Wyo	8/30/59	P	1	------	7.4	2.45	1.02	.28	.04	2.52	1.21	.03	.01	.00	213	174	48	347	8.0
Do	4/23/60	P	1	------	7.5	2.35	.82	.40	.04	2.33	1.27	.03	.01	.00	210	158	42	348	8.0
Do	8/ 4/60	P	1	------	------	2.15	1.03	.23	------	[12] 2.28	1.06	------	------	------	204	159	45	311	8.6
HENRYS FORK BASIN																			
Buffalo River at Ponds Lodge, Idaho	4/22/60	H	1	------	34	.30	.03	.70	.06	.82	.06	.08	.09	.00	96	16	0	111	7.3
Do	8/ 5/60	L	1	------	40	.25	.11	.74	.07	.90	.05	.11	.15	.00	111	18	0	127	7.3
Fall River near Ashton, Idaho	8/27/57	------	1	------	46	.32	.08	1.00	.08	.97	.08	.28	.15	.01	120	20	0	144	7.9
Do	4/22/60	------	1	------	37	.37	.14	1.17	.07	1.18	.08	.34	.12	.00	136	26	0	174	7.8
Fall River near Chester, Idaho	8/28/59	L	1	------	------	------	------	1.04	------	[4] 1.23	------	.28	------	------	------	28	0	175	8.3
Do	4/21/60	H	1	------	36	.50	.16	1.04	.07	1.31	.06	.34	.12	.00	132	33	0	179	8.2
Henrys Fork at Ashton, Idaho	4/1/48–10/ 4/49	D	†28	1,655	------	.75	.35	.50	.17	[13] 1.36	.19	.24	------	------	[3] 126	55	0	------	------
Henrys Fork near Macks Inn, Idaho	8/28/59	L	1	------	11	1.50	.87	.09	.05	2.41	.05	.01	.01	.01	144	118	0	233	8.2
Do	4/22/60	H	1	------	15	1.75	.87	.11	.05	2.67	.07	.04	.01	.02	163	131	0	264	7.9
Henrys Fork near Rexburg, Idaho	10/17/51	------	1	2,370	36	.80	.40	------	------	1.41	.11	.25	------	.02	------	60	0	170	------
Do	8/28/59	------	1	1,520	32	.70	.37	.57	.06	[14] 1.41	.07	.11	.11	.01	126	54	0	158	8.8
Do	4/21/60	------	1	1,710	32	.60	.26	.65	.06	1.28	.06	.16	.09	.00	115	43	0	159	7.6

Teton River near Driggs, Idaho	4/22/60		1		12	2.69	1.18	.09	.02	3.70	.25	.02	.01	.04	213	194	8	371	8.0
Teton River near Newdale, Idaho	7/3/58		1		17	1.70	1.02	.23	.04	2.69	.10	.06	.03	.01	155	136	2	258	8.2
Do	8/28/59	L	1		13	1.95	1.07	.13	.04	[15] 3.01	.12	.06	.01	.01	172	151	0	294	8.5
Do	4/22/60	H	1		16	2.20	.90	.16	.03	[16] 2.99	.20	.06	.01	.02	186	155	9	296	8.3
Warm River near Warm River, Idaho	7/24/57		1		36	.40	.08	.16	.04	.56	.09	.07	.06	.00	71	24	0	65	7.3
HOBACK RIVER BASIN																			
Cliff Creek near Bondurant, Wyo	8/4/60		1		4.7	5.99	2.04	.15	.03	2.59	5.29	.03	.00	.00	514	402	272	710	8.0
Dell Creek near Bondurant, Wyo	8/4/60		1			3.44				3.82	.96				274			437	8.1
Granite Creek near Jackson, Wyo	8/4/60		1			1.75				[4] 2.54	.20				143			261	8.4
Hoback River above Granite Creek near Jackson, Wyo.	8/4/60		1			3.94				3.18	2.29				343			501	7.9
Hoback River at mouth near Jackson, Wyo	8/31/59	P	1		7.1	5.19	1.72	.17	.03	2.62	4.37	.03	.02	.00	458	346	214	641	7.9
Do	4/23/60	P	1		5.5	3.89	1.22	.22	.03	2.92	2.31	.03	.01	.00	324	256	110	494	8.0
Do	8/3/60	P	1		5.3	4.74	1.89	.17	.03	2.80	3.89	.04	.02	.00	436	332	192	613	8.0
Hoback River above Willow Creek near Jackson, Wyo.	8/4/60		1			5.14				3.11	3.19				461			643	8.0
Willow Creek near Jackson, Wyo	8/4/60		1			4.44				3.15	3.19				412			585	7.9
IMNAHA RIVER BASIN																			
Imnaha River at Imnaha, Oreg	9/18/59	L	1	185	22	1.55	.21	.22	.05	1.59	.42	.02	.01	.00	132	88	8	198	7.9
Do	4/5/60	H	1	1,120	27	.60	.15	.14	.04	.82	.12	.01	.01	.00	84	38	0	95	7.8
MALHEUR RIVER BASIN																			
Bully Creek near Vale, Oreg	4/15/58	H	1	372	28	1.15	.45	.65	.11	1.93	.31	.08	.01	.02	179	80	0	228	7.8
Do	9/17/59	L	1	33				4.83		5.97		.82				252	0	960	7.9
Do	4/6/60		1	142	40	1.10	.48	.83	.11	1.87	.48	.08	.02	.03	182	78	0	246	7.8
Malheur River near Drewsey, Oreg	3/2/51		1	130	42	.65	.55			1.66	.23	.09		.01		60	0	187	7.8
Do	8/22/56		1	12	45	1.75	1.23	2.61	.13	4.79	.48	.28		.05	343	149	0	524	
Do	9/16/59	L	1	3.2	49	1.90	1.18	2.87	.14	5.31	.56	.14	.04	.01	369	154	0	538	8.1
Do	4/7/60	H	1	1,620	31	.45	.18	.37	.07	.92	.12	.03	.01	.01	89	32	0	109	7.5
Malheur River near Ontario, Oreg	8/25/60–7/25/61	M	12		42	3.54	2.28	10.06	.31	[16] 7.41	7.05	1.71	.04	.08	1,030	291	0	1,480	
SF Malheur River at Venator, Oreg	4/7/60		1		33	.80	.46	.65	.09	1.70	.15	.10	.01	.00	145	63	0	191	7.8
Willow Creek at Ironside, Oreg	6/27/57		1			2.79	.90	.70	.11	3.24									
Willow Creek near Vale, Oreg	9/17/59		1					8.70		7.62		1.10			1,000	330	0	1,400	8.1
Do	4/7/60		1		46	3.99	1.80	7.05	.23	6.75	5.45	.93	.03	.09	807	290	0	1,170	8.2
MUD LAKE-LOST RIVER BASINS																			
Big Lost River at Mackay, Idaho	4/12/48–10/13/48	D	†12	503		1.77	.78	.24	.25	[4] 2.54	.38	.28			[3] 179	128	1		
Birch Creek near Gilmore, Idaho	5/25/57		1		12	1.90	1.48	.26	.03	[14] 2.87	.58	.14	.01	.02	196	169	25	335	8.4
Do	8/28/59		1					.21		2.57		.14				149	20	302	8.2
Do	4/21/60		1		11	2.10	1.12	.23	.02	2.79	.56	.14	.02	.01	190	161	22	323	8.1
Camas Creek near Kilgore, Idaho	7/25/56		1		26	.95	.47	.18	.04	1.52	.06	.03	.02	.01	110	71	0	156	8.5
Little Lost River near Howe, Idaho	7/22/57		1		15	1.35	.64	.13	.02	1.95	.15	.06	.01	.01	123	99	2	202	8.0
Medicine Lodge Creek near Small, Idaho	7/25/56		1		18	2.94	1.40	.34	.05	3.70	.85	.19	.02	.01	269	217	32	526	8.4
Mud Lake near Terreton, Idaho	6/15/49–10/3/49	M	†7			1.06	.89	.56	.15	[17] 1.97	.34	.36			[3] 154	98	0		
OWYHEE RIVER BASIN																			
Crooked Creek near Rome, Oreg	3/4/51		1		68	.75	.40			[18] 2.87	.65	.51		.03		57	0	400	8.4
Do	9/3/59		1		57	.75	.25	2.96	.20	[12] 2.94	.62	.48	.09	.04	295	50	0	405	8.5
Do	4/7/59		1		60	.75	.19	3.04	.18	[19] 2.83	.60	.51	.09	.03	278	47	0	397	8.7
EF Owyhee River at Owyhee, Nev	9/3/60		1		25	1.45	.42	.57	.10	2.26	.16	.11	.03	.00	167	94	0	243	7.7
Do	4/26/60		1		24	.85	.23	.23	.04	1.15	.17	.06	.01	.00	104	54	0	131	7.8
Jordan Creek near Jordan Valley, Oreg	3/4/51		1	190	35	.75	.53			1.56	.25	.16		.02		64	0	189	7.7
Do	9/3/59	L	1	1.0				8.09		[20] 3.88		4.74				141	0	1,070	8.8
Do	4/7/60	H	1	1,230	23	.35	.13	.19	.05	.56	.07	.00	.01	.03	76	24	0	72	7.2
Owyhee River near Adrian, Oreg	8/22/56		1			3.19	1.97	4.35								258	28	1,130	7.6
Do	7/25/58		1		34	3.24	1.45	4.13	.18	3.74	3.91	1.33	.05	.07	575	235	48	863	7.5
Do	9/3/59		1		34	3.74	1.57	5.74	.24	4.80	5.02	1.41	.08	.06	732	266	26	1,080	7.8
Do	4/7/60		1		40	5.59	2.56	9.00	.33	5.41	9.06	2.96	.09	.11	1,120	408	137	1,610	7.8
Owyhee River at Owyhee Reservoir	4/7/48–10/3/49	D	†24			1.08	.56	1.11	.14	1.81	.70	.37			[3] 193	82	0		
Owyhee River at Rome, Oreg	9/3/59–9/16/60	M	10		28	.88	.38	1.66	.09	1.98	.53	.32	.13	.02	180	63	0	295	
PALOUSE RIVER BASIN																			
Cow Creek near Benge, Wash	8/25/59		1					.96		[11] 3.25		.18				131	0	336	8.5
Do	4/4/60		1		21	1.55	1.09	.91	.71	[21] 3.35	.21	.13	.03	.03	208	132	0	341	8.7
Palouse River near Hooper, Wash	7/30/59–6/21/60	M	12		25	1.10	.62	.64	.10	[22] 2.09	.15	.13	.02	.11	160	86	0	235	
Palouse River near Princeton, Idaho	8/25/59		1					.12		.54		.01			84	21	0	64	7.2
Do	4/4/60		1		22	.17	.01	.08	.03	.26	.04	.00	.01	.01	51	9	0	36	7.1
Union Flat Creek near Lacrosse, Wash	8/25/59		1					1.30		3.77		.26				148	0	408	7.4
Do	4/4/60		1		37	1.70	.58	.87	.09	2.74	.19	.10	.02	.24	200	114	0	315	7.7

See footnotes at end of table.

TABLE 1.—*Representative analyses of surface waters of the Snake River Basin*—Continued

[Sampling frequency: D, daily; M, monthly; P, periodic; H, high flow; L, low flow. Number of samples: Analyses by U.S. Geol. Survey except as indicated by asterisk (U.S. Bur. Reclamation) and by dagger (Idaho Univ. Agr. Expt. Sta.)]

Location	Sampling period	Sampling frequency	Number of samples	Discharge (cfs)	Silica (SiO_2) (ppm)	Equivalents per million: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180° C) (Parts per million)	Hardness as $CaCO_3$: Calcium, magnesium (Parts per million)	Noncarbonate (Parts per million)	Specific conductance (micromhos at 25° C)	pH
PAYETTE RIVER BASIN																			
MF Payette River at Crouch, Idaho	2/11/59		1		22	0.40	0.04	0.28	0.02	0.69	0.03	0.01	0.04	0.00	62	22	0	72	7.2
NF Payette River at Cascadé, Idaho	2/11/59		1	537	5.6	.15	.06	.09	.03	.31	.02	.00	.02	.01	29	10	0	37	6.7
Do	8/30/60		1	575	2.5	.17	.06	.10	.02	.34	.02	.00	.01	.00	28	12	0	41	6.6
NF Payette River at McCall, Idaho	2/11/59		1	128	6.3	.10	.02	.04	.01	.20	.01	.00	.01	.00	18	6	0	18	6.6
Do	8/30/60		1	248	6.2	.10	.01	.05	.01	.20	.00	.00	.00	.00	22	6	0	21	6.7
NF Payette River above SF Payette River near Banks, Idaho	8/23/56		1		6.2	.22	.04	.09	.02	.20		.01		.07	37	13	3	42	6.1
Do	7/22/58		1					.11		.33						11	0	34	6.4
Do	2/11/59		1		9.6	.20	.03	.12	.03	.36	.02	.00	.02	.01	36	12	0	43	6.7
Payette River at Black Canyon Dam near Emmett, Idaho	3/29/48–10/7/49	D	†27	3,445		.43	.23	.18	.11	.66	.17	.14			[3] 68	33	0		
Do	10/1/58–9/30/59	D	27	2,348	13	.37	.07	.17	.02	.56	.04	.01	.03	.01	49	22	0	63	
Payette River at Horse Shoe Bend, Idaho	8/23/56		1	3,600	6.0	.30	.03	.11	.02	.43		.01		.00	36	17	0	49	6.7
Do	7/22/58		1	3,620	8.2	.25	.05	.11	.02	.41	.02	.01	.02	.01	35	15	0	43	6.8
Do	2/11/59		1	1,500	14	.40	.10	.20	.02	.64	.04	.00	.03	.00	54	25	0	70	7.2
Payette River near Payette, Idaho	12/10/48		1	1,200	12	.90	.29			1.54	.31	.14		.01	119	59	0	184	
Do	10/20/50		1	1,660	15					1.10	.18	.08		.02		36	0	136	7.0
Do	7/22/58		1	1,470	19	.80	.28	.87	.05	1.62	.23	.13	.03	.02	126	54	0	191	7.4
Do	2/12/59		1	1,800	18	.65	.23	.57	.04	1.15	.18	.07	.03	.01	99	44	0	146	7.6
SF Payette River near Banks, Idaho	8/23/56		1	1,900	10	.39	.02	.15	.02	.49		.02		.01	41	21	0	60	6.8
Do	7/23/58		1	1,150				.19		.62						24	0	67	7.2
Do	2/11/59		1	700	18	.60	.01	.27	.02	.82	.06	.01	.11	.00	66	30	0	94	7.2
Squaw Creek near Sweet, Idaho	7/22/58		1					.37		1.74						76	0	168	7.4
PORTNEUF RIVER BASIN																			
Marsh Creek near McCammon, Idaho	8/29/59		1	53				2.52		6.74		1.47			560	350	13	897	8.0
Do	4/24/60		1	66	35	3.39	2.26	1.91	.17	5.26	.94	1.44	.02	.03	444	282	20	716	8.1
Portneuf River near Chesterfield, Idaho	8/29/59		1					.52		3.80		.37				217	27	451	8.2
Do	4/23/60		1		17	3.49	2.22	.61	.13	[15] 5.19	.79	.45	.02	.01	349	286	26	571	8.4
Portneuf River near Pocatello, Idaho	4/24/60	H	1	359	22	3.19	2.02	1.17	.15	4.79	.71	.85	.01	.05	358	260	21	604	7.8
Do	8/3/60	L	1	61	25	2.74	2.51	1.70	.20	4.97	.81	1.18	.02	.04	396	262	14	642	8.2
Portneuf River near Portneuf, Idaho	8/29/59	L	1		34	3.49	2.56	2.18	.26	[12] 6.05	.98	1.35	.02	.02	473	302	0	756	8.3
Do	4/24/60	H	1		24	3.39	1.82	1.22	.16	4.95	.71	.87	.01	.04	360	260	13	605	8.2
Portneuf River at Topaz, Idaho	5/16/48–10/3/49	D	†23	239		3.32	2.58	1.21	.47	[23] 5.72	.86	1.00			[3] 413	295	9		
Rabbit Creek at Inkom, Idaho	8/29/59	L	1					.44		2.66		.31				136	3	296	7.6
Do	4/23/60	H	1		11	.80	.34	.23	.02	1.10	.14	.14	.01	.02	90	57	2	138	7.3
POWDER RIVER BASIN																			
Eagle Creek near New Bridge, Oreg	3/8/60–9/27/60	P	5		15	.91	.14	.11	.03	1.09	.08	.02	.00	.01	78	52	0	118	
Pine Creek near Wingville, Oreg	11/46–6/47	P	*5			1.02	.19	.20	.01	1.15	.23	.08			[3] 88	60	3	127	
Powder River above Baker, Oreg	11/46–9/47	P	*8			.82	.57	.48	.02	1.62	.24	.05			[3] 127	70	0	160	
Powder River below Baker, Oreg	8/25/60–7/25/61	M	11		20	1.03	.52	.71	.09	[24] 1.79	.31	.17	.01	.04	153	78	0	228	
Powder River at Haines, Oreg	11/46–9/47	P	*8			1.49	.70	1.08	.05	2.58	.29	.11			[3] 206	110	0	249	
Powder River near Richland, Oreg	11/16/59–9/27/60	M	11		25	.94	.40	.77	.08	1.82	.27	.07	.01	.01	152	68	0	203	
Powder River at Sumpter, Oreg	9/17/59	L	1		16	.80	.33	.14	.04	.75	.58	.00	.01	.00	94	56	19	140	7.6
Do	4/ 6/60	H	1		17	.35	.11	.10	.02	.44	.17	.01	.01	.00	52	23	1	75	7.2
RAFT RIVER BASIN																			
Cassia Creek at Malta, Idaho	4/25/60		1		23	1.50	.45	.78	.08	2.08	.20	.51	.03	.00	176	98	0	278	7.1
Do	8/ 2/60		1		41	3.49	.50	2.91	1.43	1.03	.31	6.15	.09	([25])	745	200	148	815	4.7
Raft River near Almo, Idaho	8/ 2/60		1		27	2.99	1.20	1.57	.10	2.36	.58	2.96	.00	.00	367	210	92	618	8.2

Raft River near Bridge, Idaho	9/ 1/59	...	1	3.8	...	...	7.40	...	...	1.98	...	5.58	...	...	900	128	29	1,460	8.1
Do	4/25/60	...	1	11	32	4.89	1.30	3.00	.15	3.41	1.12	4.85	.02	.00	569	310	139	968	8.2
Raft River near Rupert, Idaho	7/23/58	...	1	...	49	3.99	3.30	7.09	.49	6.67	1.81	6.32	.03	.05	872	365	31	1,430	8.1
Do	9/ 1/59	...	1	...	...	...	...	6.70	...	7.15	...	9.64	...	...	...	338	0	1,400	7.8
Do	4/24/60	...	1	...	61	3.84	3.15	6.79	.49	6.52	1.92	5.78	.03	.05	846	350	24	1,410	8.2
Do	8/ 5/60	...	1	...	46	3.14	3.25	8.66	.74	6.36	1.77	7.61	.03	.05	974	320	2	1,560	8.1
ROCK CREEK BASIN (POWER COUNTY)																			
Rock Creek at Rockland, Idaho	8/ 3/60	...	1	...	49	4.09	2.86	1.26	.36	6.42	.44	1.41	.01	.07	489	348	26	766	7.9
ROCK CREEK BASIN (TWIN FALLS COUNTY)																			
Rock Creek near Rock Creek, Idaho	6/10/58	...	*1	46	...	.66	.18	.22	.12	.91	.08	.05	...	.00	93	42	0	...	7.6
Do	7/23/58	...	1	12	34	2.20	.96	.70	.16	2.75	.67	.39	.03	.09	248	158	20	374	7.6
SALMON FALLS CREEK BASIN																			
Cedar Creek near Rogerson, Idaho	4/25/60	...	1	...	30	.25	.09	.19	.06	.41	.06	.03	.01	.05	73	17	0	62	7.3
House Creek near Rogerson, Idaho	4/25/60	...	1	...	30	.30	.06	.22	.08	.52	.07	.03	.01	.02	77	18	0	70	7.4
Salmon Creek Falls near Buhl, Idaho	11/11/51	...	1	...	62	4.89	2.88	...	...	4.52	4.50	2.14	...	.16	...	388	162	1,040	...
Do	6/ 2/52	...	1	...	...	4.14	1.89	...	...	3.65	3.41	1.55	...	.10	...	302	119	840	...
Do	6/27/57	...	1	...	...	4.14	2.14	2.87	.24	4.10	...	...	...	...	...	314	109	879	8.1
Do	9/ 2/59	...	1	...	40	3.89	2.22	2.74	.24	4.16	3.44	1.52	.05	.10	568	306	98	864	8.2
Do	4/25/60	...	1	...	39	3.99	1.96	2.61	.22	4.03	3.10	1.52	.06	.11	559	298	96	559	8.2
Salmon Falls Creek near Contact, Nev	4/25/60	H	1	202	33	.65	.18	.30	.10	1.00	.14	.08	.02	.00	108	42	0	123	7.5
Do	8/ 2/60	L	1	28	45	1.30	.52	.65	.20	[1]2.20	.27	.16	.02	.00	193	91	0	243	8.4
SALMON RIVER BASIN																			
Lemhi River near Lemhi, Idaho	8/28/59	...	1	133	27	3.39	1.82	1.17	.11	[15]4.76	1.27	.45	.02	.00	370	260	22	582	8.4
Do	4/21/60	...	1	289	20	2.10	1.64	.61	.07	[11]3.42	.65	.37	.01	.00	243	187	16	402	8.7
Little Salmon River at Riggins, Idaho	8/24/56	...	1	...	14	1.15	.33	.17	.03	1.33	...	.01	...	.00	103	74	8	163	7.3
Do	7/22/58	...	1	380	16	.90	.26	.15	.03	1.13	.20	.01	.01	.01	86	58	2	128	7.6
Do	8/27/59	L	1	223	16	1.10	.22	.19	.05	1.28	.27	.01	.01	.00	98	66	2	154	8.2
Do	4/19/60	H	1	1,720	20	.47	.17	.15	.02	.74	.09	.01	.01	.00	67	32	0	80	8.0
Pahsimeroi River near May, Idaho	8/28/59	...	1	...	20	2.35	1.27	.48	.06	3.47	.42	.21	.01	.01	232	181	8	382	8.2
Do	4/21/60	...	1	...	16	1.90	1.14	.37	.03	[1]2.87	.33	.20	.01	.02	181	152	8	311	8.4
Salmon River at Carmen, Idaho	8/31/60	...	1	...	18	2.15	.89	.87	.06	3.05	.69	.20	.03	.00	241	152	0	364	8.0
Salmon River above Stanley, Idaho	8/31/60	...	1	...	17	1.35	.18	.22	.01	1.62	.10	.02	.05	.00	113	76	0	170	7.6
Salmon River near White Bird, Idaho	11/4/58–9/28/59.	M	10	...	14	.86	.28	.30	.03	1.15	.20	.05	.02	.00	91	57	0	139	...
SF Salmon River near Knox, Idaho	8/27/59	...	1	49	17	.22	.02	.27	.02	.46	.04	.01	.05	.00	48	12	0	55	7.3
Do	8/30/60	...	1	45	19	.22	.04	.27	.01	.46	.05	.03	.05	.00	47	13	0	55	7.3
Valley Creek at Stanley, Idaho	10/1/58–9/30/59.	D	24	194	11	.40	.04	.12	.02	.52	.04	.01	.03	.00	43	22	0	57	...
SALT RIVER BASIN																			
Salt River near Alpine, Wyo	8/29/59	L	1	558	7.8	3.09	1.50	.41	.05	4.06	.67	.28	.00	.05	271	230	26	460	7.6
Do	4/22/60	H	1	851	8.4	2.84	1.03	.61	.03	3.51	.52	.48	.01	.04	247	194	18	437	8.0
Salt River near Smoot, Wyo	8/29/59	...	1	...	7.0	2.64	.95	.17	.03	[12]3.01	.73	.03	.01	.00	211	180	29	341	8.3
Do	4/23/60	...	1	...	6.9	2.35	.67	.11	.02	2.64	.46	.01	.01	.00	174	151	19	297	8.0
SNAKE RIVER MAIN STEM																			
Snake River at Central Ferry, Wash	10/1/55–9/30/56.	D	27	66,750	18	.90	.44	.57	.06	1.31	.42	.20	.02	.02	131	67	2	194	...
Do	10/1/56–9/30/57.	D	23	58,980	...	.95	.49	.65	...	1.44	.48	.22	...	.02	141	72	0	214	...
Do	10/1/57–7/16/58.	D	15	59,640	...	.95	.47	.65	...	1.39	.46	.21	...	.02	136	71	2	206	...
Snake River near Heise, Idaho	1/8/53–9/30/53.	D	24	7,736	12	2.35	.90	.44	.05	2.56	.83	.28	.02	.02	211	162	34	351	...
Do	10/1/53–9/30/54.	D	36	6,898	11	2.30	.99	.43	.05	2.56	.85	.28	.02	.01	214	164	36	352	...
Do	10/1/54–9/30/55.	D	36	5,651	14	2.40	.99	.48	.05	2.56	.98	.31	...	.02	225	169	41	368	...
Do	10/1/55–9/30/56.	D	36	8,985	12	2.30	.90	.40	.05	2.54	.73	.24	...	.02	206	160	33	340	...
Do	10/1/56–9/30/57.	D	36	6,424	10	2.44	.90	.44	.05	2.66	.85	.28	...	.02	219	168	35	362	...
Do	10/1/57–9/30/58.	D	13	6,007	9.3	2.45	.99	.44	.05	2.69	.92	.23	...	.02	224	172	38	375	...
Do	10/1/58–9/30/59.	D	12	6,142	8.6	2.50	.90	.48	.05	2.69	.90	.31	...	.01	220	170	36	371	...
Do	10/1/59–9/30/60.	D	24	6,091	...	...	...	.48	...	2.66	...	...	...	...	223	170	37	373	...

See footnotes at end of table.

TABLE 1.—*Representative analyses of surface waters of the Snake River Basin*—Continued

[Sampling frequency: D, daily; M, monthly; P, periodic; H, high flow; L, low flow. Number of samples: Analyses by U.S. Geol. Survey except as indicated by asterisk (U.S. Bur. Reclamation) and by dagger (Idaho Univ. Agr. Expt. Sta.)]

Location	Sampling period	Sampling frequency	Number of samples	Discharge (cfs)	Silica (SiO_2) (ppm)	Equivalents per million: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Parts per million: Dissolved solids (residue on evaporation at 180° C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH
SNAKE RIVER MAIN STEM—Con.																			
Snake River at King Hill, Idaho	3/27/51–9/30/51	D	19	11,920	31	2.35	1.56	1.30	0.16	3.39	1.06	0.68	0.03	0.05	310	196	26	491	------
Do	10/ 1/51–9/30/52	D	36	13,900	31	2.30	1.56	1.26	.12	3.41	1.04	.68	.03	.05	309	193	22	486	------
Do	10/ 1/52–9/30/53	D	32	10,330	34	2.35	1.73	1.43	.11	3.51	1.19	.79	------	.05	330	204	28	525	------
Do	10/ 1/53–9/30/54	D	34	9,400	35	2.35	1.73	1.48	.11	3.59	1.21	.79	------	.05	334	204	24	531	------
Do	10/ 1/54–9/30/55	D	35	9,455	36	2.35	1.64	1.44	.11	3.54	1.17	.76	------	.05	334	200	23	527	------
Do	10/ 1/55–9/30/56	D	34	11,800	------	2.35	1.56	1.35	------	3.46	1.10	.68	------	.04	318	196	23	506	------
Do	10/ 1/56–9/30/57	D	13	11,140	------	2.40	1.56	1.35	------	3.47	1.12	.68	------	.05	317	198	24	511	------
Do	10/ 1/57–9/30/58	D	15	9,772	------	2.50	1.56	1.39	------	3.51	1.15	.70	------	.05	325	203	28	515	------
Do	10/ 1/58–9/30/59	D	21	8,655	------	------	------	1.44	------	3.57	------	------	------	------	332	204	25	525	------
Do	10/ 1/59–9/30/60	D	20	8,368	------	------	------	1.44	------	[5] 3.54	------	------	------	------	327	197	20	520	------
Snake River at Marsing, Idaho	3/29/48–9/30/49	D	†26	------	------	2.11	1.55	1.49	.26	[26] 3.23	1.23	.92	------	------	[3] 331	183	22	------	------
Snake River at Minidoka Dam near Rupert, Idaho	4/26/48–10/ 6/49	D	†26	9,322	------	2.27	1.31	.87	.27	[18] 3.01	.93	.77	------	------	[3] 262	183	28	------	------
Snake River near Moran, Wyo	8/30/59	------	1	2,760	------	------	------	.44	------	1.03	------	.17	------	------	------	47	0	150	7.8
Do	4/23/60	------	1	186	17	.80	.19	.57	.05	1.13	.23	.19	.05	.00	108	50	0	174	7.8
Snake River near Pasco, Wash	7/28/60–6/26/61	M	12	------	19	1.09	.66	.90	.06	1.78	.61	.29	.02	.02	171	88	0	266	------
Snake River at Weiser, Idaho	8/25/60–7/25/61	M	12	------	27	2.03	1.36	1.99	.12	3.30	1.40	.66	.04	.04	335	170	4	526	------
Snake River at Yellowstone Park Boundary, Wyo	8/ 4/60	------	1	------	32	1.00	.38	1.26	.12	[4] 1.56	.69	.48	.09	.00	200	69	0	284	8.3
Do	8/30/61	------	1	------	33	1.10	.29	1.30	.12	1.57	.73	.48	.11	.01	198	70	0	293	7.5
TUCANNON RIVER BASIN																			
Tucannon River near Delaney, Wash	7/30/59–6/21/60	M	12	------	37	.43	.26	.12	.05	.84	.02	.01	.01	.00	.82	34	0	87	------
WEISER RIVER BASIN																			
Crane Creek near Weiser, Idaho	2/10/59	------	1	8.2	48	1.15	.91	.83	.16	2.36	.33	.20	.02	.01	208	103	0	286	8.1
Do	4/27/59	------	1	6	34	1.15	.95	.91	.16	2.31	.40	.28	.02	.00	202	105	0	296	7.6
Little Weiser River near Indian Valley, Idaho	2/10/59	------	1	------	28	.55	.38	.15	.03	1.05	.03	.01	.01	.00	80	46	0	107	7.6
Do	4/27/59	------	1	------	26	.40	.22	.13	.03	.77	.02	.01	.01	.01	65	31	0	80	7.1
MF Weiser River near Council, Idaho	7/22/58	------	1	------	------	------	------	.22	------	.85	------	------	------	------	------	34	0	87	7.1
Do	2/11/59	------	1	------	26	.45	.29	.23	.03	.90	.08	.03	.01	.00	73	37	0	98	7.4
Pine Creek near Cambridge, Idaho	2/11/59	L	1	16	30	.70	.29	.18	.04	1.20	.03	.01	.01	.01	95	50	0	125	7.2
Do	4/27/59	H	1	42	29	.60	.20	.16	.05	1.00	.02	.01	.01	.00	84	40	0	101	7.6
Weiser River near Cambridge, Idaho	4/ 6/58	H	*1	1,530	------	.88	.33	.20	.06	1.28	.02	.01	------	.00	------	60	0	------	8.1
Do	7/22/58	L	1	134	27	.65	.17	.28	.05	1.00	.09	.05	.00	.00	85	41	0	106	7.6
Do	2/11/59	L	1	285	28	.50	.31	.26	.03	.95	.10	.04	.01	.02	84	40	0	109	7.5
Do	4/27/59	H	1	1,640	25	.37	.14	.14	.03	.67	.03	.00	.02	.00	68	26	0	71	7.3
Weiser River at Tamarack, Idaho	2/11/59	L	1	16	28	.55	.35	.18	.03	1.05	.02	.00	.01	.00	82	45	0	102	7.3
Do	4/27/59	H	1	224	25	.35	.15	.12	.03	.61	.01	.04	.01	.01	61	25	0	63	7.0

Weiser River near Weiser, Idaho	5/ 7/48–10/ 4/48	D	†10	1,151		.67	.47	.28	.16	1.14	.17	.25			[3] 100	57	0		
Do	6/ 8/49–10/10/49	D	†8	162		.63	.57	.35	.10	1.35	.22	.12			[3] 114	60	0		
Do	11/12/58–9/29/59	M	10		27	.58	.33	.28	.06	1.07	.08	.03	.02	.01	100	46	0	119	
WILLOW CREEK BASIN																			
Willow Creek near Ozone, Idaho	8/28/57		1		22	2.30	1.15	.52	.05	3.48	.21	.28	.02	.01	221	172	0	369	8.1
Wiiiow Creek near Ririe, Idaho	7/23/58	P	1		10	2.15	.97	.32	.04	2.47	.67	.17	.02	.01	186	156	32	317	7.8
Do	4/22/60	P	1		16	2.40	.88	.32	.05	3.18	.31	.28	.01	.00	216	164	5	360	8.0

[1] Includes 0.13 epm CO_3.
[2] Includes 0.15 epm CO_3.
[3] Sum of determined constituents plus estimated silica, fluoride, and nitrate concentrations.
[4] Includes 0.10 epm CO_3.
[5] Includes 0.03 epm CO_3.
[6] Includes 0.58 epm CO_3.
[7] Includes 0.23 epm CO_3.
[8] Includes 0.26 epm CO_3.
[9] Includes 0.06 epm CO_3.
[10] Includes 0.47 epm CO_3.
[11] Includes 0.37 epm CO_3.
[12] Includes 0.17 epm CO_3.
[13] Includes 0.11 epm CO_3.
[14] Includes 0.20 epm CO_3.
[15] Includes 0.27 epm CO_3.
[16] Includes 0.07 epm CO_3.
[17] Includes 0.28 epm CO_3.
[18] Includes 0.40 epm CO_3.
[19] Includes 0.43 epm CO_3.
[20] Includes 0.50 epm CO_3.
[21] Includes 0.33 epm CO_3.
[22] Includes 0.05 epm CO_3.
[23] Includes 0.31 epm CO_3.
[24] Includes 0.02 epm CO_3.
[25] Stream pollution by milk wastes; total nitrogen as NO_3 57 ppm.
[26] Includes 0.48 epm CO_3.

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