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CHEMICAL QUALITY OF WATER AND SEDIMENTATION IN THE MOREAU RIVER DRAINAGE BASIN, SOUTH DAKOTA

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By B. R. Colby, C. H. Hembree, and E. R. Jochens

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of the Department of the Interior for
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ABSTRACT

This report gives the results of an investigation by the U. S. Geological Survey of the sediments and dissolved minerals that are transported by the Moreau River.

The Moreau River drainage basin is a narrow basin in northwestern South Dakota that covers about 5,360 square miles of rolling, grassy plains, which are broken by buttes and by some small areas of badlands. It is underlain by shales, sandstones, siltstones, and limestones that are primarily of Cretaceous age. Precipitation averages about 16 inches per year. Average annual runoff is about 0.7 inch but varies widely from year to year.

The chemical quality of the water in the Moreau River is directly related to the geology of the area. Water affected by the Hell Creek formation and Fox Hills sandstone is predominantly a sodium bicarbonate type, whereas water affected by the Pierre shale is a sodium sulfate type. In general, water from streams that drain areas underlain by the Pierre shale is more mineralized than water that drains from areas underlain by the Fox Hills sandstone. Water that drains from areas underlain by the Hell Creek formation is least mineralized.

The short-term chemical-quality records obtained during a wet climatic cycle are not representative of a long term. The average specific conductance and average percent sodium, each weighted with the water discharge and adjusted to include estimates during unsampled periods of low flow, were computed for the 3-year period at Bixby, S. Dak. The averages show that if all the water for the entire period were impounded without loss, the specific conductance would be 632 micromhos and the percent sodium would be 57. This water rates as good to permissible for irrigation. However, the estimated rating for a 21-year period is permissible to doubtful. In addition, water impounded during a dry climatic cycle would be conducive to the formation of black alkali if this water were applied to the soil. Therefore, the impounded water should be used only on land where adequate drainage facilities are provided and where infiltration rates are sufficient to provide low rates of evaporation and high rates of flushing.

Suspended sediment transported by the Moreau River is mostly fine material, principally clay sizes. Median particle sizes not weighted with water discharge averaged about 0.0016 millimeter for the stations at Bixby and near Faith.

From April 28, 1949, to September 30, 1951, the Moreau River at Bixby discharged about 175,000 acre-feet of water and about 1,080,000 tons of suspended sediment. Approximately 90 percent of the water and the suspended sediment was discharged during the water year that ended September 30, 1950. During this water year the streamflow averaged about 2½ to 3 times the normal flow. If deposited in a reservoir, the 1,080,000 tons of sediment would occupy a computed space of about 980 acre-feet soon after deposition.

From August 15, 1946, to September 30, 1949, the Moreau River near Faith discharged about 380,000 acre-feet of water and nearly 2,000,000 tons of suspended sediment. If deposited in a reservoir, the sediment would occupy a computed space of about 1,820 acre-feet soon after deposition.

INTRODUCTION

Purpose and Scope of Investigation

The investigation by the Geological Survey of chemical quality of surface waters and of sedimentation in the Moreau River drainage basin is part of the program of the Department of the Interior for the development of the Missouri River basin. The overall plan includes regulation and control of flood waters, irrigation of additional land, and production of hydroelectric power. One requirement for the planning of successful and economical projects for this overall plan is a knowledge both of the chemical quality of the surface waters and of the quantity and particle sizes of the sediment that is transported by the streams.

Successful irrigation depends not only on the type of soils, drainage, and climate but also on the chemical quality of the water to be used. Data on the chemical quality of surface water in the Moreau River basin were collected and interpreted to show the variation in the quality of the water and the changes that may be expected in the chemical quality when the water is impounded in a reservoir. In this investigation the quality and quantity of dissolved constituents in the main stream were correlated insofar as possible with geologic, climatic, hydrologic, and cultural characteristics of the drainage basin.

The samples analyzed for dissolved constituents were collected at four gaging stations that are operated by the Geological Survey. Samples were collected daily at stations at Bixby, March 1949 to September 1951, and near Faith, April 1947 to September 1949, and infrequently at stations near Faith, November 1945 to March 1947, and Eagle Butte and Promise, November 1945 to September 1951. The analyses of these samples and, in addition, the analyses of samples that were collected from major tributaries for a special salinity study are the basis for the chemical-quality discussions of this report. Dissolved solids, specific conductance, pH, silica, iron, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, fluoride, nitrate, boron, percent sodium, total hardness, and noncarbonate hardness usually were determined. For some samples sodium and potassium were calculated and reported as sodium; boron was not always determined.

The investigation of sedimentation in the Moreau River basin was undertaken to determine (1) the quantity of sediment in transport in the Moreau River, (2) the initial specific weight of the suspended sediment after deposition in a reservoir, and (3) the probable sources of the sediments. The Geological Survey operated daily sediment stations on the Moreau River near Faith from August 1946 to September 1949 and at Bixby from April 1949 to September 1951. Samples of suspended sediment were collected at these stations to be analyzed for particle size as well as for concentration of suspended sediment.

Geologic studies were made during the investigation to provide a background of information that is essential to the understanding and interpretation of the base data, both on chemical quality and on sediment. Pertinent published reports were reviewed, and a reconnaissance of the basin was made to study the rocks of the area and their relationship to the dissolved minerals and to the sediment that is transported by the streams. The sediment and dissolved solids carried by the streams in solution, in suspension, or as bed load were originally derived from the rocks that underlie the basin.

Previous Investigations

From April 1941 to May 1945, employees of the Bureau of Reclamation collected and analyzed quality-of-water samples from stations on the Moreau River. They also collected and analyzed two samples from Rabbit Creek, a tributary above the gaging station near Faith.

Measurements of suspended-sediment discharge were made by the Corps of Engineers, U. S. Army, on the Moreau River at Promise on 4 days April 13 to 16, 1931. Surface samples were obtained at Promise during the period February 8 to July 31, 1931 (Congressional documents, 1934, p. 37). 1/ Suspended-sediment records were also obtained by the Corps of Engineers from June 1947 to September 1951.

Many reports on the geology of the Moreau River basin have been published, but most of them were concerned principally with coal resources and structural geology. So far as is known, no one has used geology to assist in solving the quality-of-water and sedimentation problems of the area.

1 See p. 35 for literature cited.

Personnel and Acknowledgments

This investigation was made by the Geological Survey in cooperation with other agencies of the Department of the Interior. It was conducted by the Water Resources Division of the Geological Survey, C. G. Paulsen, chief hydraulic engineer, and S. K. Love, chief of the Quality of Water Branch, Washington, D. C., and was under the general supervision of P. C. Benedict, regional engineer, Lincoln, Nebr.

Water samples for chemical analyses and for suspended-sediment determinations were collected by employees of the Bureau of Reclamation for the station at Bixby from March 1949 to September 1951.

Chemical analyses of surface-water samples were made by personnel of the office at Lincoln, Nebr., under the supervision of H. A. Swenson.

Records of suspended-sediment discharge of the Moreau River were obtained by personnel of the office at Dickinson, N. Dak., under the supervision of E. J. Tripp.

Unpublished streamflow records were furnished by R. E. Marsh and H. M. Erskine, district engineers, Geological Survey, Bismarck, N. Dak.

An unpublished report in the open files of the Geological Survey by H. A. Swenson entitled "A progress report on the chemical character of surface waters in the Moreau River basin, South Dakota," covered the chemical-quality data that had been collected before October 1, 1947. It was used as a basis for much of the discussion of chemical quality of water in this report.

MOREAU RIVER DRAINAGE BASIN

Location and Extent

The Moreau River drainage basin is in northwestern South Dakota and covers an area of 5,360 square miles. (See fig. 1.) The drainage basin is bounded by low divides that separate it from the drainage basins of the Grand River to the north, the Cheyenne River to the south, and the Little Missouri River to the west.

The Moreau River is formed by the junction of the South Fork and the North Fork. The two forks head near the South Dakota-Montana State line and flow eastward to a junction in the southwest corner of T. 14 N., R. 11 E. From this confluence the Moreau River flows eastward to join the Missouri River in T. 16 N., R. 31 E., about 18 miles south of Mobridge. The Moreau River drainage basin is about 180 miles long.

The principal tributaries of the Moreau River are the North and South Forks, Deep Creek, Flint Rock

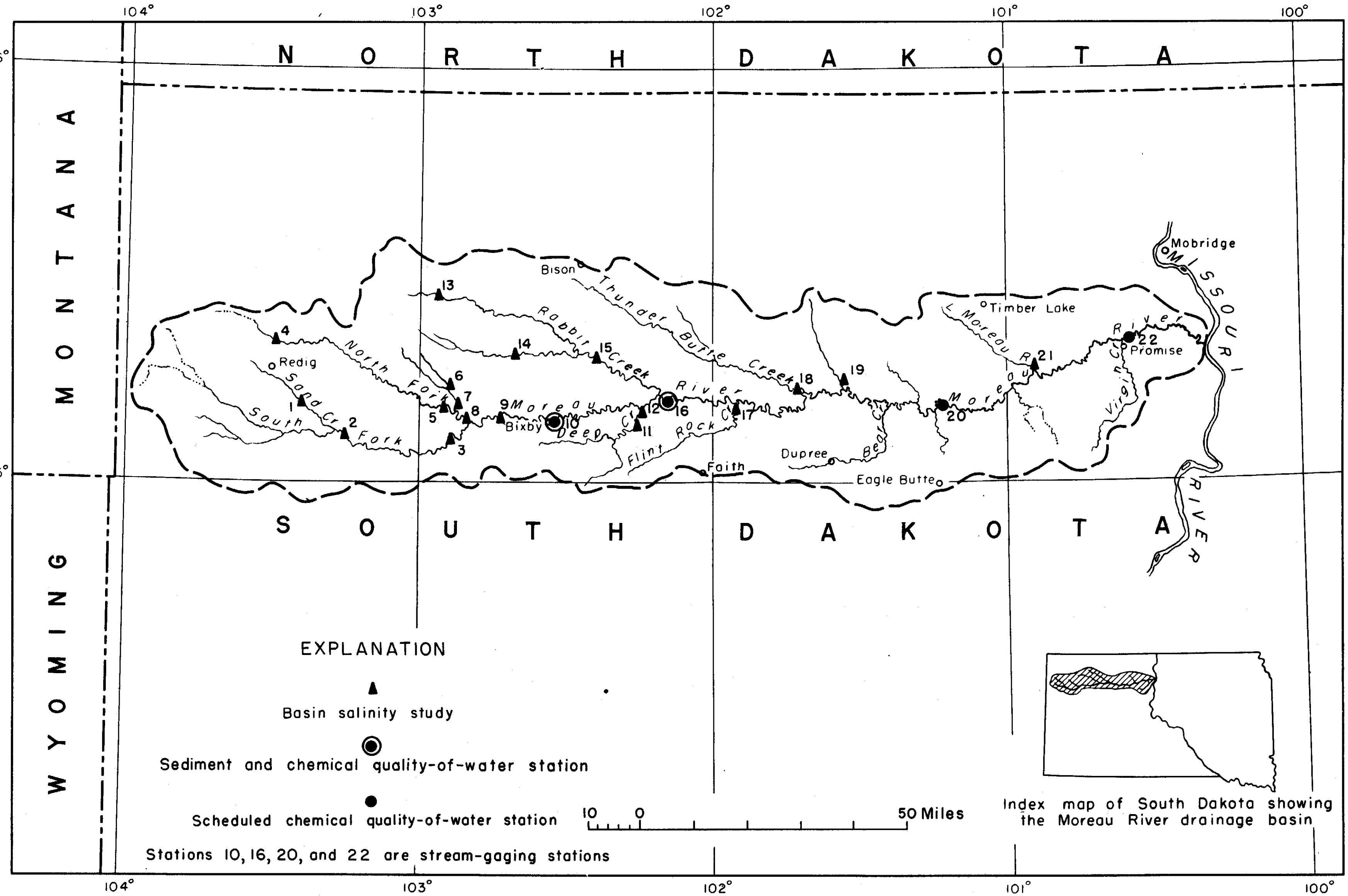


Figure 1.--Map showing location of sampling stations for chemical-quality and suspended-sediment investigations in the Moreau River drainage basin, South Dakota.

Creek, Rabbit Creek, Thunder Butte Creek, Bear Creek, and the Little Moreau River.

Topography

The Moreau River drainage basin is a part of the Missouri Plateau division of the Great Plains province. The general topography of the area is shown by figure 2. The basin is an area of rolling plains partly dissected by streams and broken in places by buttes and badlands. (See fig. 3.) Most of the badlands and associated buttes are in the western half of the basin. The stream valleys in this part of the basin are well below the general level of the land, but they do not have the canyonlike proportions of stream valleys in the eastern part.

In general, the valleys are narrow and have a series of terraces that rise stairlike from the present flood plain up to and blend into the uplands. The stream channels, except where they impinge against high terraces, have low but steep banks. Like the valleys in which they flow, the streams have a meandering pattern. (See fig. 4.) Parts of the lowlands along the streams are used for growing hay, but most of the land of the stream valleys and the rolling uplands is used for grazing. Some small grains are grown in the eastern part of the basin.

Buttes, which rise sharply from the plains, are scattered throughout the basin but are most numerous in the western part. They are so numerous in one county that it is called Butte County. The buttes were formed by weathering and erosion of sedimentary strata that have different degrees of resistance to erosion. The relatively soft rock beneath a more resistant cap rock erodes rapidly and produces the flat-topped hills with clifflike sides. Debris from the undermined cap rock forms a border of rubble at the base of the buttes or lies temporarily on the side slopes.

Badlands are not extensively developed and occupy only a small part of the basin. Gumbo-producing shales, the most abundant rocks in the area, erode into rounded hills rather than into badlands. The badlands are associated principally with the buttes, but minor areas of badlands are found along the deeper stream valleys and at the heads of the tributaries. These tributaries head along the divides that separate the Moreau River drainage basin from basins to the north and to the south.

Climate

The Moreau River basin, owing to a small range in altitude (about 1,500 to 3,500 feet) and to the east-west orientation of the basin, has a fairly uniform climate. Average annual precipitation and temperature increase slightly from west to east. (See fig. 5.) The annual precipitation for the entire area averages about 16 inches and the temperature about 44.8°F.

The climate of the basin is semiarid and is characterized by low precipitation. Summers are hot, and winters are cold. The temperature ranges from about -35° to 115°F. Annual snowfall of the basin averages about 36 inches, which is equivalent to approximately 3.6 inches of precipitation or a little more than one-fifth of the average annual precipitation. Runoff from the basin is low, about 0.7 inch per year.

Soils and Vegetation

The soils in the Moreau River drainage basin belong to one broad soil group, the Chestnut group. All the soils are similar except in texture, because the climate and geology are generally uniform throughout the basin.

Most of the basin is underlain by rocks of Cretaceous age--the Pierre shale, Fox Hills sandstone, and Hell Creek formation. (See fig. 6.)

Soils derived from the Pierre shale in the western part of the basin are known locally as black gumbo and have been classed as Pierre clay in an unpublished report of the Bureau of Land Management. The soils developed on the Pierre shale in the eastern part of the basin have been classed as the Boyd series. The surface of these soils is dark brown to dark olive brown. Both the Boyd series and the Pierre clay are shallow, immature residual soils. The unaltered or partly weathered shale is usually within 3 feet of the surface of level land and is much closer under sloping surfaces. The shallowness and immaturity of soils on the Pierre shale are due more to the imperviousness of the parent rock rather than to erosion or any other cause. Soils overlying the Pierre shale absorb water slowly and are readily eroded on the steeper slopes.

Soils developed from the Fox Hills sandstone and Hell Creek formation belong to the Morton series and cover about half the basin. These soils have a 4- or 5-inch surface layer of dark-brown friable loam or silt loam. Because they absorb and hold water, they sustain a dense stand of vegetation on the more level surfaces.

Grassland is typical of the entire drainage basin. Cottonwoods and some boxelder, ash, buffaloberry, chokeberry, and other small trees grow along the streams. Juniper and pine are confined mainly to the buttes. The most common grasses are gramagrass, wheatgrass, buffalograss, bluegrass, niggerwool, green needlegrass, and needle-and-thread grass. Sagebrush grows only in a few small areas.

GENERAL GEOLOGY OF THE MOREAU RIVER DRAINAGE BASIN

The Moreau River drainage basin is underlain by sedimentary rocks, such as shales, sandstones, siltstones, and limestones. (See fig. 6.) Only rocks of Cretaceous and Tertiary age are exposed at the surface; rocks that represent nearly all periods of the Paleozoic and Mesozoic eras are below the surface.

The area now drained by the Moreau River and its tributaries was once the scene of alternate encroachment and retreat of great inland or epicontinental seas. Erosion was active during periods of emergence but gave way to deposition as the seas advanced. Logs of deep wells and measurements of outcrops in and on the flanks of the Black Hills indicate that several thousand feet of sedimentary material was deposited over

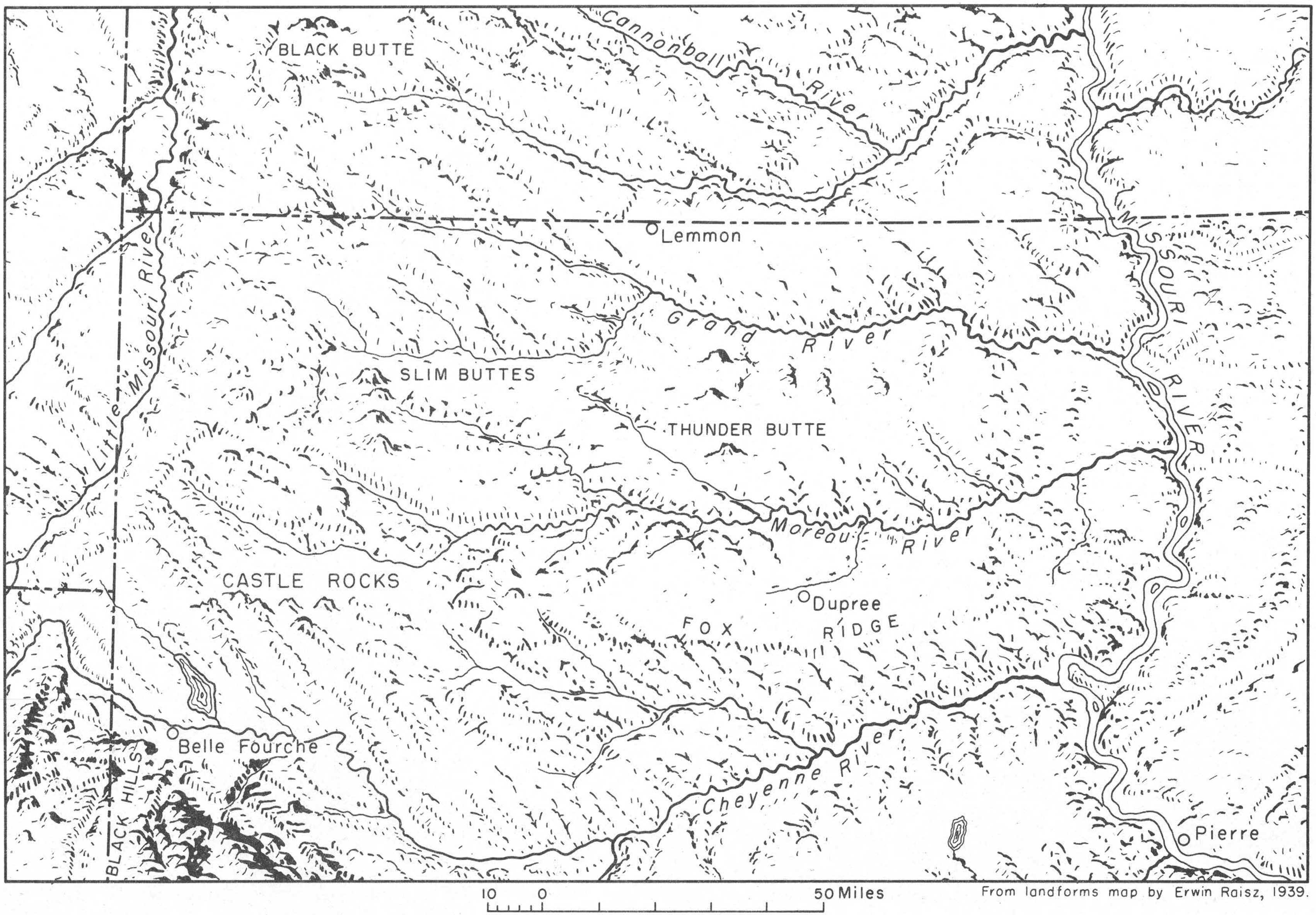


Figure 2. --Map of the landforms of the Moreau River drainage basin of South Dakota and surrounding areas.

Figure 3.--Badlands near Fox Ridge, S. Dak. Note the small area of badlands and, in the background, the rolling plains and buttes.

Figure 4.--Moreau River near Dupree, S. Dak. In the background the meandering channel is indicated by scattered trees.

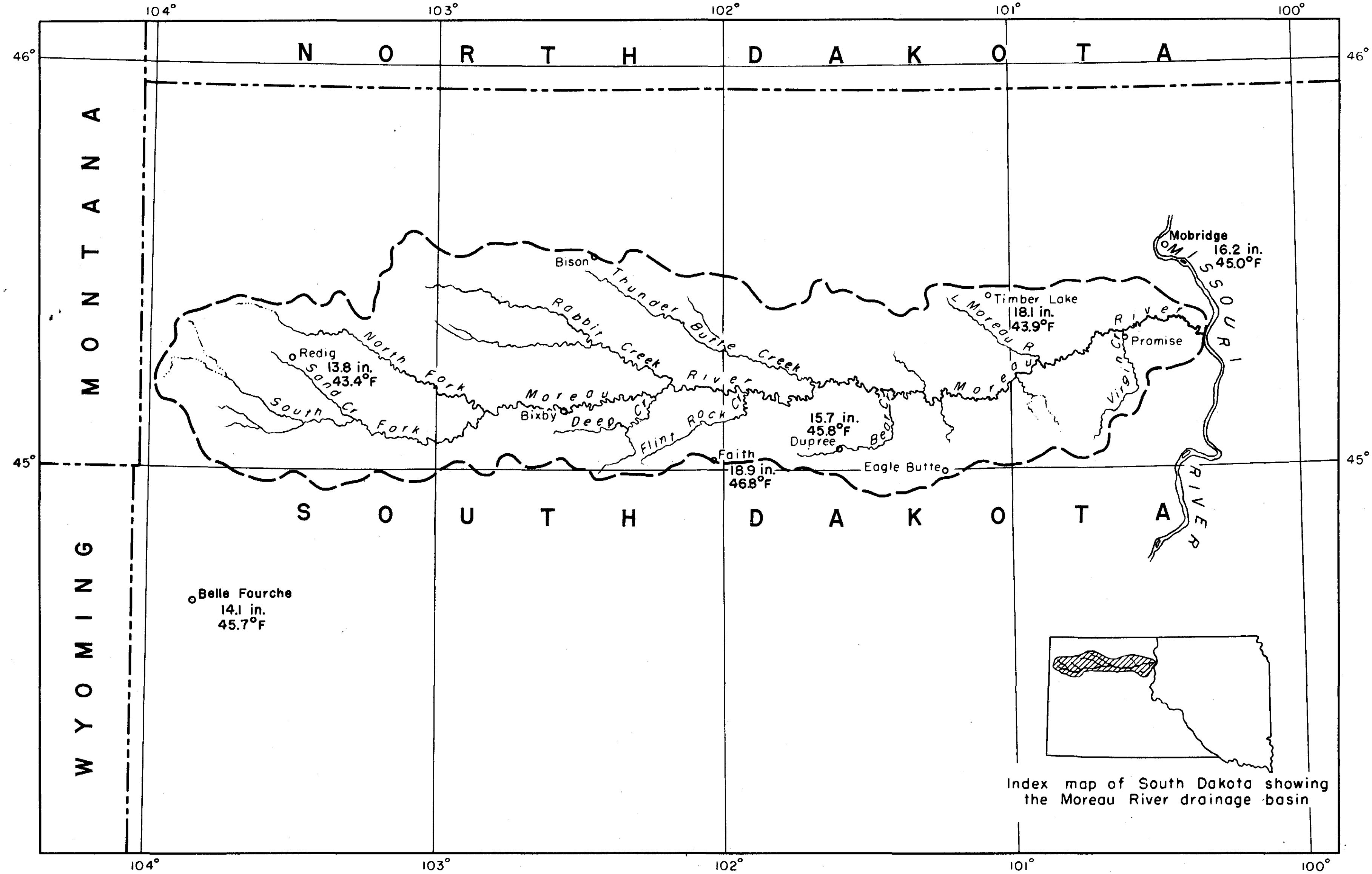


Figure 5.--Map showing average temperature and average annual precipitation in and near the Moreau River drainage basin, South Dakota.

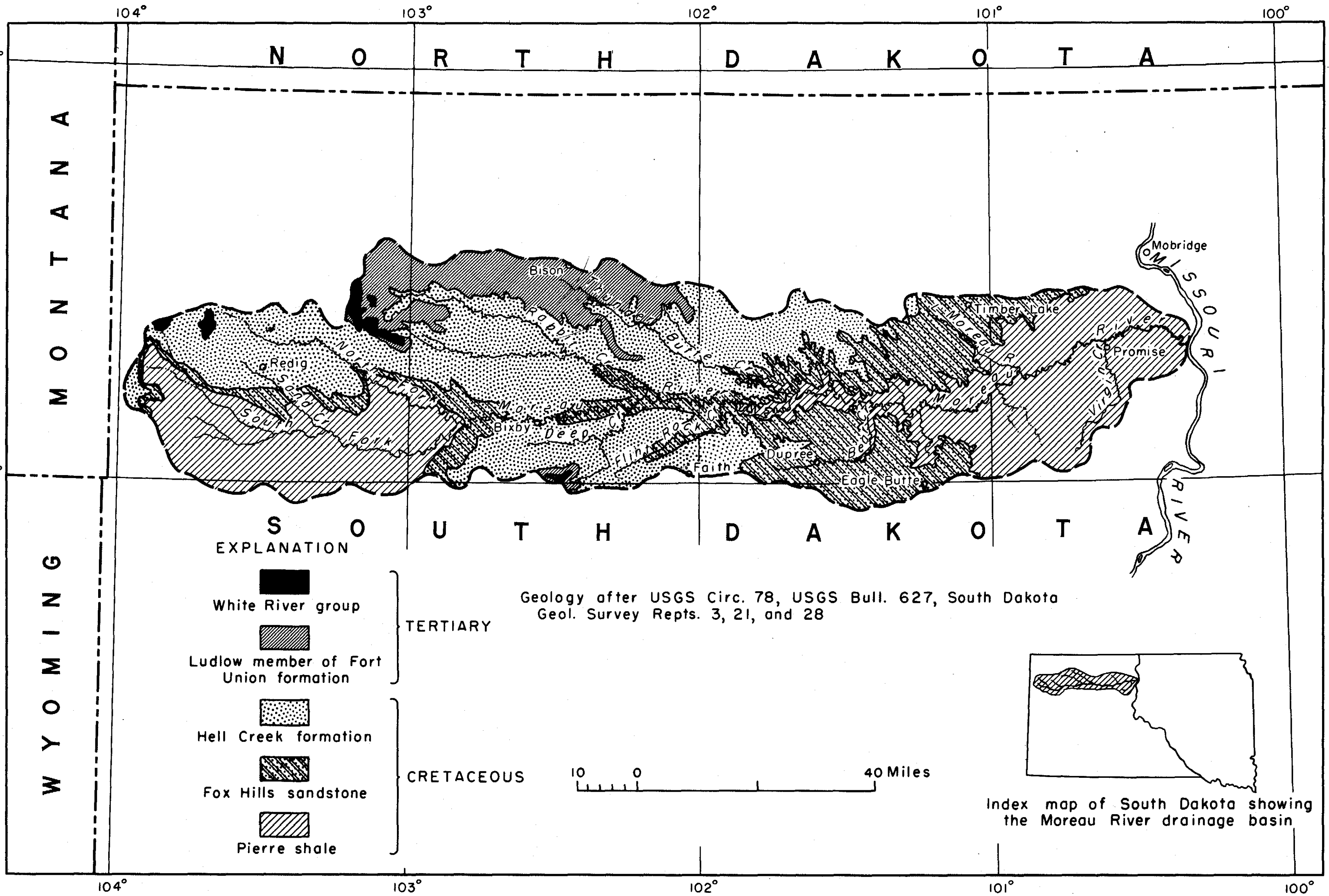


Figure 6.--Geologic map of the Moreau River drainage basin, South Dakota.

the region during the Paleozoic and Mesozoic eras (Rothrock and Robinson, 1938, p. 4-28).

The rocks of the Pierre shale are the oldest exposed in the drainage basin. The material composing them was deposited in the great inland sea that covered South Dakota, as well as most of central North America, during the Cretaceous period. The Pierre shale was formed from fine particles that were carried to the sea by the streams, carbonates that were precipitated when the fresh waters of the rivers mingled with the saline waters of the sea, and volcanic dust. The Pierre shale consists principally of very dark gray to black clays and shales. Beds of marl and impure chalk, as well as calcareous and gypsiferous concretions, are in the formation. Bentonite, an alteration product of volcanic dust, is characteristic of the Pierre shale. It occurs in thin beds and is interspersed in the shale itself.

As the Cretaceous sea slowly retreated from the land, near-shore deposits of sand and sandy clay were laid down over the clays of the Pierre shale. These near-shore deposits became the brown to yellow sandstones and sandy shales of the Fox Hills sandstone. In some exposures of the contact of the two formations, a distinct difference in the color and lithology can be seen between the top of the Pierre shale and the bottom of the Fox Hills sandstone. However, in other exposures the change is gradual from the dark-gray shale of the Pierre shale to the well-cemented sandstone of the Fox Hills sandstone.

After the deposition of the near-shore deposits of the Fox Hills sandstone, the land was elevated above the sea long enough for 200 to 300 feet of continental sediments to be deposited. The continental deposits consist of alternating strata of sandstone, shale, bentonite, and thin beds of coal. Plant fragments, coal, land vertebrate remains, and the lack of continuity of the beds indicate the continental origin of these deposits, which have been grouped together under the name Hell Creek formation.

During the Paleocene epoch of the Tertiary period the seas covered part of the Moreau River basin. Marine deposits in the eastern part of the basin were laid down contemporaneously with continental deposits in the western part of the basin. The Cannonball formation consists of material that was deposited in the sea, and the Ludlow member of the Fort Union formation is composed of continental deposits. All the Cannonball formation has been removed from the basin by erosion but is still present farther north. Only a small area of the Ludlow member still remains. This member consists of sandstone, shale, coal, and clay and can be distinguished from the underlying Hell Creek formation mainly by color. The Ludlow member is characteristically yellowish, whereas the Hell Creek formation is dull brown to gray.

Small remnants of the White River group of Oligocene age remain on the tops of several buttes in the western part of the basin. Rocks younger than the Ludlow member and older than the White River group probably were originally present over much of this area, but they were eroded away before the deposition of the White River group. The Chadron formation, which is the basal formation of the White River group, consists of gravels, sandstone, clay, and silt and is a buff color. The overlying Brule clay is composed of silt, clay, volcanic ash, and minor amounts of sandstone.

Rocks of Miocene and Pliocene age probably were once present in the area but have been removed by post-Pliocene erosion.

Although the Moreau River basin was profoundly affected by Pleistocene glaciation, it was not covered by continental glaciers except in the extreme eastern part. Scattered erratic boulders along the lower reaches of the Moreau River are probably residuals left by erosion of drift.

Before Pleistocene glaciation the Missouri River did not flow through South Dakota. In pre-Pleistocene time the present Moreau, Grand, and Cheyenne Rivers were the headwaters of the Red River of the North, which then, as now, flowed into the Husdon Bay (Petsch, 1946, p. 8). During the Pleistocene epoch the Moreau River and other streams parallel to it were blocked by the Kansan or Nebraskan ice sheets or both. The combined flow of these streams was diverted to the southeast along the front of the ice sheet and eroded the present channel of the Missouri River. The diversion of the Moreau River radically changed its gradient and caused rapid downcutting, especially in the lower reaches.

Recent alluvial deposits are present along all streams in the drainage basin. Their lateral extent and depth depend on several variable factors, such as the relative erodibility of the rocks in the uplands, the area of the drainage basin, and the runoff. Recent alluvial deposits are probably the largest immediate source of sediment in the Moreau River basin. The depth and lateral extent of these deposits are partly dependent on the supply of material from the consolidated rocks. Therefore, areas of high sediment yield are directly related to areas of exposed rocks that have relatively low resistance to erosion.

PHYSICAL CHARACTERISTICS OF STREAMS

Among the factors controlling the characteristics of a drainage area are climate, topography, and the rocks that underlie the area. The interaction of these and other factors determines the characteristics of the stream. The environmental factors are interdependent. That is, if the environmental factors of two drainage areas are identical at the beginning of an erosion cycle, the soils, vegetation, and topography of the two areas will be similar at the end of a given time provided the climate does not change. If, however, the rocks of the two areas are different and the climate is the same, the vegetation and topography will gradually become dissimilar in the two areas. For example, the climate of the Moreau River basin and the climate of the lower part of the White River basin are much alike, yet badlands are characteristic of the White River basin and rolling hills are typical of the Moreau River basin. The different types of rocks that underlie the two basins account for this difference in topography.

Moreau River

The Moreau River is formed by the junction of its North and South Forks in the southeast corner of T. 14 N., R. 11 E. It falls about 4 feet per mile as it flows eastward to join the Missouri River at a point about 18 miles south of Mobridge. From the junction of its forks to T. 19 E., R. 14 N., northwest of Dupree, the river flows successively over outcrop areas of the Pierre shale, Fox Hills sandstone, Hell Creek formation, and again over an outcrop area of the Fox Hills sandstone. For most of the distance it flows over the outcrop area of the Fox Hills sandstone. After leaving the outcrop area of the Fox Hills sandstone, the river flows to the Missouri River over an area underlain by the Pierre shale. East of T. 19 E., in the section underlain by Pierre shale, the Moreau River has cut a meandering valley 200 to 300 feet below the uplands.

Although the suspended-sediment load that is transported by the Moreau River is composed almost entirely of particles of clay and silt sizes, most of the bed material is sand size or larger. The velocity of the stream may be sufficient to prevent deposition of the smaller particles, but probably the dissolved mineral characteristics of the stream are also a factor. The effect of sodium in preventing flocculation, together with the capacity of the stream to transport clay- and silt-size particles, impedes the deposition of small particles on the stream bed.

South Fork Moreau River

The South Fork Moreau River rises near the South Dakota-Montana State line in T. 14 N., R. 1 E. and flows eastward to join the North Fork at a point about 6 miles northeast of Inland. The drainage basin of the South Fork is underlain by the Pierre shale except for a few areas that are underlain by the Fox Hills sandstone and the Hell Creek formation and are drained by tributaries. One of these tributaries, Sand Creek, whose upper reaches are underlain by the Hell Creek formation, has a very descriptive name. Above the junction with Sand Creek the South Fork flows between high banks of alluvium and on a bed of fine material. Below the junction with Sand Creek its bed is composed of sand and coarser material.

North Fork, Deep Creek, Rabbit Creek, Flint Rock Creek, and Thunder Butte Creek

The gumbo clays and sands of the Hell Creek formation underlie most of the drainage areas of the North Fork and Deep, Rabbit, Flint Rock, and Thunder Butte Creeks. In the upper reaches, all these streams are actively eroding their channels; but in the lower reaches, where the channel slopes are lower, they meander and have much the same characteristics as the Moreau River.

Little Moreau River, Bear Creek, and Virgin Creek

Pierre shale and the Fox Hills sandstone underlie the drainage areas of the Little Moreau River and Bear Creek. The drainage basin of Virgin Creek, which discharges into the Moreau River at Promise, is underlain by Pierre shale. All three streams have cut deep valleys; and, except for Bear Creek, they have steep gradients near their headwaters.

RUNOFF

Most tributaries of the Moreau River are intermittent. They flow after heavy rainfall and during the spring when the winter snow is melting. The Moreau River itself has no flow during parts of many years.

Records of the flow of the Moreau River have been obtained at four gaging stations (fig. 1). No continuous streamflow records have been obtained on the tributaries.

Periods of streamflow records of the Moreau River before October 1, 1951

No. on map (fig. 1)	Gaging station	Drainage area (square miles)	Period of record
10	At Bixby	1,570	May 1, 1948, to Sept. 30, 1951
16	Near Faith	2,660	Mar. 8, 1943, to Sept. 30, 1951
20	Near Eagle Butte	4,320	Mar. 6, 1943, to Sept. 30, 1951
22	At Promise	5,223	Aug. 28, 1928, to Sept. 30, 1951

Flow of the Moreau River varies widely from year to year. (See fig. 7.) At Promise the water discharge for the 21-year period that ended September 30, 1951, averaged 273 cfs. The minimum annual average discharge during the period was 20 cfs during water year 1934, and the maximum annual average discharge was 812 cfs during water year 1950.

Diversions and storage for irrigation have no appreciable effect on the flow of the Moreau River. Small amounts of water are collected in stock ponds during periods of surface runoff.

Runoff from the Moreau River drainage basin averaged about 0.7 inch during the period of streamflow records at Promise. Some runoff comes from the snowmelt, but most comes from rains during late spring and early summer. Ground-water inflow to the Moreau River is low during most years, and the river has no flow for many days in some years. As the climate, topography, and soils are nearly uniform throughout the drainage basin, runoff is probably about the same from all parts of the basin. Figure 7 shows that the discharge per square mile by water years differs only a little from one gaging station to another.

CHEMICAL QUALITY OF THE WATER

Proposed reservoir construction for irrigation should be preceded by study and consideration of the chemical quality of the water. If the water from the

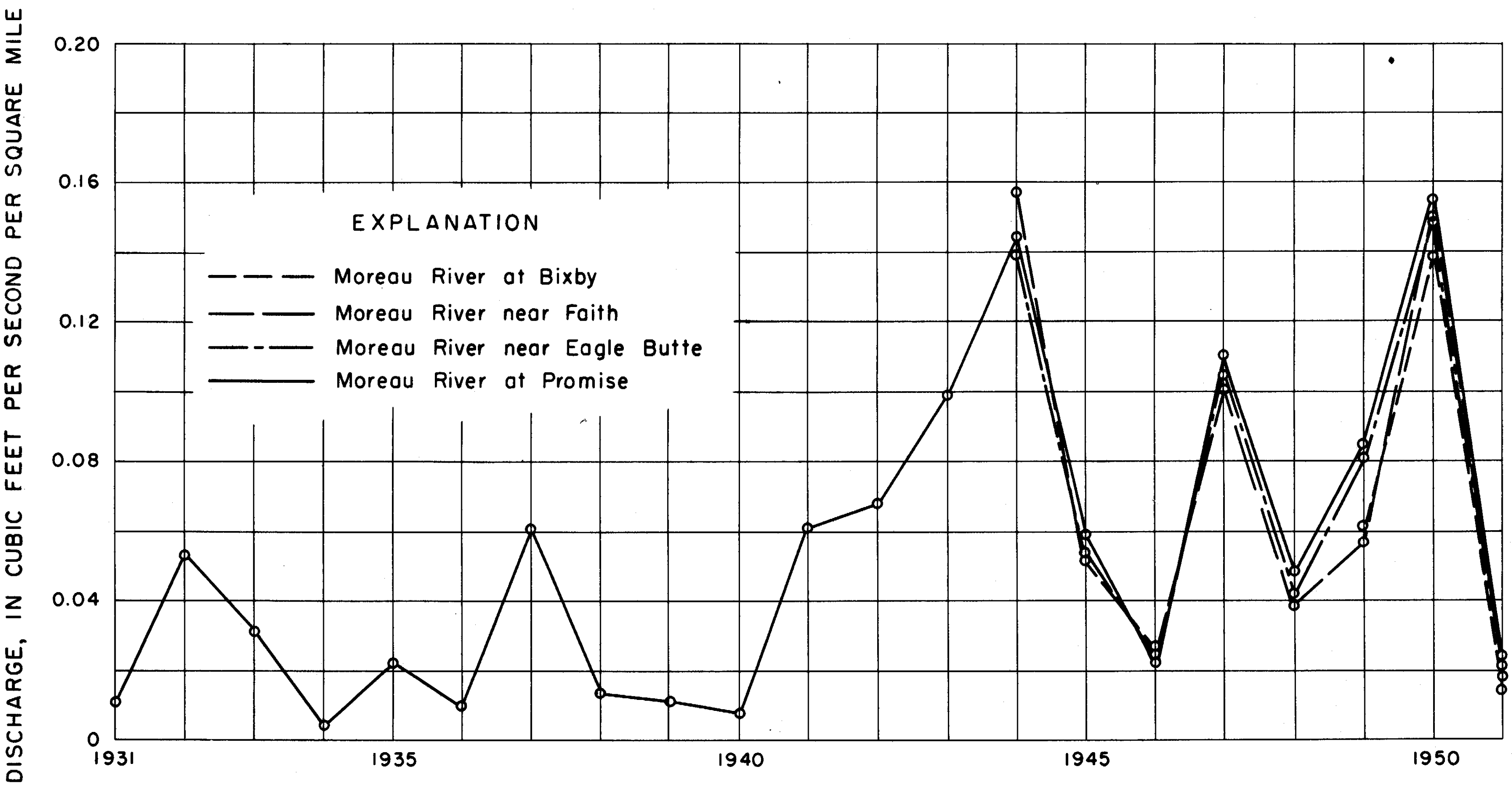


Figure 7.--Discharge per square mile by water years at gaging stations in the Moreau River drainage basin.

Moreau River is to be impounded, salt concentrations during periods of low and normal flows and the effect of dilution by flood flows should be evaluated. A study of the relationship between the geology and the dissolved minerals in the water may help toward a better understanding of the changes in the quality of the water from one place to another. Therefore, places for collection of samples on the Moreau River were so selected as to obtain analytical data on composition and concentration of the water in the upper, middle, and lower parts of the river. In addition, information on the chemical quality of the major tributaries and on the effect of tributary inflow on the Moreau River was obtained by a special salinity survey. The locations of sampling sites are shown in figure 1.

Geochemistry of Water

The mineral matter dissolved in natural waters is derived from the rocks and soils. Differences in the mineral composition of waters are due to many factors, some of which are (1) the availability of soluble minerals in the rocks and soils, which is decreased by leaching and is increased by exposure of fresh surfaces to erosion; (2) the rate of leaching of minerals, which depends on the solubility of the minerals, the length of time the water is in contact with these minerals, and the temperature of the water; and (3) the character of the rocks.

Soluble minerals are abundant in the rocks and soils of the Moreau River basin, but they are more available in the upper reaches, where slumping has exposed more fresh surfaces.

The length of time during which the water is in contact with the rocks and soils has a direct bearing on the salinity of many streams and rivers. However, in the Moreau River basin most of the water leaves the basin in a relatively short period of time, usually 2 to 4 months. Nevertheless, the surface waters of the Moreau River basin are not especially low in mineralization during relatively high flows. The soluble salts deposited on the surface of the valley sides by capillary action and evaporation during the dry months of the year are immediately available for solution by rain or storm waters. (See fig. 8.) Thus, the concentration of minerals in the Moreau River water may be appreciable even during relatively high water discharges.

The chemical character of a water is directly related to the lithology or composition of the rocks with which the water comes into contact. For the most part, the Moreau River basin is underlain by the nonmarine Hell Creek formation, the marine Fox Hills sandstone, and the marine Pierre shale, all of which affect the water quality.

Relation of the Rocks to Quality of Water

Water draining from the Hell Creek formation usually has a high percent sodium. The sodium is in solution primarily as sodium bicarbonate. The Hell Creek formation contains minerals that are necessary to produce a sodium bicarbonate or sulfate water. Several reactions are involved. For example:

1. A calcium bicarbonate water forms from the reaction of the carbon dioxide-charged meteoric waters with the calcareous sands, which are common in the Hell Creek formation.

$$H_2O + CO_2 + CaCO_3 \longrightarrow Ca^{++} + 2HCO_3^-$$

2. Calcium or magnesium is replaced with sodium from beidellite in the bentonitic clay in the formation.

$$Ca^{++} + 2HCO_3^- + \text{beidellite}\cdot 2Na \longrightarrow 2Na^+ + 2HCO_3^- + \text{beidellite}\cdot Ca$$

3. Gypsum in the formation changes the sodium bicarbonate water to a sodium sulfate water. Sodium sulfate usually is characteristic of certain formations of Cretaceous age in the west. (Lindgren, 1932.)

$$2Na^+ + 2HCO_3^- + Ca^{++} + SO_4^= \rightleftarrows 2Na^+ + SO_4^= + CaCO_3 + CO_2 + H_2O$$

The oxidation of the pyrites and marcasites in the Hell Creek formation may also account for part of the sulfate.

$$FeS_2 + 7O^= + H_2O \longrightarrow Fe^{++} + 2H^+ + 2SO_4^=$$

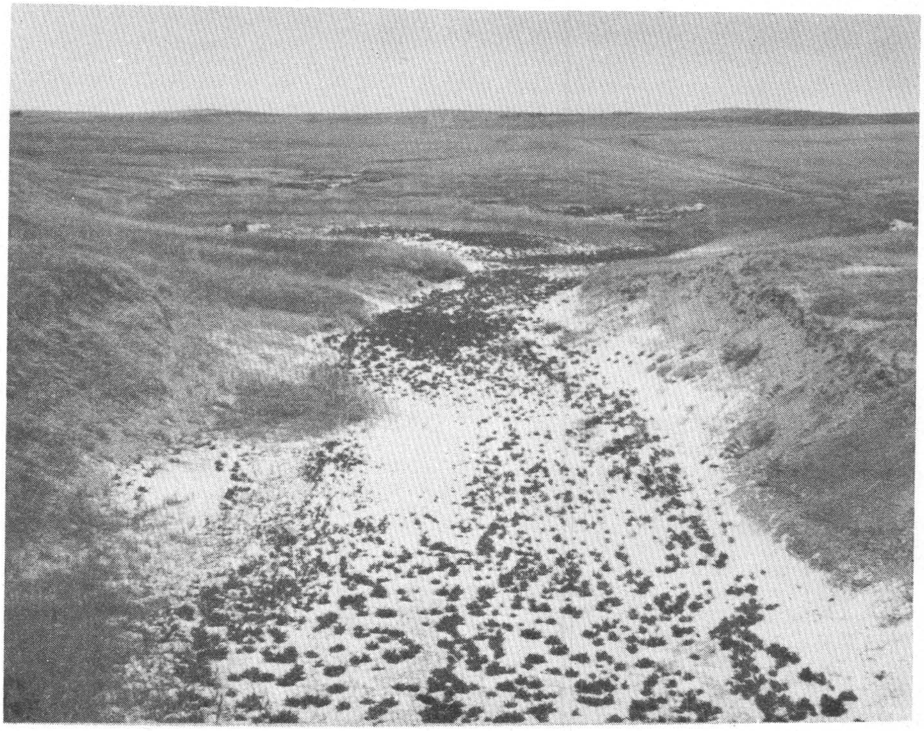
$$2Na^+ + 2HCO_3^- + 2H^+ + SO_4^= \longrightarrow 2Na^+ + SO_4^= + 2H_2O + 2CO_2$$

Water that drains from the Fox Hills sandstone is very similar in type to water that drains from the Hell Creek formation. The gray glauconitic marine quartz sandstone, sometimes interbedded with greenish-gray marine shales, produces a water ordinarily high in sodium and bicarbonate. The sodium bicarbonate in water is formed by the same processes as in the Hell Creek formation; however, the water that drains from the marine Fox Hills sandstone should be more saline.

Water influenced by the Pierre shale is somewhat different in type than waters influenced by the Hell Creek formation and Fox Hills sandstone. Calcium sulfate in the form of gypsum, calcium carbonate as calcite or aragonite, sodium salts in the form of bentonite, and iron sulfide in the form of pyrite or marcasite are in the exposures. As a result of solution and other chemical reactions with these minerals, the water that drains from the Pierre shale is characteristically a sodium sulfate type. The water contains large quantities of dissolved constituents because soluble minerals are abundant and because constant slumping of exposed shale brings unweathered minerals to the surface. The percent sodium is somewhat lower in water that drains from the Pierre shale than in water that drains from the Hell Creek formation and Fox Hills sandstone. This is probably due to the presence of the alkaline earth minerals, rather than the absence of alkali metal minerals.

Chemical Quality Records

The general relationship between the quality of the water in the tributaries and the quality of the water in the main stem of the Moreau River can be seen from the special salinity study. More detailed records of the four stations on the main stem are listed separately.



A. Unnamed tributary on Pierre shale uplands

B. Moreau River at Promise

Figure 8.--Salt deposits resulting from capillary action and evaporation, Moreau River drainage basin.

The mineral concentrations during periods of high and low flows in the Moreau River for the years 1945-51 are shown in figure 9. These concentrations do not represent weighted averages. They show the diluting action of snowmelt and heavy rains and the high concentrations of the water during low flows. The graphs for each station are for periods of sampling at that station; therefore, graphs for one station should not be compared with graphs for another station.

Expression of Results of Analyses

The expressions of results are in accordance with those listed in the U. S. Geological Survey Water-Supply Paper 1102 (1952, p. 5-6) as follows:

> The dissolved mineral constituents are reported in parts per million. A part per million is a unit weight of a constituent in a million unit weights of water. . . . An equivalent per million is a unit chemical combining weight of a constituent in a million unit weights of water and is calculated by dividing the concentration in parts per million by the chemical combining weight of the constituents. For convenience in making this conversion the reciprocals of chemical combining weights of the most commonly reported constituents are given in the following table:

Constituent	Factor
/Basic radicals/	
Iron (Fe^{++})	0.0358
Iron (Fe^{+++})	.0537
Calcium (Ca^{++})	.0499
Magnesium (Mg^{++})	.0822
Sodium (Na^{+})	.0435
Potassium (K^{+})	.0256
/Acid radicals/	
Carbonate (CO_3^{--})	.0333
Bicarbonate (HCO_3^{-})	.0164
Sulfate (SO_4^{--})	.0208
Chloride (Cl^{-})	.0282
Fluoride (F^{-})	.0526
Nitrate (NO_3^{-})	.0161

> Results given in parts per million can be converted to grains per United States gallon by dividing by 17.12. A calculated quantity of sodium and potassium is given in some analyses and is the quantity of sodium needed in addition to the calcium and magnesium to balance against the acid radicals.

> The total hardness, as calcium carbonate ($CaCO_3$), is calculated from the equivalents of calcium and magnesium . . . The hardness caused by calcium and magnesium (and other ions if significant) equivalent to the carbonate and bicarbonate is called carbonate hardness; the hardness in excess of this quantity is called noncarbonate hardness.

> In the analyses of most waters used for irrigation, the quantity of dissolved solids is given in tons per acre-foot as well as in parts per million. Percent sodium has been computed for those analyses where sodium and potassium are reported separately by dividing the equivalents per million of sodium by the sum of the equivalents per million of calcium, magnesium, sodium, and potassium and multiplying the quotient by 100. In analyses where sodium and potassium were calculated and reported as a combined value, the value reported for percent sodium will include the equivalent quantity of potassium. In most waters of moderate to high concentration, the proportion of potassium is much smaller than that of sodium. . . . Hydrogen-ion concentration (pH) is given as the negative logarithm of the number of moles of ionized hydrogen per liter of water.

> A weighted-average analysis represents approximately the composition of water that would be found in a reservoir containing all of the water passing a given station during the year /or period/ after thorough mixing in the reservoir. The weighted-average analysis is computed by multiplying the discharge for the sampling period by the quantities of the individual constituents for the corresponding period and dividing the sum of the products by the sum of the discharges.

Specific conductance, expressed as micromhos, is an electrical measurement of the ionized salts in solution.

Salinity Study

Spot samples were taken from the major tributaries and main stem of the Moreau River April 12 to 16, 1949, after the major part of the water from the spring thaw had run off. The following discussion is therefore not applicable for periods of flood or other high runoff. However, a correlation between geology and water quality during normal or low flow, when the percentage of ground water in the stream is greater, is more reliable than at times when storm or melt waters dilute the streamflow. The locations of sampling sites for this special salinity survey are shown in figure 1, and the analyses of 21 surface-water samples are given in table 6. The principal mineral constituents are expressed graphically in figure 10.

The concentrations of dissolved minerals are highest in samples from the South Fork, which drains an area that is underlain by the Pierre shale. The dissolved mineral matter in these samples is predominantly sodium sulfate and contains appreciable amounts of calcium and magnesium and a small amount of bicarbonate. Samples from all other tributaries represent waters that drain from areas underlain mostly by the Fox Hills sandstone and the Hell Creek formation. Sodium bicarbonate characterizes these waters.

Waters from Deep, Rabbit, Antelope, and Sand Creeks and the North Fork Moreau River drain from areas underlain principally by the Hell Creek formation and have a higher percent sodium than other surface waters of the basin. However, the water from Sand Creek at Mason has been influenced by the Fox Hills sandstone and Pierre shale, as shown by high mineral content and high percentage of sulfate. Flint Rock, Thunder Butte, and Worthless Creeks drain areas underlain principally by the Hell Creek forma-

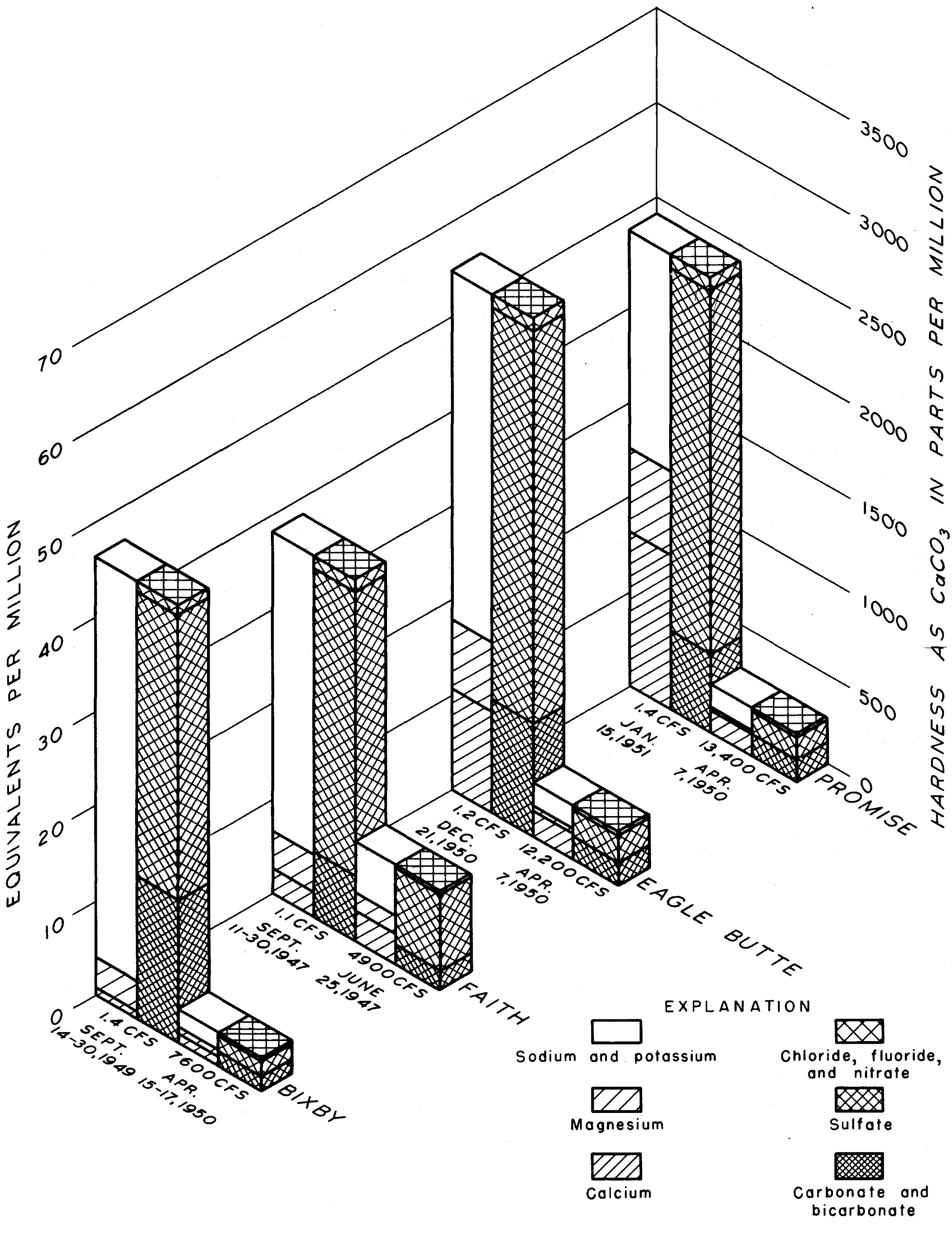


Figure 9.--Principal mineral constituents during periods of high and low flows at sampling stations, Moreau River drainage basin, 1945-51.

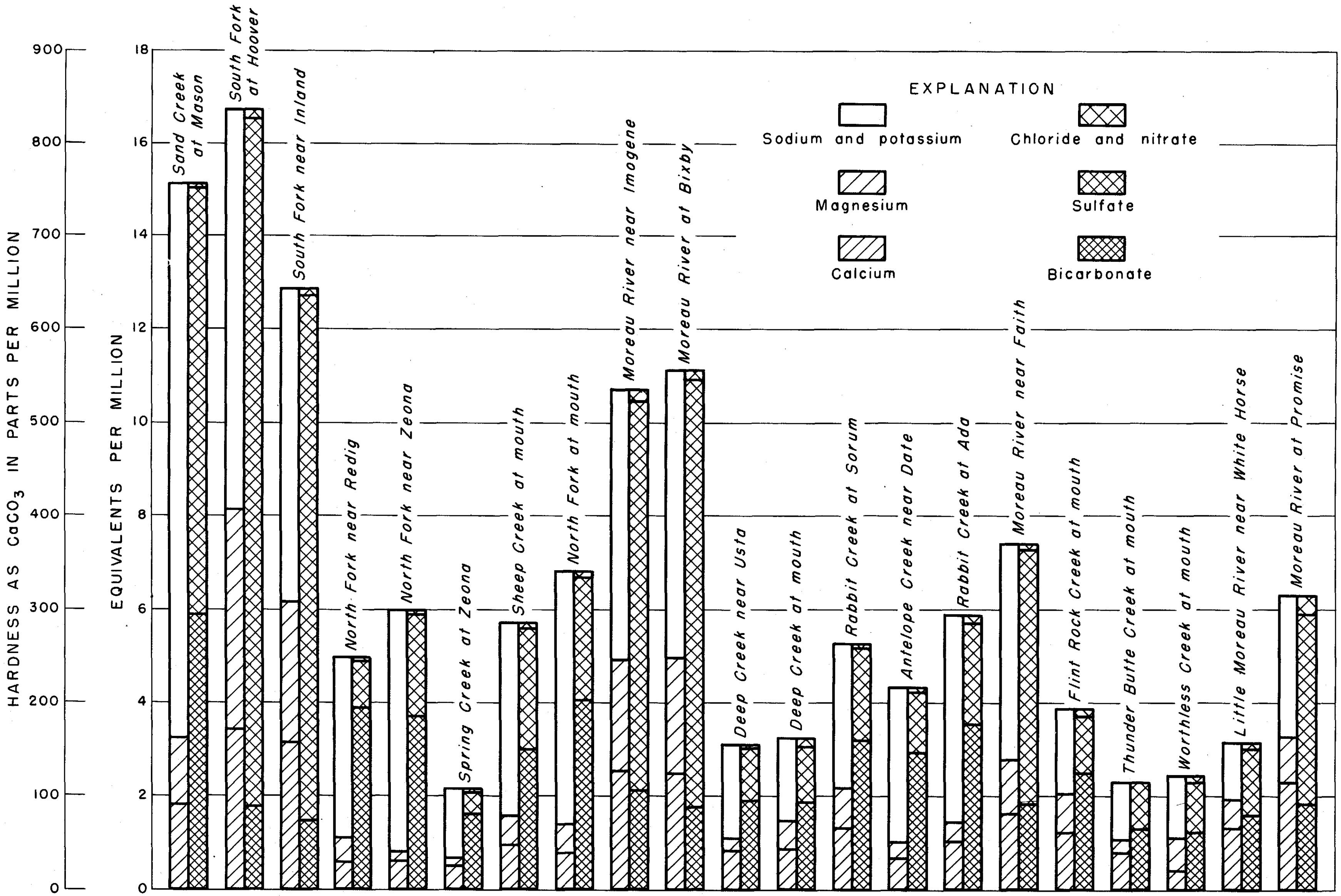


Figure 10.--Principal mineral constituents in surface waters, salinity survey, April 12 to 16, Moreau River drainage basin.

tion except in the lower reaches, which are underlain by the Fox Hills sandstone. Therefore, the samples represent mixtures of two types of water. Waters that drain from the Fox Hills sandstone and Pierre shale are more mineralized than waters that drain from the Hell Creek formation. The difference in concentrations is probably related to the nonmarine origin of the Hell Creek formation and to the marine origin of the Fox Hills sandstone and the Pierre shale.

The percentage composition of the water in the South Fork and in the entire main stem of the Moreau River shows the effect of the outcrops of Pierre shale, and the percentage is not altered materially by the relatively dilute water that drains from areas that are underlain by the Hell Creek formation.

Moreau River at Bixby

Samples were collected daily from the Moreau River at Bixby from March 6, 1949, to September 30, 1951. The results of chemical analyses are given in table 7.

Water passing the station at Bixby is a mixture of water from the North and South Forks. Consequently, the Hell Creek formation, Fox Hills sandstone, and Pierre shale jointly contribute to the mineralization of the water. (See fig. 6.) When the discharge is low, nearly base flow, the water is highly mineralized and predominantly sodium sulfate. This is chiefly due to the Pierre shale, which underlies most of the South Fork and part of the North Fork.

Moreau River near Faith

Analyses of seven samples that were collected from April 16, 1941, to May 7, 1945, were furnished by the Bureau of Reclamation. Seven additional spot samples were collected by the Geological Survey from November 29, 1945, to March 26, 1947. Samples were collected daily from April 9, 1947, through September 30, 1949. Results of chemical analyses for all these samples are given in table 8.

The water in the Moreau River near Faith is similar to the water at Bixby. However, water from Rabbit and Deep Creeks enters the main stem upstream from the station near Faith and causes a slight increase in percent sodium and a decrease in concentration. These changes are due to the fact that Rabbit and Deep Creeks are underlain mostly by the Hell Creek formation. The water quality at Bixby can be compared approximately with the water quality near Faith from the weighted-average figures for the 1949 water year (tables 7 and 8), as both stations were then sampled on a daily basis.

Moreau River near Eagle Butte

Analyses of 13 samples that were collected from April 17, 1941, to July 8, 1943, were furnished by the Bureau of Reclamation. Since November 30, 1945, the Geological Survey has collected samples at irregular intervals. The analytical results for all samples are given in table 9. In general, the water near Eagle Butte contains less sodium than the water at Bixby or near Faith, but it is more highly mineralized. The change in lithology between Faith and Eagle Butte is the principal reason for the change in water quality.

Moreau River at Promise

Analyses of eight samples that were collected from October 10, 1941, to June 15, 1943, were furnished by the Bureau of Reclamation. Since November 30, 1945, the Geological Survey has collected samples at irregular intervals. The analytical results for all samples are given in table 10.

The composition of the water at Promise is somewhat similar to the composition of the water near Eagle Butte. However, the water at Promise has a higher ratio of calcium and magnesium to sodium.

Suitability of Water for Irrigation

The suitability of water for irrigation, as determined by water-quality criteria only, depends primarily on mineral concentration, percent sodium, and concentration of boron. All these factors may vary considerably with water discharge. Thus, weighted-average analyses by water years are helpful in determining concentrations to be expected only if the water is impounded. However, concentrations as shown by these analyses may be misleading because they will be lower or higher during a wet or dry climatic cycle than long-term average concentrations.

For the Moreau River study, relatively short-term chemical-quality records are available. Weighted averages have been calculated from analyses of water samples from the river near Faith (1948 and 1949 water years) and at Bixby (1949, 1950, and 1951 water years) and are given in tables 7 and 8. No other daily chemical-quality stations in the basin have been operated. In order to determine whether the 3-year records for Bixby and the 2-year records for Faith are representative of a wet, dry, or average climatic period, it is necessary to compare the discharge records of these years with a long-term average discharge. As a long-term average discharge is not available for the two stations, it must be calculated after consideration of certain factors, which are (1) the climate throughout the basin is fairly uniform and consequently has a very small variance in average annual precipitation, and (2) the geology and topography are fairly uniform; therefore, the runoff does not vary appreciably from one place to another. As a result of these two factors, the discharge per square mile of drainage area is relatively constant for the entire length of the river's main stem, as shown in figure 7. A 21-year record of discharge is available for the station at Promise. Thus, the discharge per square mile at Bixby and Faith can be calculated with reasonable accuracy for periods when no records of streamflow are available.

The average annual discharge at the Promise station for the 21-year period that ended September 30, 1951, was 273 cfs from the drainage area of 5,223 square miles. The calculated discharge per square mile equals 0.052 cfs, which when multiplied by the drainage areas above the other stations gives the approximate 21-year average discharge for each of these areas. Thus, the 21-year average discharge at Bixby (drainage area, 1,570 sq miles) is about 82 cfs; near Faith (2,660 sq miles), about 138 cfs; and near Eagle Butte (4,320 sq miles), about 225 cfs. Discharge for each year of sampling is compared with the 21-year average for each station in table 1. The discharges for several of the years are lower than the calculated 21-year averages. However, the average discharge for the period of sampling is somewhat higher than the 21-year average. This indicates that the period of sampling was during a relatively wet climatic cycle. Consequently, an average discharge-weighted concentration of dissolved minerals for the period of sampling would be lower than normal, and the percentage composition would not be representative of a long-term average.

Table 1.--Discharges for periods of sampling compared with calculated 21-year averages for stations on the Moreau River

Station	Years of sampling (water years)	Annual average discharge (cfs)	Average discharge for period of sampling (cfs)	Calculated 21-year average discharge (cfs) 1/
Bixby	1949	97.0	112	82
Do	1950	216		82
Do	1951	21.9		82
Faith	1946	70.1	149	138
Do	1947	270		138
Do	1948	102		138
Do	1949	152		138
Eagle Butte	1946	105	304	225
Do	1947	454		225
Do	1948	176		225
Do	1949	350		225
Do	1950	645		225
Do	1951	92.4		225
Promise	1946	116	388	273
Do	1947	575		273
Do	1948	251		273
Do	1949	446		273
Do	1950	812		273
Do	1951	126		273

1 Drainage area in square miles x 0.052.

Note.--At Faith, infrequent samples included; at Eagle Butte and Promise, infrequent samples only.

Weighted-average concentrations for incomplete years are not necessarily representative of the water that flows past a station during a full year. For example, there were days when the water was not sampled at the Bixby station during the 3-year period of record. The following table compares the estimated weighted averages of specific conductance and percent sodium for 3 complete years of record at Bixby with the weighted averages for the sampling periods only. From these estimated annual figures, the 3-year weighted average for specific conductance would be 632 micromhos and the 3-year weighted average for percent sodium would be 57. The graphic method of rating a water for irrigation as proposed by Wilcox (1948) would rate the water as good to permissible.

Weighted averages of specific conductance and percent sodium for water in the Moreau River at Bixby, 1949-51

Water year	Percent of flow sampled	Specific conductance (micromhos per cm at 25°C)		Percent sodium	
		Period sampled	Estimated for water year	Period sampled	Estimated for water year
1949	94	698	735	54	55
1950	81	544	518	56	56
1951	98	1,300	1,300	79	79
Weighted average 1949-51			632	---------------	57

The results of analyses of composited samples for the stations at or near Bixby, Faith, Eagle Butte, and Promise have been used to classify graphically the water for irrigation (fig. 11). In general, the water becomes less suitable as the streamflow decreases. Therefore, if the period of sampling is during a wet cycle, the short-term weighted averages would imply that the water is of better quality than would actually be available over a long period of time. By correlation of the calculated 21-year average discharge at the Bixby station (82 cfs) with the data given in figure 11, it is estimated that water impounded at Bixby for an

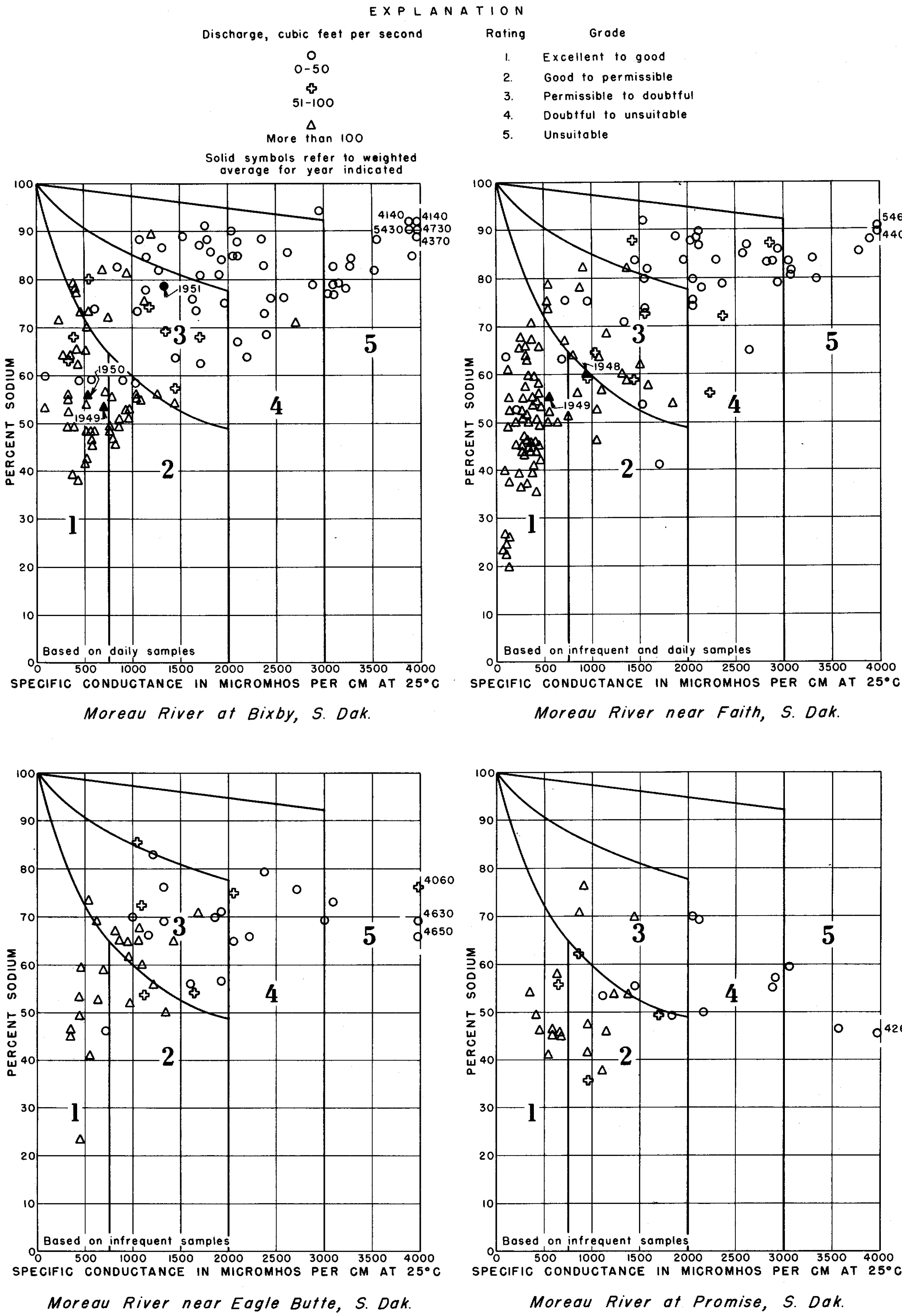


Figure 11.--Classification of surface water for irrigation, Moreau River drainage basin (after Wilcox).

average year would be permissible to doubtful for irrigation. Of course, some years the water would be more suitable for irrigation and some years less suitable than the average would indicate. However, Wilcox states that the graphical classification of irrigation water is dependent on permeability, drainage, quantity of water used, climate, and crops, and that irregularities that relate to any of these would alter the intended use of the graph. Therefore, heavy soils, low permeability, inadequate drainage, high rates of evapotranspiration, the application of too little water, or the growing of crops with poor salt tolerance may alter the classification of the water.

Other chemical-quality characteristics besides total concentration and percent sodium must be considered in rating the water for irrigation. Boron in irrigation water can be toxic to crops if the concentration exceeds the limits suggested by Scofield (1936, p. 286). Water in the Moreau River usually contains low concentrations of boron, and the higher concentrations during certain low-flow periods would not cause quality-of-water problems if the water were impounded. Eaton (1949, p. 38) states:

> . . . if the water contains more HCO_3-CO_3 than it does Ca plus Mg, then with evaporation the Ca and Mg carbonates are precipitated and there remains sodium carbonate, and Na is the only important base. Since the strong base, Na, is present with the excess of carbonate, a weak acid, the solution becomes strongly alkaline. It is the presence or absence of this residual sodium carbonate that now appears to furnish a criterion of whether black alkali can or cannot develop in irrigated soils.

Black-alkali soil is the descriptive name applied to a soil that has a pH of 8.4 or more and contains organic matter. The organic matter is dissolved by the alkaline solution, and the soil becomes dark brown to black. During certain periods of time, low-flow water at the Bixby station contained amounts of carbonate and bicarbonate in excess of calcium plus magnesium, as shown in figures 12, 13, and 14. The relation to discharge of carbonate and bicarbonate in excess of calcium and magnesium (shown by crosshatching), hydrogen ion concentration, and percent sodium indicates that the excess carbonate and bicarbonate, hydrogen ion concentration, and percent sodium vary inversely with the discharge. However, the decrease of the percent sodium, pH, and excess bicarbonate is not so rapid as the increase of the discharge. Consequently, the concentrations of the constituents may temporarily remain high when the discharge increases. Figures 12, 13, and 14 show that during low flows carbonate and bicarbonate are in excess of calcium and magnesium, and the weighted average for the 1951 water year shows an excess because the ratio of flood flows to low flows is low. However, the weighted averages for the 1949 and 1950 water years show no excess because the ratio is high. During the 1951 water year the percent sodium was high, and the hydrogen ion concentration (pH) exceeded 8.0 much of the time.

The chemical-quality data for the station at Bixby for the 1951 water year may be used to estimate the water quality for previous years. Figure 7 shows that from 1931 to 1940 the discharge per square mile for 6 of the years was less than during 1951, and figure 12 shows that excess carbonate, percent sodium, and pH are all high when water discharges are low. Therefore, during many years of a dry period, such as 1931-40, the water would contain excess amounts of bicarbonate and high percent sodium, and the pH would probably exceed 8.0. This water would be conducive to the formation of black alkali.

Eaton (1949, 1950) has made an extensive study of the relations of residual carbonate and percent sodium to the occurrence of black alkali and the suitability for irrigation of water in the Nile River basin. His findings are applicable to any natural water that may be used for irrigation. He stated (1949, p. 38-39):

> During period of low water the Nile water has a pH well above 8.0. The water has such a large proportion of HCO_3-CO_3 that when it is greatly reduced in volume by evaporation it precipitates much of its Ca and Mg as carbonates and silicates, giving rise to an alkaline solution with little else than sodium salts of carbonate, chloride, and sulfate. Such a solution washing onto a soil from neighboring land, or rising from below and moving through it, would bring about the replacement of exchangeable calcium and magnesium, produce a high pH, establish impermeability, and, in other words, create those conditions that are descriptive of black-alkali soils . . . . If the possibility of black-alkali formation can be anticipated by recognition of the ionic relations of the water supply, advantage can be taken of the facts, not necessarily as a basis for condemning a water, but rather as a means of establishing the need of precautionary measures. Productivity can be maintained by adequate water use and drainage at less expense than it can be restored by reclamation.

In the following table, a comparison is shown between the composition of waters of the Moreau River during the 1951 water year and of the Nile River during 8 months of low flow.

A comparison of waters from the Nile and Moreau Rivers
[Results in equivalents per million except percent sodium]

Source	Calcium	Magnesium	Excess bicarbonate	Bicarbonate and carbonate	Percent sodium
Nile River (8 months of low flow) 1/---	0.87	0.72	1.44	3.03	56
Moreau River weighted average (1951 water year)----------------------	1.65	1.07	2.33	5.05	79

1 Eaton, 1949, p. 37.

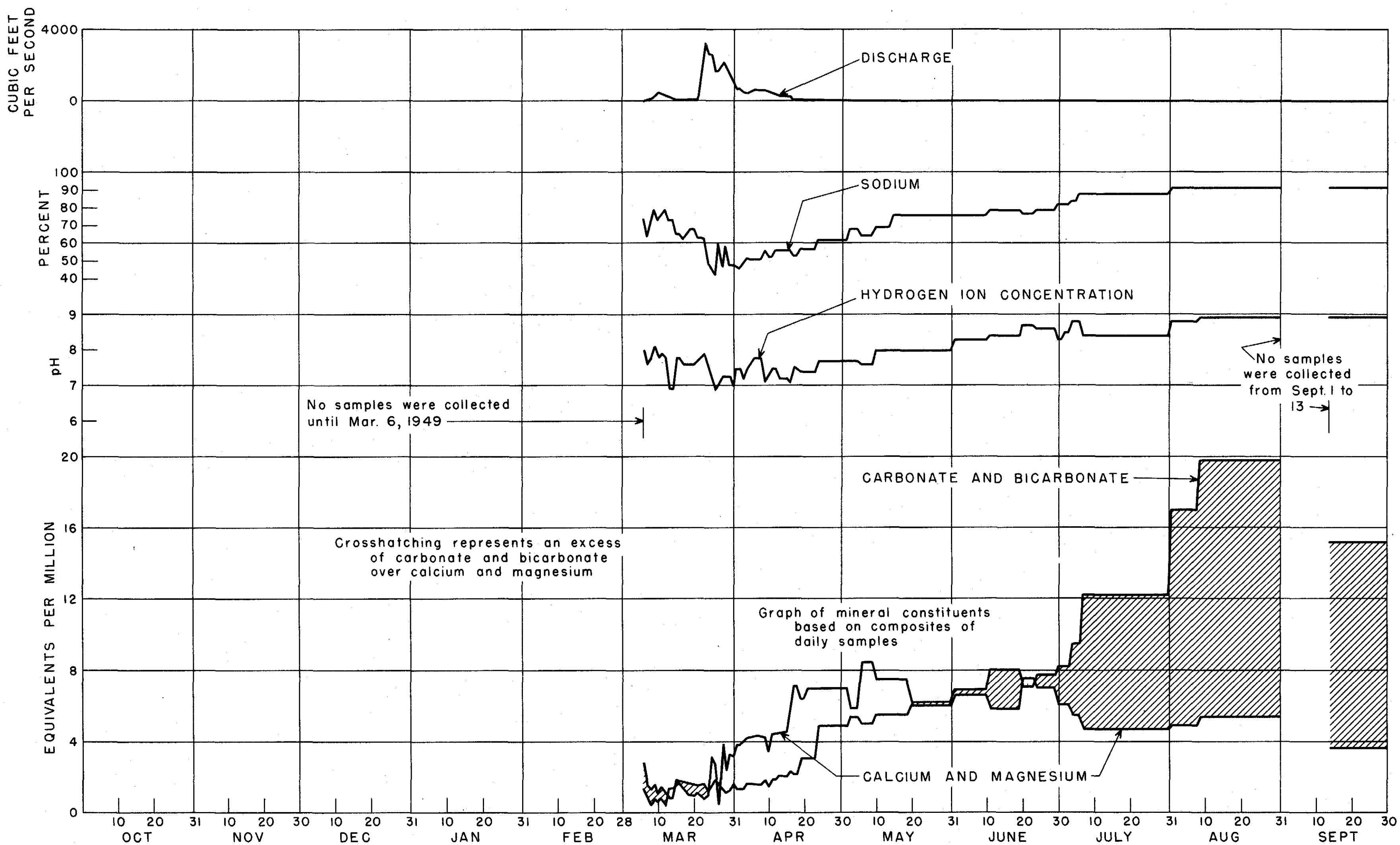


Figure 12.--Comparison to discharge of carbonate and bicarbonate in excess of calcium and magnesium, hydrogen ion concentration, and percent sodium, Moreau River at Bixby, water year 1949.

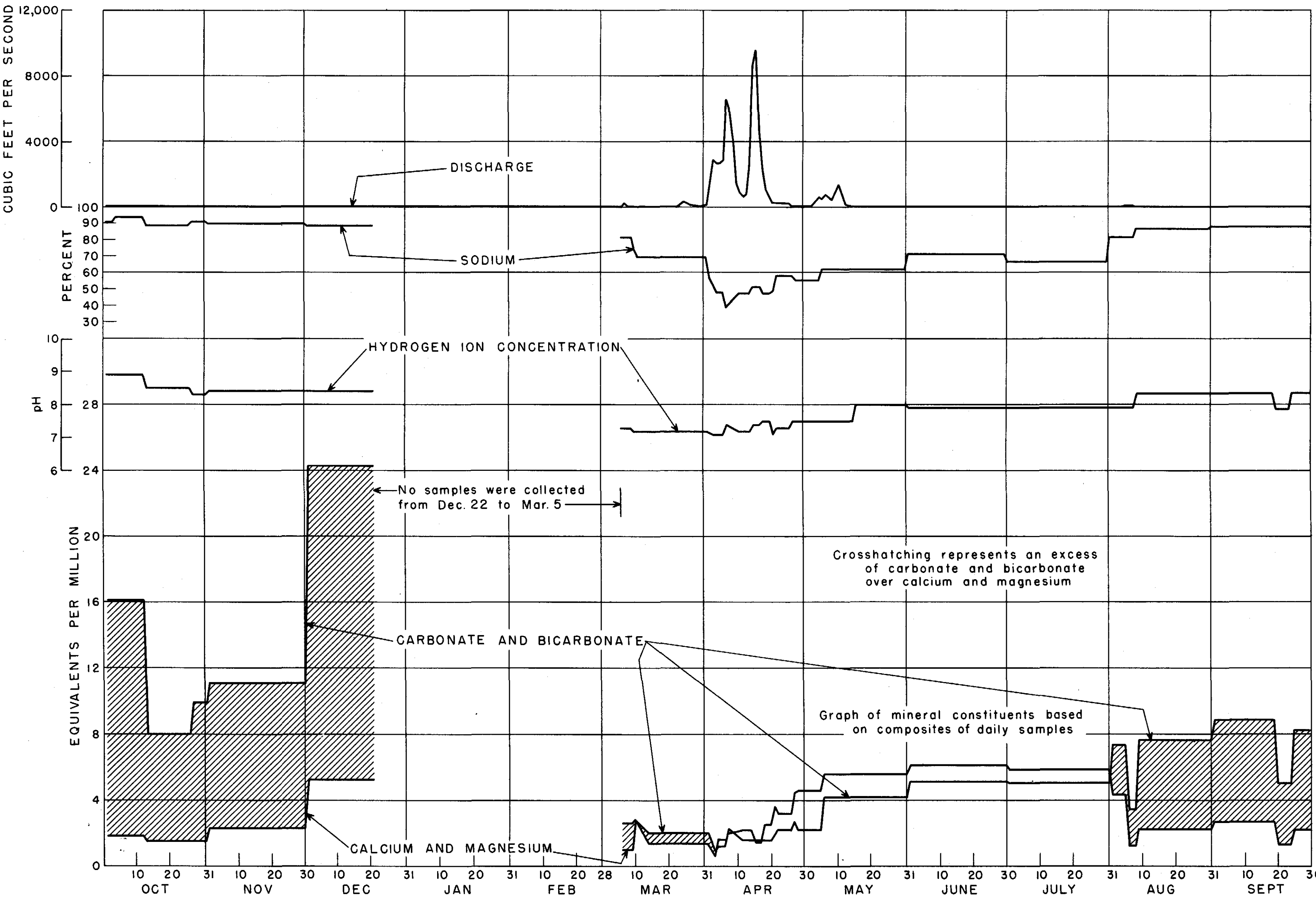


Figure 13. --Comparison to discharge of carbonate and bicarbonate in excess of calcium and magnesium, hydrogen ion concentration, and percent sodium, Moreau River at Bixby, water year 1950.

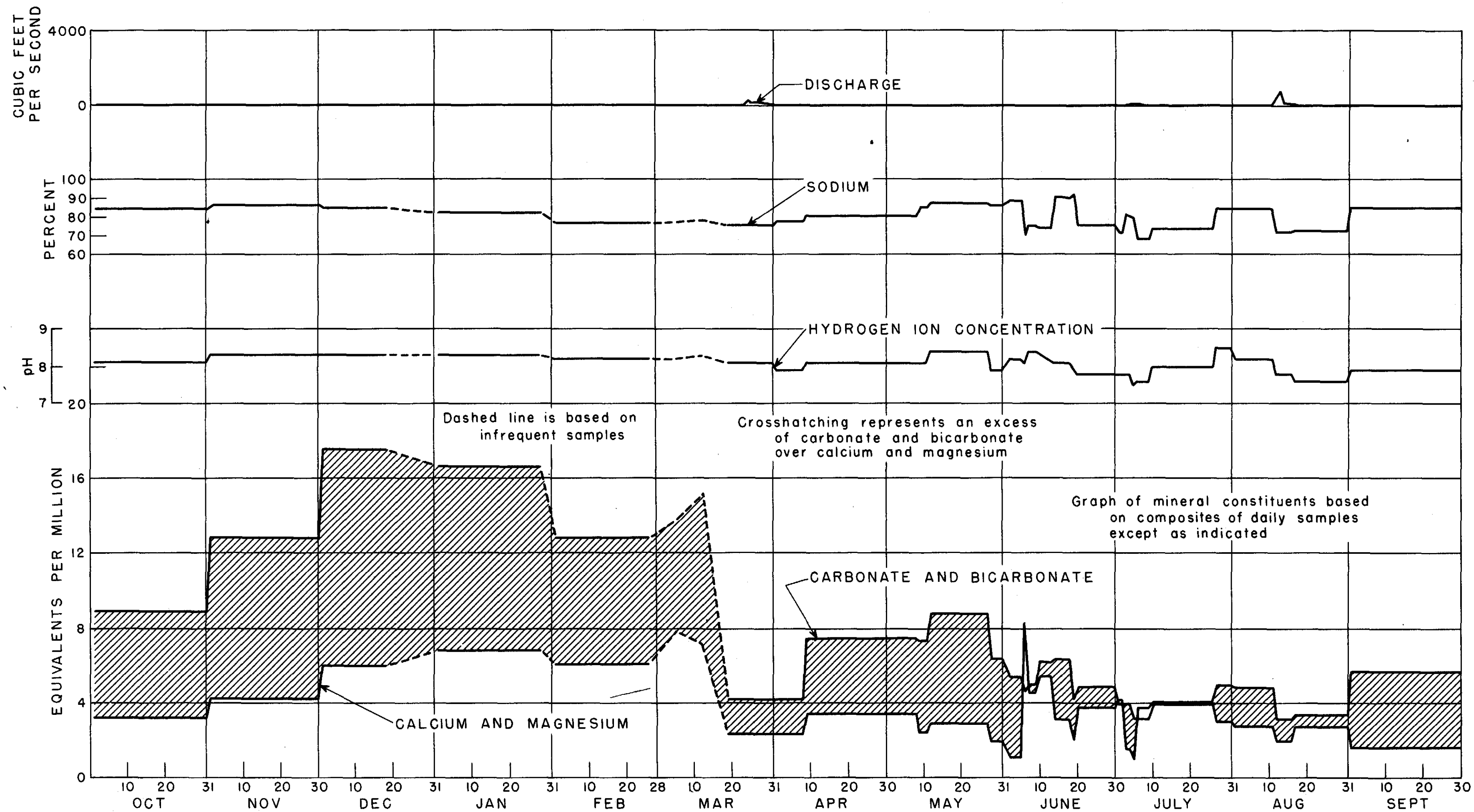


Figure 14. --Comparison to discharge of carbonate and bicarbonate in excess of calcium and magnesium, hydrogen ion concentration, and percent sodium, Moreau River at Bixby, water year 1951.

The quality of the water in the Moreau River at Bixby is so poor for irrigation that a complete evaluation of soil, permeability, drainage, climate, application rates, and crops is necessary. During the dry periods of the climatic cycle, when irrigation would be needed most, the water quality is very poor.

The use of the water for irrigation is not precluded where adequate drainage is provided and where infiltration rates are sufficient to provide low rates of evaporation and good flushing.

Downstream from Bixby the water becomes progressively better for irrigation. However, the improvement is not great by the time the water reaches the station near Faith. Data are inadequate to foretell satisfactorily the suitability for irrigation of the water at the stations near Eagle Butte and at Promise. Available data (tables 9 and 10) seem to indicate that the percent sodium is lower and amounts of carbonate and bicarbonate in excess of calcium and magnesium are much less likely to be troublesome than in the water at upstream stations.

FLUVIAL SEDIMENT

Information on the sediment yield of a drainage basin should include rates and quantities of discharge of all the sediment that is transported either in suspension or as bed load, the particle-size distribution of the suspended sediment and of the bed load, and the principal sources of the sediment. This report contains only the measured rates and quantities of suspended sediment and the results of particle-size analyses of suspended sediments.

Stream slopes are low and the particle sizes of the suspended sediment are small, so bed-load discharge must be low. Also few data are available for computing rates and quantities of sediment that is discharged as bed load. For these reasons the bed-load discharge of the Moreau River was not computed.

Definition of Terms

As the definitions of terms that relate to fluvial sediments are not completely standardized, some of the terms in this report are defined as follows:

Sediment is fragmental material that originates from weathering of rocks and is transported by, suspended in, or deposited by water or air or is accumulated in beds by other natural agencies.

Fluvial sediment is sediment that is transported by, suspended in, or deposited by water.

Suspended sediment or suspended load is sediment that moves in suspension in water and is maintained in suspension by the upward components of turbulent currents or by colloidal suspension.

Bed load or sediment discharged as bed load includes both the sediment that moves in essentially continuous contact with the stream bed (contact load) and the material that bounces along the bed in short skips or leaps (saltation load).

Sediment sample is a quantity of water-sediment mixture that is collected to represent the average concentration of suspended sediment, the average size distribution of suspended or deposited sediment, or the specific weight of deposited sediment.

Depth-integrated sediment sample is a sediment sample that is accumulated continuously in a sampler that moves vertically at a constant transit rate and that admits sediment-water mixture at a velocity about equal to the stream velocity at every point. Because depth-integrated sediment samplers are not designed to collect water-sediment mixture within about 0.3 foot of the stream bed, the suspended-sediment discharge based on such samples is less than the total suspended-sediment discharge. However, for sediment in the silt and clay sizes, the difference is usually negligible. As the suspended sediments of the Moreau River are nearly all smaller than sand size, the term "suspended-sediment discharge" is applied to the sediment discharge that is computed from depth-integrated sediment samples.

Sediment discharge is the rate at which dry weight of sediment passes a section of a stream or is the quantity of sediment, as measured by dry weight or by volume, that is discharged in a given time.

Specific weight of sediment is weight of solids per unit volume of deposit in place.

The size classification used in this report is the classification recommended by the American Geophysical Union Subcommittee on sediment terminology (Lane, 1947, p. 937). According to this classification, clay size particles have diameters between 0.0002 and 0.004 millimeter, silt size particles have diameters between 0.004 and 0.062 millimeter, and sand size particles have diameters between 0.062 and 2.0 millimeters.

According to Twenhofel and Tyler (1941, p. 110):

> The median, or median diameter, is the midpoint in the size distribution of a sediment of which one-half of the weight is composed of particles larger in diameter than the median and one-half of smaller diameter. The median diameter may be read directly from the cumulative curve by noting the diameter value at the point of intersection of the 50 percent line and the curve.

Water discharge is the discharge of natural water of a stream. The natural water contains both dissolved solids and suspended sediment.

Measurement of Suspended-Sediment Discharge

Discharge of suspended sediment is proportional to the product of water discharge and average concentration of suspended sediment. Procedures for gaging the flow of streams are fairly well standardized and are explained in Water-Supply Paper 888 (Corbett, 1943).

Concentration of suspended sediment in the Moreau River basin was determined usually from depth-integrated samples. These samples were collected either with the US DH-48 hand sampler or with the US D-43 sampler. A bucket-type sampler was used when no better sampler was available or when the air temperatures were too low for a sampler with a nozzle.

At each sediment sampling station, samples were collected generally at one vertical in the stream cross section, called the daily sampling station, once or twice a day except during periods of high or rapidly changing concentration or discharge when samples were taken more frequently. Engineers collected additional samples periodically at the daily sampling stations. Usually they also sampled at a few verticals that were spaced to represent equal quantities of water discharge. The average concentration of the samples from these verticals was used as the average concentration of suspended sediment for the entire cross section. At some measuring stations, the average concentration for the cross section sometimes differed significantly from the simultaneous concentration at the daily sampling station. For such stations, corrections were applied to adjust concentrations that were based on samples at the daily sampling station to average concentrations for the cross section.

The concentration of suspended sediment in each sample was determined in the laboratory. First, each sample was weighed. Then, after the sediment had settled, the supernatant water was drawn off. The residue was filtered or evaporated, and the sediment was dried and weighed. Corrections were applied for any appreciable quantity of dissolved solids that remained with the sediment after the water was evaporated.

Daily mean concentrations of suspended sediment were computed by plotting the concentrations of samples from the daily sampling station on the gage-height graph, drawing a smooth curve through the plotted points, and picking the daily mean concentrations for the daily sampling station from this graph. If the concentrations at the daily sampling station were not representative of the concentration for the entire cross section of the stream, a coefficient was applied to compute the daily mean concentrations.

Discharge of suspended sediment in tons per day usually was computed by multiplying daily concentration, in parts per million, by daily mean water discharge, in cubic feet per second, and by 0.0027. On days when both concentration and water discharge were changing rapidly, each day was subdivided, and sediment discharge was computed for parts of the day. For days when no samples were collected, the daily discharges of suspended sediment were estimated on the basis of water discharge, concentration for adjacent days, weather records, and records for other stations.

Suspended-Sediment Records

Daily records of suspended-sediment discharge of the Moreau River have been obtained and computed for the gaging station near Faith from August 15, 1946, to September 30, 1949, and for the gaging station at Bixby from April 28, 1949, to September 30, 1951. Sediment samples were also collected at Bixby on March 24 and April 13, 1949. The locations of the sediment stations at Bixby and near Faith are shown on figure 1 (map reference nos. 10 and 16).

Table 2 is a summary of the more detailed record (tables 11 and 12) of suspended-sediment discharge for the two stations. The average concentration weighted with water discharge was about 3,700 ppm for the station near Faith and about 4,600 ppm for the station at Bixby. The difference in average concentration at the two stations is due mostly to having sediment records during the water year of 1950 at Bixby but not at Faith. During the water year of 1950, the streamflow of the Moreau River was 2½ to 3 times normal. At the station near Faith the suspended-sediment discharge averaged about 650,000 tons per year during the period of record or slightly less than 250 tons per square miles annually. Water discharge during this period averaged somewhat less than 130,000 acre-feet annually. The Moreau River at Bixby discharged about 1,000,000 tons of suspended sediment and about 160,000 acre-feet of water during the water year of 1950 but only about 80,000 tons and 16,000 acre-feet during the water year of 1951. Sediment yield per square mile averaged nearly 350 tons per year. Available records are for too short a time to prove that the average sediment yield per square mile is appreciably different at the station at Bixby than at the station near Faith. As soils, topography, vegetation, precipitation, and runoff all seem to be about uniform throughout the Moreau River basin, the sediment yields per square mile are probably reasonably uniform within the basin except in small areas of badlands or active gullies.

Table 2.--Summary of records of suspended-sediment discharge of the Moreau River

Gaging station	Drainage area (sq miles)	Period	Water discharge (acre-ft)	Suspended-sediment discharge (tons)	Average concentration 1/ (ppm)
At Bixby--------------------	1,570	Apr. 28 to Sept. 30, 1949	2,440	3,940	1,190
		Water year 1949-50	156,700	997,100	4,670
		Water year 1950-51	15,840	81,920	3,800
Near Faith------------------	2,660	Aug. 15 to Sept. 30, 1946	4,050	32,120	5,830
		Water year 1946-47	195,500	1,077,000	4,050
		Water year 1947-48	74,380	353,600	3,490
		Water year 1948-49	110,300	515,400	3,430

1 Weighted with water discharge.

Suspended-sediment discharge fluctuates with changes in any one of several interrelated variables, which include water discharge, turbulence and temperature of the flowing water, and availability of sediments of each size range. The fluctuations are large and frequent and have only a general relation to water discharge. Except, perhaps, at very high water discharges, the suspended-sediment discharge generally increases more rapidly than the water discharge because the concentration also tends to increase with water discharge. Throughout much of the range covered by the records, the suspended-sediment discharge increases approximately as the square of the water discharge. (See figs. 15 and 16, which show the relation of daily discharges of suspended sediment to water discharge.) In general, for a given water discharge, concentrations of suspended sediment are much lower during the spring than at other seasons of the year.

Size Composition of Suspended Sediment

At the sediment sampling stations at Bixby and near Faith, representative samples were collected periodically for particle-size analyses. (See tables 13 and 14.) One or both of two general types of particle-size distributions were determined from a sample. One type showed particle sizes according to settling velocities in native water in which the degree of flocculation may have been somewhat the same as might occur in a pool or reservoir. The other type of particle-size distribution was the classification of particles by their settling diameters when the particles were completely dispersed. For particle sizes smaller than 0.031 millimeter, the difference between the two types of particle-size distributions is large. The difference is due to flocculation of the soil particles, which is caused by certain dissolved solids in the native water. Average size distributions of samples for which duplicate portions were analyzed in native water and in distilled water are plotted on figures 17 and 18. Also plotted on these figures are the curves of average particle-size distributions for all samples that were analyzed in distilled water. All average particle sizes are simply arithmetic averages of the size distributions of the particles; that is, particle sizes were not weighted with sediment discharge except that more samples were collected for particle-size analyses during periods of high flow than during periods of low flow.

Particle sizes resulting from analyses in native water are helpful in estimating the rates and locations of sediment deposition in slowly moving parts of a stream and in reservoirs. However, the degree of flocculation in a reservoir may not be the same as in the sedimentation cylinder in the laboratory.

Absolute particle sizes, measured by settling velocities of dispersed particles in distilled water, are probably the most suitable size distributions for computing the specific weight of sediment after it is deposited in a reservoir. The specific weight of sediment increases as the absolute sizes of the sediment particles increase. Sediment particles, even though they may flocculate to a larger settling diameter in the process of deposition, will, after they are deposited in a reservoir, probably assume the same specific weight that they would have had if they had been deposited while the particles were dispersed. Also the available data for defining the relation between median particle size of deposited sediments and specific weight were obtained from samples that were analyzed usually when the particles were dispersed.

Until 1950 the particle-size analyses, both in native and in distilled water, were made with the bottom-withdrawal tube. During 1950 and 1951 many samples were analyzed for particle size by the sieve-pipette method (Twenhofel and Tyler, 1941, p. 54-55). In this method particles coarser than 0.062 millimeter are separated from the finer particles by a combination of wet and dry sieving. The coarser portion is then weighed and discarded or is subdivided into different size classifications by dry sieving. The finer portion is analyzed according to sedimentation diameters by the pipette method.

The suspended sediment transported by the Moreau River is mostly fine material. (See figs. 17 and 18.) The average percentage of particles in the sand range (0.062 to 2.0 mm) was 10 percent at Bixby and 6 percent for the station near Faith. The larger percentage of coarser particles at Bixby probably was due to the abnormally high water discharges during 1950. Median particle sizes as shown by the average sizes of the dispersed samples were, by extrapolation, about 0.0017 millimeter for the station at Bixby and about 0.0015 millimeter for the station near Faith (figs. 17 and 18). The samples were not weighted with water discharge or sediment discharge.

Specific Weight of Fluvial Sediment

One significant factor in the design of reservoirs is the rate of depletion of storage capacity by sediment deposits. Estimates of the rate of reservoir depletion should be based on a knowledge of the probable location and specific weight of the deposited sediments. The location of the deposited sediments is dependent on inflow-outflow relationships or elevation of water surface in the reservoir, sedimentation diameter of particles in transport, mineral constituents in solution, and effect of density currents. The specific weight of sediment deposits depends on the type of material in transport, absolute particle size, effect of change in concentration of the mineral constituents in solution, degree of sorting, and amount of consolidation.

The rate of deposition of sediment in the upper reaches of a reservoir is a function of the stream velocity (turbulence) and the settling diameters of the material in transport. The coarsest material will be deposited where the backwater begins, but some of the finest material will eventually reach the downstream end of the reservoir because of density currents or reservoir drawdown or both. The reservoir operation may result in deposition of coarse and fine material in alternate lenses at the same location.

The specific weight of material deposited in reservoirs increases with compaction. If all the sediment particles have about the same specific gravity, the specific weight of the deposits is determined solely by the porosity of the deposit. The porosity depends chiefly on (1) the shape and arrangement of the particles, (2) the degree of assortment of the particles,

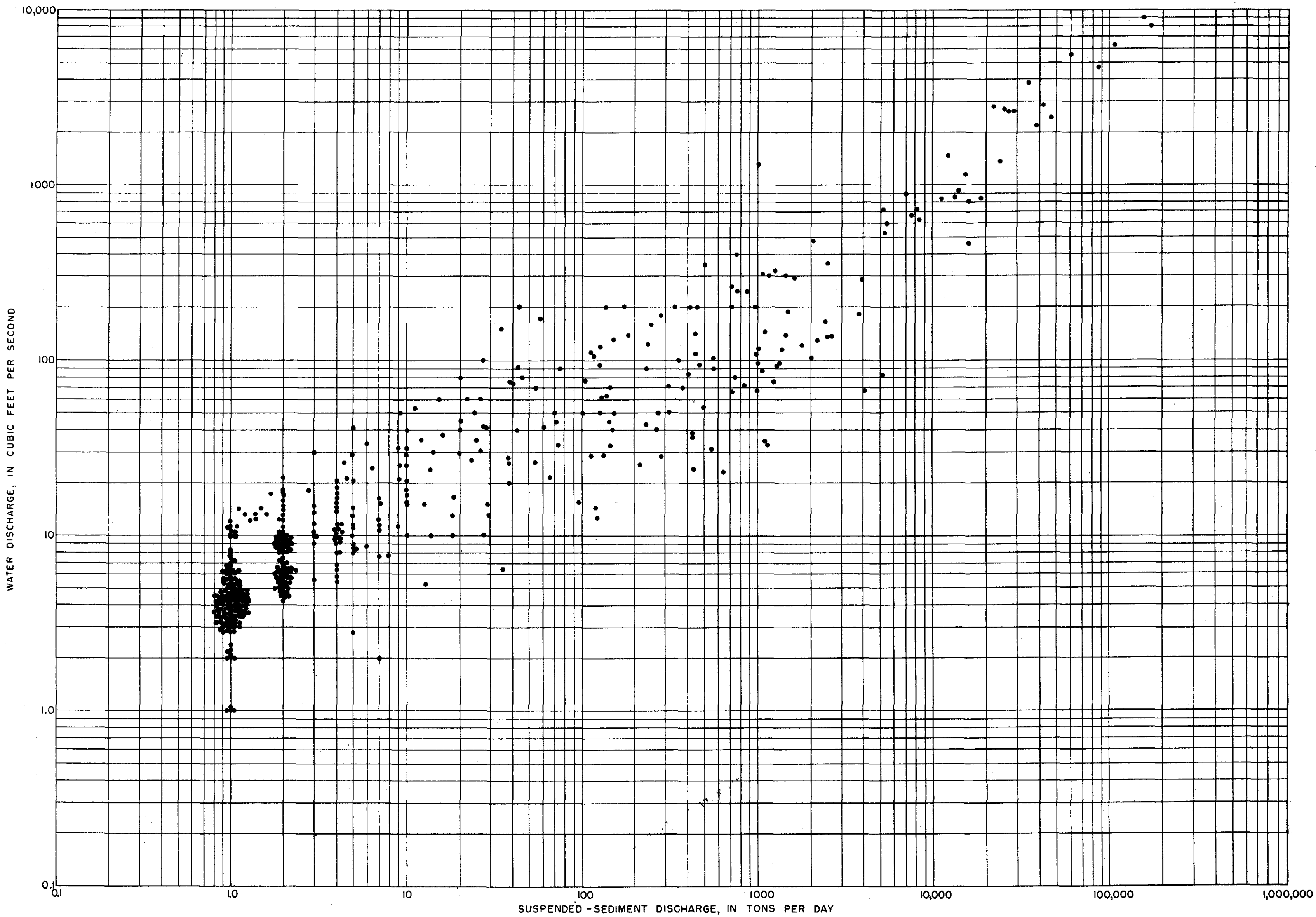


Figure 15.--Relation of suspended-sediment discharge to water discharge, Moreau River at Bixby, March 24, 1949, to September 30, 1951.

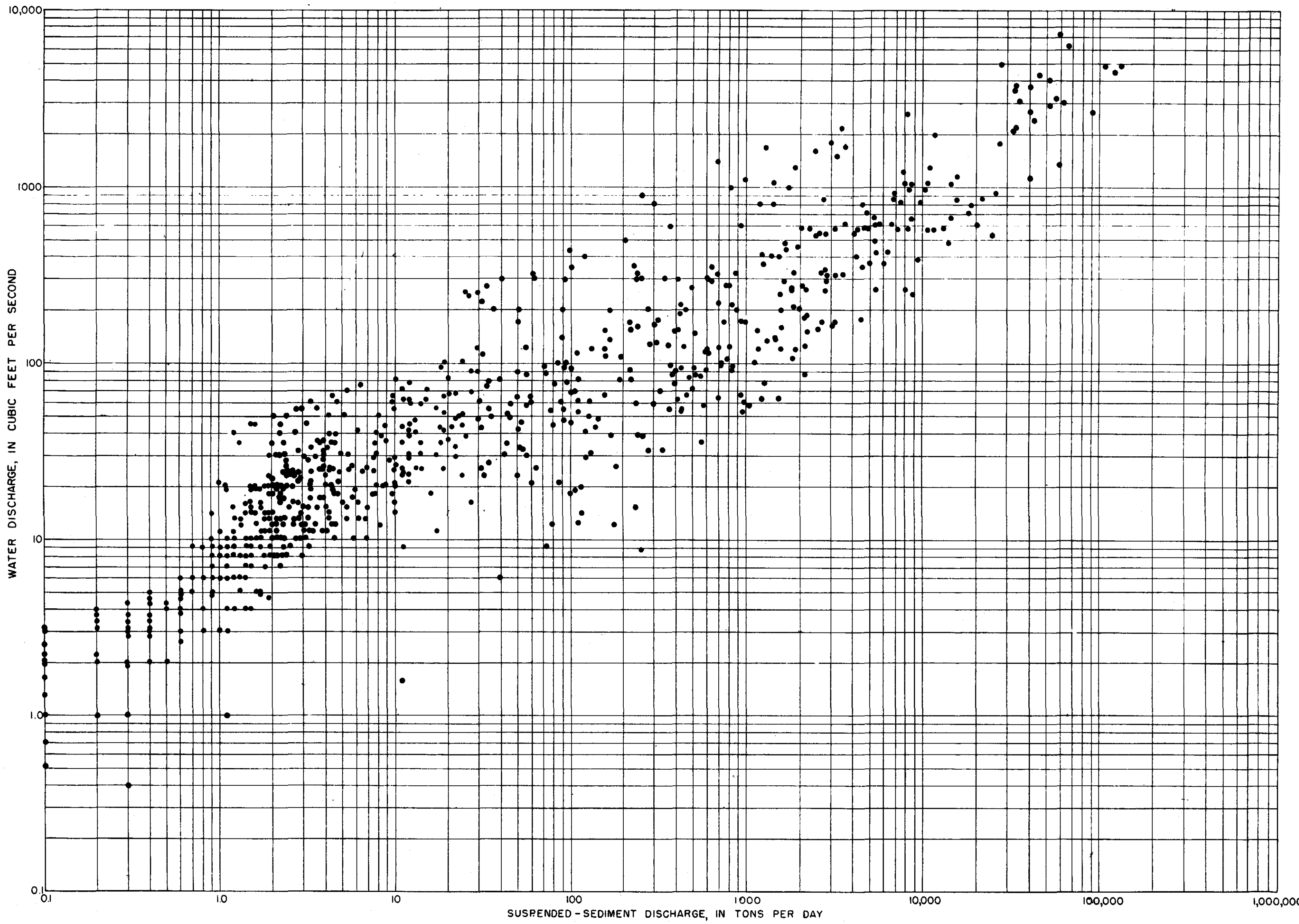


Figure 16.--Relation of suspended-sediment discharge to water discharge, Moreau River near Faith, August 15, 1946, to September 30, 1949.

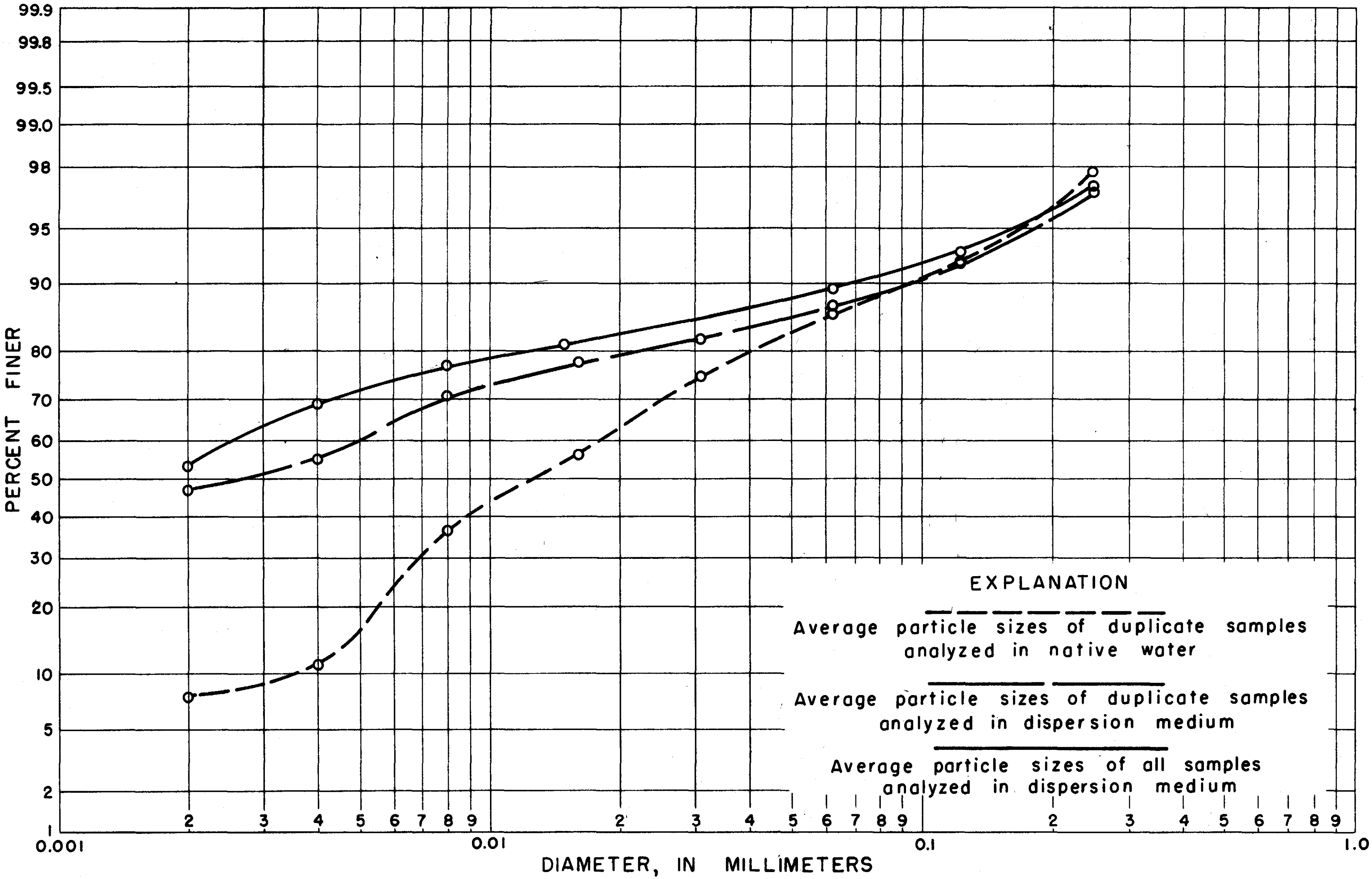


Figure 17.--Average particle-size distributions of suspended-sediment samples, Moreau River at Bixby.

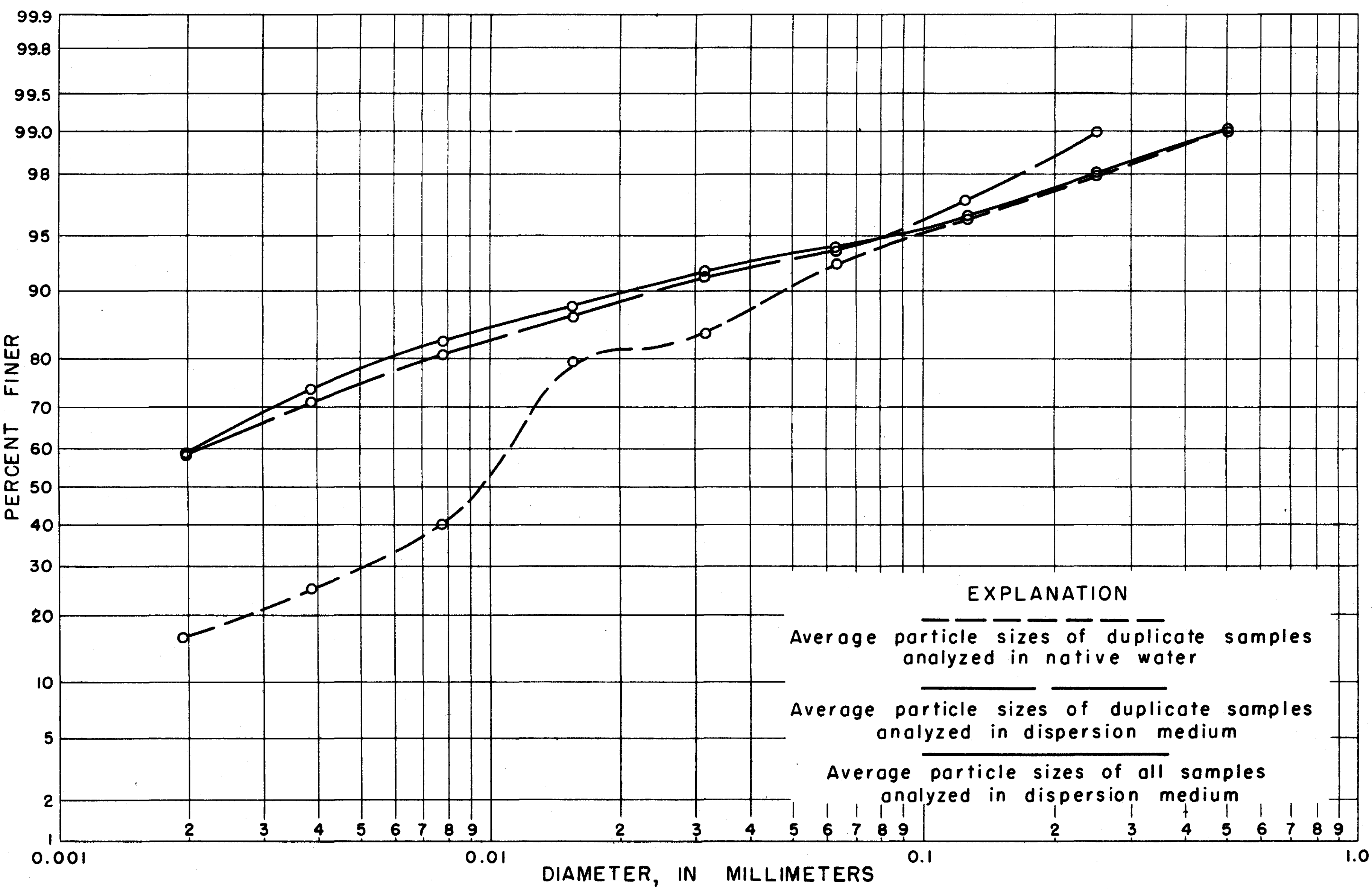


Figure 18. --Average particle-size distributions of suspended-sediment samples, Moreau River near Faith.

and (3) the cementation and compaction to which the deposit has been subjected since its deposition. The degree of assortment is particularly important in fixing porosity. Sediment of completely uniform particle size (perfectly graded sediment) will have the greatest porosity. If all particles were uniform spheres, the size of the particles would have no effect on the porosity of uniform deposits. However, deposits of silts and clays usually have greater porosity and smaller specific weight than deposits of coarser particles, partly because the range in particle size is usually greater in coarser deposits and partly because the smaller particles fill some pores between the larger particles.

The specific weight is increased and the volume of a sediment deposit is decreased as part of the interstitial water is forced out and as the sediment particles become packed closer together. The smaller the pore spaces, the greater are the friction and other forces that resist compaction of the sediment. Hence, fine-grained deposits usually compact at a much slower rate than coarse-grained deposits. The rate and amount of increase of specific weight depend not only on the particle size of the deposits but also on the method of operation of the reservoir and on the depth of the sediment deposits. The rate of compaction is probably relatively rapid during the first few years after deposition but decreases with time.

An average figure for the specific weight of a deposit that might be formed from the sediment in transport is necessary to compute the space that a given tonnage of the sediment might occupy when first deposited in a reservoir. The accuracy of such a computed average figure is affected not only by reservoir operation but also by inaccuracies in measuring the total sediment discharge and the particle sizes. At present only the suspended sediment is measured; the bed load must be estimated. Hence, only an approximate figure can be computed for the average specific weight that the sediment deposit will have soon after it accumulates in a reservoir.

The specific weight of suspended sediment was determined by a method that is based on the median particle size of the suspended sediment. This method is believed to be superior to others that apply specific weights to different size grades because it is simple and is based on actual measurements of specific weights.

This method is as follows: The median particle size of each sample that was analyzed in a dispersed state was plotted against the instantaneous suspended-sediment discharge in tons per day. (See fig. 19.) For predetermined class intervals of suspended-sediment discharge, the corresponding median particle sizes were taken from the curve of figure 19 and were listed in tables 3 and 4.

Figure 20 shows the relation between the median particle size and the specific weight of relatively uncompacted sediment deposits in reservoirs in the United States (Hembree and others, 1952, p. 83-85). The specific weights corresponding to the different median particle sizes that are listed in tables 3 and 4 were determined from figure 20. The specific weight of reservoir deposits that might be formed from the suspended sediment in the Moreau River at Bixby and near Faith was then computed (tables 3 and 4) and was found to be 51 and 50 pounds per cubic foot, respectively. These specific weights, which are for sediment deposits that have not been compacted during a long period of time or under the weight of appreciable amounts of overlying deposits, were used to convert tons of suspended sediment to acre-feet of sediment. (See table 5.) The computed volumes of sediment indicate that the probable maximum space that would be occupied by the suspended sediment that was discharged by the Moreau River at Bixby from April 28, 1949, to September 30, 1951, would be about 980 acre-feet and near Faith from August 15, 1946, to September 30, 1949, would be about 1,820 acre-feet. Flow of the Moreau River was probably appreciably above normal during the period of sediment records for the station near Faith and probably averaged much above normal during the period of sediment records at Bixby.

Table 3.--Specific weight based on median particle size for the Moreau River at Bixby

Suspended-sediment discharge: Middle of class interval (tons per day)	Suspended-sediment discharge: Total tons in class interval	Median particle size (mm)	Specific weight (lb per cu ft)	Total tons divided by specific weight
0.55	273	0.0012	42	6
5.4	1,183	.0012	42	28
60	3,600	.0012	42	86
344	13,416	.0013	43	312
1,002	28,056	.0015	44	638
1,900	15,200	.0017	45	338
3,065	9,195	.0019	46	200
4,940	34,580	.0022	46	752
8,000	32,000	.0025	47	681
12,950	64,750	.0029	48	1,349
21,000	105,000	.0035	49	2,143
34,000	136,000	.0041	51	2,667
54,500	163,500	.0049	52	3,144
88,500	177,000	.0059	53	3,340
161,000	322,000	.0073	55	5,855
----------------------	1,105,753	------------------	------------------	21,539

Specific weight in pounds per cubic foot = $\frac{1,105,753}{21,539}$ = 51.3.

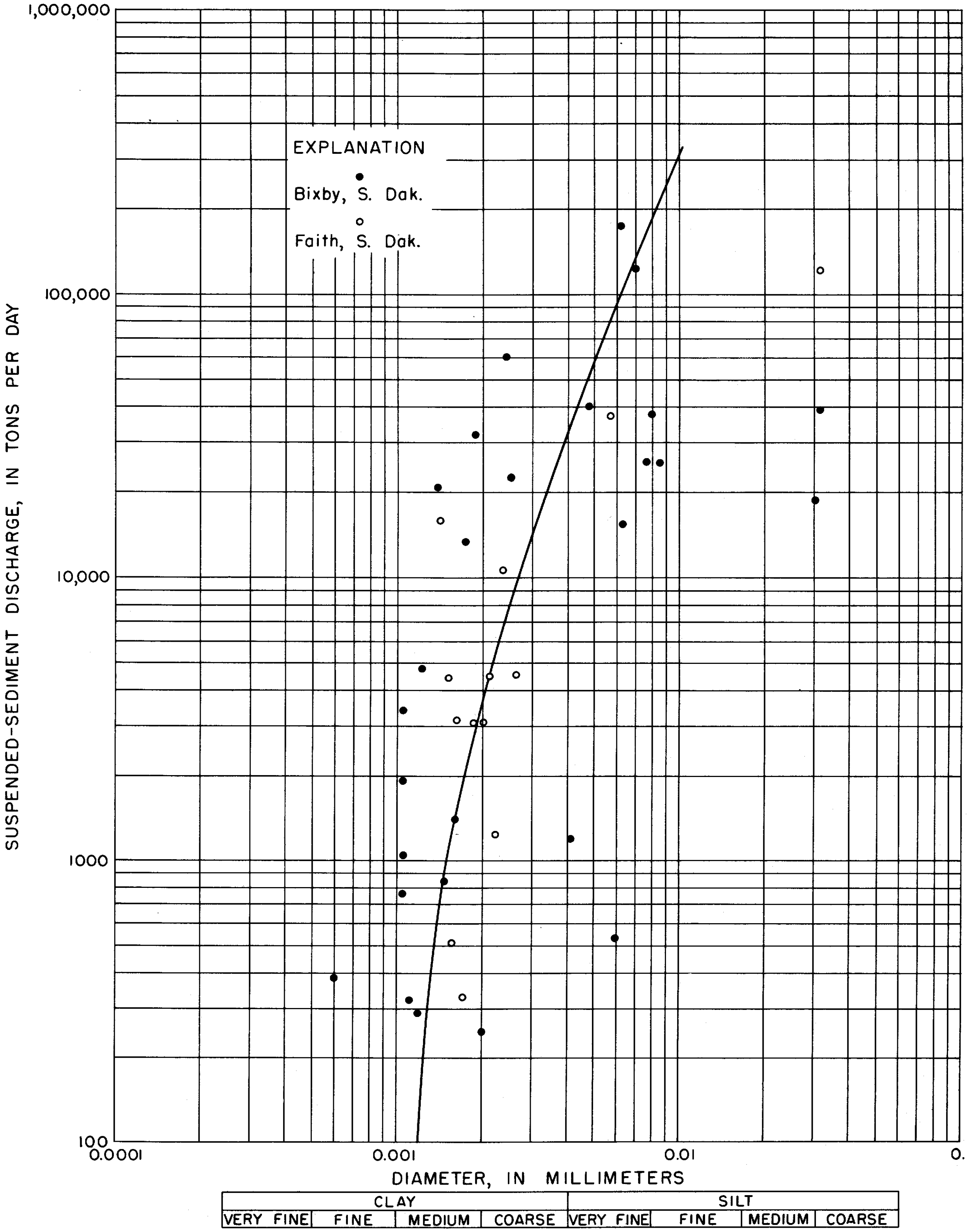


Figure 19.--Median particle size versus suspended-sediment discharge, Moreau River.

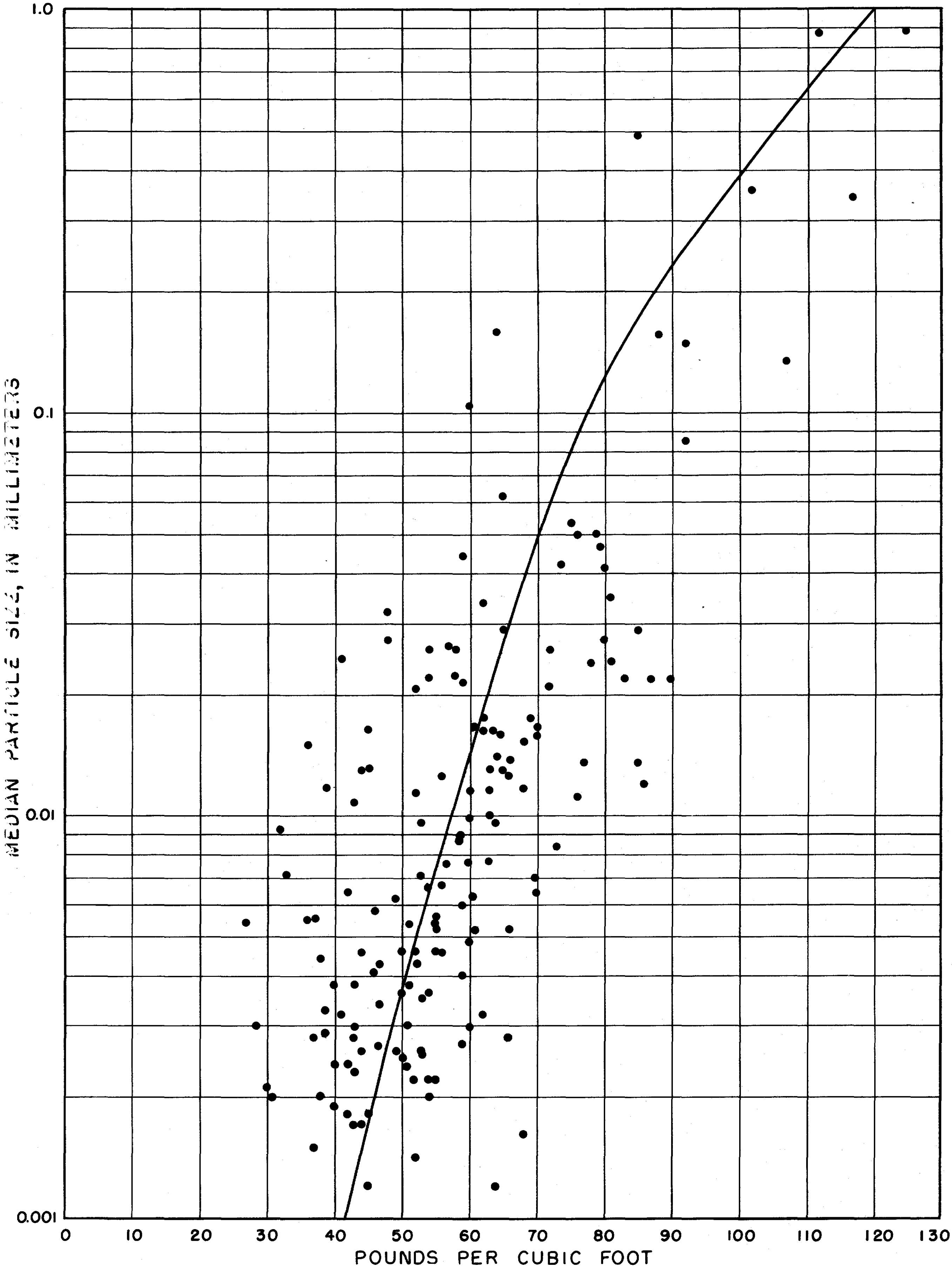


Figure 20.--Relation of specific weight of sediments deposited in reservoirs to median particle size.

Table 4.--Specific weight based on median particle size for the Moreau River near Faith

Suspended-sediment discharge		Median particle size (mm)	Specific weight (lb per cu ft)	Total tons divided by specific weight
Middle of class interval (tons per day)	Total tons in class interval			
0.5	188	0.0012	42	4
5.5	1,754	.0012	42	42
60	8,400	.0012	42	200
275	19,525	.0013	43	454
770	34,650	.0014	43	806
1,425	37,050	.0016	44	842
2,275	68,250	.0018	45	1,517
3,625	54,375	.0020	46	1,182
5,775	98,175	.0023	46	2,134
9,200	156,400	.0026	48	3,258
14,650	131,850	.0031	49	2,691
23,400	187,200	.0036	50	3,744
37,400	374,000	.0042	51	7,333
59,750	418,250	.0051	52	8,043
94,250	188,500	.0060	54	3,488
125,000	250,000	.0068	54	4,627
----------------------	2,028,567	-------------------	-----------------	40,365

$$\text{Specific weight in pounds per cubic foot} = \frac{2,028,567}{40,365} = 50.3.$$

Table 5.--Volume of suspended-sediment discharge, Moreau River

Station	Period	Suspended-sediment discharge (tons)	Volume of deposited sediment (acre-ft)
At Bixby----------------------------	Apr. 28 to Sept. 30, 1949	3,940	3
	Water year 1949-50	997,100	898
	Water year 1950-51	81,920	74
Total -------------------------	------------------------	1,082,960	975
Near Faith--------------------------	Aug. 15 to Sept. 30, 1946	32,120	29
	Water year 1946-47	1,077,000	989
	Water year 1947-48	353,600	325
	Water year 1948-49	515,400	473
Total-------------------------	------------------------	1,978,120	1,816

SUMMARY

Soils, climate, and vegetation are fairly uniform throughout the Moreau River basin. The exposed rocks are of Cretaceous and Tertiary age. The Moreau River is a meandering intermittent stream that flows in a shifting, sandy-bottomed channel.

Runoff from the basin averages about 0.7 inch per year and has been about uniform over the basin during the period of streamflow records. Some of the runoff comes from melting of snow, but most of it probably comes from rains during late spring and early summer.

The chemical quality of the water in the Moreau River and tributaries is dependent on and directly related to the lithologic character of the exposed rocks of the Pierre shale, Fox Hills sandstone, and the Hell Creek formation. Water that drains from areas underlain by the Hell Creek formation and Fox Hills sandstone contains predominantly sodium bicarbonate, whereas water from areas underlain by Pierre shale contains predominantly sodium sulfate.

Samples collected daily or infrequently at four places on the main stem and single samples collected from the tributaries for a special salinity study show the relationship between quality of water and geology and also the effects of tributary flow on the water in the main stem. The complexity of the water quality is shown by extremes in concentration and rapid changes in composition.

The suitability of the water for irrigation is determined from relatively short-term records by comparison with long-term discharge records, consideration of the significance of the calculated weighted averages, and consideration of certain ionic relationships. On the basis of concentration and percent sodium, the water in the Moreau River at Bixby is classed as permissible to doubtful for irrigation. On the basis of the ratio of bicarbonate to calcium plus magnesium, percent sodium, and hydrogen ion concentration, the water is conducive to the formation of black alkali on soils during dry periods. The quality of the water of the Moreau River is so poor that all other pertinent factors must be considered before the water is used for irrigation.

During 3 complete water years immediately preceding October 1, 1949, the discharge of suspended sediment of the Moreau River averaged about 650,000 tons annually at the gaging station near Faith and was transported by an annual water discharge of about 130,000 acre-feet. During the water years of 1950 and 1951, the Moreau River at Bixby discharged about 1,080,000 tons of suspended sediment and 170,000 acre-feet of water. About 90 percent of this discharge of sediment and water occurred during the water year of 1950 when the streamflow was nearly three times the normal. Sediment yields per square mile may be no greater at Bixby than at the station near Faith.

Suspended sediment transported by the Moreau River is mostly fine material. The averages of median particle sizes (not weighted with water discharge) were, by extrapolation, about 0.0017 millimeter for the station at Bixby and about 0.0015 millimeter for the station near Faith. Only 6 percent of the suspended sediment for the station near Faith and only 10 percent of the suspended sediment for the station at Bixby were coarser than the lower limit of the sand sizes, 0.062 millimeter.

Low channel slopes and small particle sizes indicate that bed-load discharge would be only a small percentage of total sediment discharge, but bed-load discharge was not computed because too few data were available.

Particle sizes of the suspended sediment of the Moreau River at Bixby and near Faith indicate specific weights of 51 and 50 pounds per cubic foot, respectively, for deposits that might form in a reservoir without being compacted over long periods of time or under the weight of appreciable quantities of overlying deposits. On the basis of these specific weights, the suspended sediment discharged at the station at Bixby from April 28, 1949, to September 30, 1951, would occupy a volume of about 980 acre-feet, and the suspended sediment discharged at the station near Faith from August 15, 1946, to September 30, 1949, would occupy about 1,820 acre-feet of space.

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TABLES OF BASE DATA

Table 6.--Mineral constituents and related physical measurements, salinity survey, April 12 to 16, 1949

[Analytical results in parts per million except as indicated]

No. on map (fig. 1)	Source	Discharge (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
1	Sand Creek at Mason----------------	5.71	53	18	0.01	37	17	260	8.0	362	0	438	3.0	0.3	1.9	0.14	964	163	0	77	1,490	8.0
2	South Fork Moreau River at Hoover-	108	46	17	.01	69	58	193	8.0	109	0	712	7.0	.4	1.3	.34	1,120	411	321	50	1,570	7.7
3	South Fork Moreau River near Inland---------------------------	196	51	14	.01	63	39	153	2.0	89	0	548	6.2	.3	.8	.17	911	318	245	51	1,220	7.4
4	North Fork Moreau River near Redig----------------------------	2.28	57	19	.01	12	6.0	85	6.0	238	0	54	2.0	.3	1.5	.27	318	55	0	73	499	7.8
5	North Fork Moreau River near Zeona----------------------------	64.9	48	11	.02	13	1.5	123	1.6	228	0	112	2.3	.1	1.1	.15	390	38	0	87	587	8.0
6	Spring Creek at Zeona-------------	1.22	49	8.3	.05	10	2.0	33	2.4	98	0	27	.8	.4	1.5	.18	156	33	0	67	-----	7.1
7	Sheep Creek at mouth--------------	--------	56	9.9	.40	19	7.4	93	6.4	182	0	122	2.0	.4	1.3	----	378	78	0	70	566	7.5
8	North Fork Moreau River at mouth--	34.3	--	16	.02	16	7.3	116	5.2	229	8	130	2.0	.2	1.6	.33	436	70	0	77	672	8.3
9	Moreau River near Imogene---------	318	51	9.4	.01	51	29	133		130	0	401	6.0	.4	2.5	.09	747	247	140	54	988	7.5
10	Moreau River at Bixby-------------	298	48	11	.01	50	30	140	2.8	107	0	442	5.0	.3	.8	.22	784	248	160	55	1,100	7.5
11	Deep Creek near Usta--------------	--------	55	10	.05	17	3.3	44	2.4	117	0	52	.5	.3	1.7	.27	208	56	0	62	343	7.4
12	Deep Creek at mouth---------------	37.7	55	11	.62	18	7.4	37	7.2	116	0	56	2.0	.4	1.8	----	212	76	0	49	320	7.2
13	Rabbit Creek at Sorum-------------	13.5	51	14	.01	27	10	72		196	0	96	1.0	.3	2.4	.05	351	109	0	59	478	7.5
14	Antelope Creek near Date----------	11.5	52	7.2	.04	14	3.8	77		180	0	63	1.0	.5	1.0	----	252	50	0	74	416	7.3
15	Rabbit Creek at Ada---------------	67.4	52	11	.04	21	4.8	102	1.2	218	0	106	3.0	.3	1.2	.18	378	72	0	75	559	7.7
16	Moreau River near Faith-----------	594	50	11	.01	33	14	104	4.0	113	0	262	3.6	.2	1.0	.14	505	140	47	61	735	7.6
17	Flint Rock Creek at mouth---------	44.9	47	8.0	.01	25	9.8	43		153	0	61	3.5	.1	2.3	.07	255	103	0	48	382	7.4
18	Thunder Butte Creek at mouth------	11.0	46	14	.10	16	3.8	29		78	0	52	.1	.2	.0	----	180	56	0	53	251	7.4
19	Worthless Creek at mouth----------	18.9	49	7.9	.02	8.0	8.5	31		76	0	50	4.0	.3	2.2	.00	176	55	0	55	237	7.2
21	Little Moreau River near White Horse----------------------------	27.4	53	7.2	.01	27	7.6	27		98	0	69	2.0	.3	2.5	.02	209	99	19	38	305	7.9
22	Moreau River at Promise-----------	1,630	53	8.3	.01	46	12	64		113	0	196	4.0	.3	1.9	.07	422	165	72	46	575	7.8

Table 7.--Mineral constituents and related physical measurements, Moreau River at Bixby, March 1949 to September 1951

[Analytical results in parts per million except as indicated]

Date of collection	Mean discharge (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
March to September 1949																							
[Analyses for periods that exceed 1 day were made of samples composited by equal volume]																							
Mar. 6, 1949	50	--	12	0.02	19	6.8	107	5.2	172	0	160	4.0	0.2	2.1	0.11	426	0.58	58	76	0	74	661	8.0
Mar. 7	150	--	14	.03	13	5.0	48	3.6	100	0	72	2.0	.1	1.2	----	224	.30	91	53	0	64	333	7.6
Mar. 8	200	--	14	.30	8.9	1.5	36	2.8	69	0	42	6.0	.2	2.0	.00	160	.22	86	28	0	71	225	7.8
Mar. 9	300	--	28	.08	12	.9	64	4.0	96	0	84	7.6	.2	1.6	.02	258	.35	209	34	0	78	362	8.1
Mar. 10	500	--	39	.06	14	4.5	71	2.0	44	0	85	----	.2	1.4	.05	306	.42	413	54	18	73	472	7.6
Mar. 11	400	--	21	.12	11	2.6	61	2.0	92	0	86	4.6	.2	1.4	.03	244	.33	264	38	0	77	364	7.9
Mar. 12	300	--	24	.20	9.9	1.1	56	3.2	62	0	73	19	.2	1.3	.04	232	.32	188	29	0	79	330	7.8
Mar. 13-14	225	--	71	.12	18	6.0	92	3.6	50	0	166	-----	.2	1.6	.04	446	.61	271	70	29	73	567	6.9
Mar. 15-16	140	--	36	.02	20	8.6	78	5.6	106	0	160	5.3	.4	1.3	----	366	.50	138	86	0	65	529	7.8
Mar. 17	120	--	30	.05	18	5.0	55	6.0	104	0	98	2.9	.4	1.7	----	276	.38	89	66	0	62	401	7.6
Mar. 18	110	--	46	.02	15	5.4	58	6.0	102	0	98	4.6	.4	1.1	.00	278	.38	83	60	0	65	377	7.6
Mar. 19-20	100	--	29	.02	14	4.0	58	5.6	101	0	92	2.0	.4	1.4	----	244	.33	66	52	0	68	352	7.6
Mar. 21	100	--	35	.02	14	5.0	52	7.6	96	0	90	2.7	.4	1.3	----	248	.34	67	56	0	63	346	7.7
Mar. 23, 11:00 a.m.	3,280	--	50	.02	11	3.3	39	6.4	100	0	46	1.5	.4	1.0	----	190	.26	1/ 2,290	41	0	63	256	7.9
Mar. 23, 4:30 p.m.	3,280	--	58	.05	19	6.4	55	7.6	83	0	104	18	.2	1.1	----	300	.41	--------	74	6	59	410	7.5
Mar. 24, 10:30 a.m.	2,790	--	74	.02	14	5.4	38	6.0	68	0	80	4.5	.2	1.0	.04	264	.36	1/ 2,010	57	1	56	300	7.5
Mar. 24, 1:30 p.m.	2,790	--	80	.02	14	4.4	39	12	60	0	94	2.5	.4	1.0	.00	278	.38	--------	53	4	55	304	7.3
Mar. 24, 4:00 p.m.	2,790	--	32	.02	20	8.3	40	4.4	64	0	114	2.9	.4	1.3	----	258	.35	--------	84	32	49	377	7.3
Mar. 25	2,710	--	12	.10	36	17	62	5.6	96	0	206	4.0	.4	1.6	----	414	.56	3,030	160	81	45	613	7.3
Mar. 26	1,780	--	9.0	.20	34	13	49	5.6	108	0	148	3.0	.4	1.3	----	346	.47	1,660	139	50	42	530	6.9
Mar. 27, 11:45 a.m.	1,780	36	10	----	8.0	1.5	31		80	0	22	1.8	.6	1.9	----	148	.20	1/ 1,160	28	0	60	168	7.0
Mar. 27, 4:55 p.m.	1,780	--	12	.10	33	12	45	4.8	92	0	144	2.2	.4	1.4	----	334	.45	--------	132	57	42	504	7.1
Mar. 28, 9:45 a.m.	2,190	--	9.0	.02	29	13	68	.4	79	0	196	2.6	.2	1.2	.09	376	.51	1/ 2,580	126	61	54	560	7.3
Mar. 28, 12:00 m.	2,190	--	8.8	.10	45	21	81		106	0	270	3.2	.4	1.9	----	530	.72	--------	199	112	47	762	7.2
Mar. 28, 2:15 p.m.	2,190	--	11	.01	37	15	66		89	0	207	3.5	.3	2.2	.05	404	.55	--------	154	81	48	583	7.2
Mar. 29, 10:00 a.m.	1,910	--	9.8	.01	25	13	79	3.6	72	0	218	3.0	.2	1.3	.10	411	.56	1/ 2,160	116	57	59	607	7.3
Mar. 29, 3:45 p.m.	1,910	--	8.0	.01	37	17	64		80	0	218	4.5	.3	2.5	.00	425	.58	--------	163	97	46	606	7.2
Mar. 30	1,500	--	15	.10	38	16	71	4.8	100	0	224	3.2	.3	.9	----	452	.61	1,830	161	79	48	657	7.3
Mar. 31	1,120	--	12	.10	37	17	71	4.8	88	0	240	2.6	.4	.7	----	454	.62	1,370	163	91	48	758	7.0
Apr. 1-2	763	--	15	.20	44	20	78	4.0	92	0	280	4.2	.2	1.4	----	526	.72	1,080	193	118	46	821	7.5
Apr. 3	595	--	10	.10	45	22	92	4.8	88	0	310	4.0	.4	.9	----	582	.79	935	203	131	49	848	7.2
Apr. 4	560	--	15	.40	48	22	106	1.6	102	0	338	4.6	.2	1.0	----	618	.84	934	211	127	52	908	7.5
Apr. 5-8	741	--	13	.02	50	23	107	4.8	99	0	364	3.4	.2	1.5	.20	648	.88	1,300	220	139	51	911	7.8
Apr. 9	708	48	11	.10	50	21	100		111	0	320	2.2	.3	1.2	----	618	.84	1,180	212	121	51	858	7.1
Apr. 10	550	--	15	.01	39	18	100	1.6	86	0	300	3.7	.2	1.0	.06	559	.76	830	172	100	56	794	7.4

See footnotes at end of table, p. 42.

Table 7.--Mineral constituents and related physical measurements, Moreau River at Bixby, March 1949 to September 1951--Continued

[Analytical results in parts per million except as indicated]

Date of collection	Mean discharge (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
March to September 1949--Continued [Analyses for periods that exceed 1 day were made of samples composited by equal volume]																							
Apr. 11-12, 1949--	417	55	11	0.02	51	23	112	4.4	116	0	364	3.6	0.3	1.8	----	664	0.90	748	222	127	52	934	7.5
Apr. 12 2/--------	374	58	12	.02	37	12	88	.8	115	0	234	4.0	.0	1.6	----	476	.65	481	142	48	57	706	7.0
Apr. 13-15--------	305	51	14	.02	52	24	137	4.0	127	0	408	3.6	.1	1.3	----	770	1.05	634	229	125	56	1,070	7.2
Apr. 13 2/--------	305	48	11	.01	50	30	140	2.8	107	0	442	5.0	.3	.8	0.22	784	1.07	645	248	160	55	1,100	7.5
Apr. 16-----------	311	54	11	.02	60	33	169		142	0	508	4.0	.1	1.5	----	924	1.26	776	285	169	56	1,250	7.1
Apr. 17-18--------	168	53	12	.02	73	43	187	3.2	134	0	640	6.4	.1	1.3	----	1,030	1.40	467	359	249	53	1,480	7.5
Apr. 19-23--------	77	60	12	.02	65	39	202	6.0	190	0	584	6.4	.3	1.0	----	1,010	1.37	210	323	167	57	1,460	7.4
Apr. 24-May 2-----	46	--	14	.02	75	40	266	5.6	297	0	660	7.6	.3	1.2	.37	1,220	1.66	152	352	108	62	1,720	7.7
May 3-5-----------	93	--	16	.02	65	33	294	6.4	331	0	646	5.6	.2	2.2	----	1,230	1.67	309	298	27	68	1,720	7.7
May 6-9-----------	37	68	15	.02	88	50	356	8.8	307	0	900	6.2	.4	1.8	----	1,580	2.15	158	425	173	64	2,210	7.6
May 10-19---------	15	68	13	.02	68	50	397	8.8	337	0	948	10	.4	.7	.31	1,660	2.26	67	375	99	69	2,390	8.0
May 20-31---------	12	69	8.8	.02	42	49	459	7.6	442	0	904	12	.5	.9	.34	1,710	2.33	55	307	0	76	2,430	8.0
June 1-10---------	9.6	70	7.2	.02	55	48	498	10	362	31	976	12	.6	.7	.43	1,820	2.48	47	335	0	76	2,640	8.3
June 11-19--------	6.6	70	6.8	.02	40	48	535	13	435	28	1,050	14	.8	.9	.48	1,950	2.65	35	298	0	79	2,850	8.4
June 20-23--------	4.6	74	7.1	.08	55	59	585	7.2	382	28	1,260	15	.6	.8	----	2,210	3.01	27	380	20	77	3,070	8.7
June 24-29--------	3.2	74	8.8	.08	54	54	630	9.6	427	24	1,280	16	.6	1.0	.45	2,290	3.11	20	357	0	79	3,150	8.6
June 30-July 1----	1.9	83	6.3	.12	41	50	675	10	489	10	1,330	18	.7	.8	----	2,390	3.25	12	308	0	82	3,280	8.3
July 2-3----------	1.7	81	8.2	.04	40	50	699	16	456	26	1,320	17	1.0	1.9	.60	2,410	3.28	11	306	0	82	3,140	8.5
July 4-6----------	4.4	--	9.0	.04	39	44	717	12	488	47	1,280	18	1.2	1.9	.87	2,410	3.28	29	279	0	84	3,290	8.8
July 7-31---------	1.4	75	7.7	.02	25	42	828	15	701	25	1,340	21	1.0	.8	.70	2,660	3.62	10	235	0	88	3,570	8.4
Aug. 1-8----------	3/ 0	75	9.4	.10	16	50	1,150	12	858	92	1,720	32	1.4	3.8	1.0	3,520	4.79	0	246	0	91	4,730	8.8
Aug. 9-31---------	3/ 0	70	9.8	.16	19	54	1,360	14	954	126	2,050	38	1.2	3.5	1.1	4,160	5.66	0	270	0	91	5,430	8.9
Sept. 14-30-------	1.4	58	7.0	.06	17	35	991	11	756	87	1,460	30	.8	1.7	.79	3,020	4.11	11	187	0	91	4,140	8.9
Weighted average 4/----------	5/ 171	--	22	0.07	35	16	87	4.9	6/ 105	---	242	6.2	0.3	1.4	----	487	0.66	225	154	68	54	698	---
Estimated weighted average 7/------	-------	--	----	----	34	15	87	4.8	-------	---	-----	----	---	---	----	-----	----	--------	---	---	55	735	---
October 1949 to September 1950 [Analyses for periods that exceed 1 day were made of samples composited by discharge]																							
Oct. 1-3, 1949----	3.2	58	7.0	0.06	17	35	991	11	756	87	1,460	30	0.8	1.7	0.79	3,020	4.11	26	187	0	91	4,140	8.9
Oct. 4-12---------	16	51	8.4	.06	14	14	708	5.6	824	79	760	16	.6	2.0	.60	2,020	2.75	87	93	0	94	2,930	8.9
Oct. 13-26--------	7.0	46	15	.12	20	6.5	316	6.0	450	20	356	7.0	.3	2.6	.20	988	1.34	19	62	0	89	1,510	8.5
Oct. 27-31--------	8.0	48	14	.08	27	2.2	401	5.6	560	24	408	9.0	.3	1.3	.30	1,170	1.59	25	77	0	91	1,760	8.3
Nov. 1-30---------	4.1	42	13	.08	32	8.3	473	5.2	640	20	532	10	.4	1.0	.30	1,410	1.92	16	114	0	90	2,080	8.4
Dec. 1-21---------	3.2	33	16	.08	51	34	1,030	13	1,390	45	1,200	24	.3	.9	.67	3,100	4.22	27	267	0	89	4,370	8.4

Note: For Apr. 16, the value 169 is printed across the Sodium and Potassium columns (sodium and potassium combined).

Mar. 6-9, 1950----	123	34	16	0.02	16	4.1	134	4.6	168	0	190	4.0	.4	2.1	.10	510	.69	169	57	0	82	701	7.3
Mar. 10-----------	100	34	13	.04	39	12	208	6.8	174	0	415	17	.4	3.6	.10	844	1.15	228	147	4	74	1,200	7.2
Mar. 14-Apr. 1----	126	--	13	.04	20	5.7	87	4.5	130	0	140	3.0	.4	2.2	.10	356	.48	121	74	0	70	525	7.2
Apr. 3------------	2,900	33	13	----	12	2.3	24	5.2	56	0	40	4.0	.4	4.4	.10	180	.24	1,410	40	0	53	176	7.1
Apr. 4-6----------	2,800	34	16	.04	23	7.1	41	3.9	83	0	95	3.0	.2	2.0	.10	242	.33	1,830	87	19	49	351	7.1
Apr. 7------------	6,590	32	16	.08	30	7.7	33	3.8	146	0	55	2.0	.2	1.9	.10	222	.30	3,950	107	0	39	350	7.4
Apr. 11-14--------	1,260	36	17	.04	31	8.4	50	4.0	107	0	120	2.5	.2	2.1	.10	316	.43	1,080	112	24	48	444	7.2
Apr. 15-17--------	7,600	42	15	.04	22	5.6	41	3.3	98	0	78	2.5	.2	1.0	.10	220	.30	4,510	78	0	52	332	7.4
Apr. 18-20--------	1,350	43	12	.02	36	10	57	4.2	99	0	170	2.5	.2	2.6	.10	346	.47	1,260	131	50	48	521	7.5
Apr. 21-----------	363	45	11	.04	46	17	83	4.9	110	0	260	3.0	.2	1.4	.20	508	.69	498	185	95	49	736	7.1
Apr. 22-26--------	280	43	13	.02	41	15	114	5.1	144	0	273	4.0	.2	1.7	.10	558	.76	422	164	46	59	819	7.3
Apr. 27-----------	160	47	12	.04	59	20	148	5.2	172	0	388	5.0	.2	1.1	.20	728	.99	314	229	88	58	1,050	7.5
Apr. 28-May 15----	470	--	16	.02	57	22	143	5.8	144	0	400	5.0	.2	1.4	.10	754	1.03	957	233	115	56	1,050	7.5
May 16-31---------	45	62	18	.02	66	30	234	7.0	264	0	545	7.5	.2	1.7	.10	1,040	1.41	126	288	72	63	1,470	8.0
June 1-30---------	30	70	9.8	.04	75	43	440	8.9	380	0	985	11	.5	1.3	.20	1,760	2.39	143	363	51	72	2,320	7.9
July 1-31---------	14	72	8.8	.04	83	46	390	9.2	316	0	935	11	.5	1.1	.20	1,640	2.23	62	398	139	67	2,140	7.9
Aug. 1-5----------	4.1	67	12	.04	39	30	480	9.2	455	0	845	16	.7	1.3	.40	1,660	2.26	18	220	0	82	2,360	7.9
Aug. 6-8----------	75	54	14	.16	20	4.4	160	6.0	216	0	230	7.0	.5	3.5	.40	574	.78	116	68	0	82	838	7.9
Aug. 9-31---------	6.7	67	10	.06	26	12	377	7.3	456	8	525	10	.5	2.2	.40	1,200	1.63	22	116	0	87	1,770	8.3
Sept. 1-19--------	4.5	65	9.8	.06	24	19	472	7.4	514	14	680	14	.5	1.4	.55	1,500	2.04	18	137	0	88	2,160	8.3
Sept. 20-24-------	34	64	17	.50	20	3.4	234	6.4	306	0	318	8.0	.6	2.4	.40	802	1.09	74	64	0	88	1,140	7.8
Sept. 25-30-------	5.2	57	10	.06	26	11	384	6.7	481	11	495	10	.5	1.2	.07	1,190	1.62	17	110	0	88	1,760	8.3
Weighted average 4/----------	8/ 234	--	15	0.04	31	9.8	75	6.6	6/ 124	--	166	3.4	0.2	1.7	0.11	380	0.52	240	118	16	56	544	---
Estimated weighted average 7/------	--------	--	----	----	30	9.5	70	6.3	------	---	------	----	---	---	----	-----	----	--------	---	--	56	518	---
October 1950 to September 1951 [Analyses for periods that exceed 1 day were made of samples composited by discharge]																							
Oct. 1-31, 1950---	6.36	--	10	0.04	27	22	410	6.2	543	0	570	11	0.5	1.5	0.10	1,330	1.81	22.8	160	0	84	1,910	8.1
Nov. 1-30---------	5.27	--	12	.04	41	27	618	7.1	753	15	825	16	.5	.7	.20	1,930	2.62	27.5	212	0	86	2,670	8.3
Dec. 1-20---------	2.00	--	14	.10	66	33	824	9.4	1,010	30	1,140	29	.6	1.3	.50	2,640	3.59	14.3	300	0	85	3,900	8.3
Jan. 1-28, 1951---	3.80	--	10	.10	81	34	740	6.6	980	18	1,050	22	.6	1.0	.47	2,450	3.33	25.1	340	0	82	3,540	8.3
Feb. 1-26---------	.85	--	10	.10	85	35	636	6.2	758	16	1,020	22	.6	.8	.48	2,210	3.01	5.07	358	0	77	3,130	8.2
Mar. 5------------	1.5	--	11	.10	89	38	656	6.1	820	14	1,070	23	.6	.9	.40	2,320	3.16	9.40	378	0	78	3,260	8.2
Mar. 12-----------	1.5	--	11	.10	77	42	644	5.7	886	24	990	25	.6	1.1	.45	2,260	3.07	9.15	364	0	79	3,180	8.3
Mar. 19-31--------	116.7	--	9.0	.10	34	9.5	196	4.8	262	0	330	7.5	.6	1.8	.15	772	1.05	243	124	0	76	1,130	8.1
Apr. 1-8----------	37.8	--	9.8	.03	28	13	213	4.3	258	0	350	6.0	.3	2.0	.26	754	1.03	76.9	122	0	78	1,120	7.9
Apr. 9-May 8------	10.7	--	8.2	.04	40	19	366	5.0	458	0	585	11	.4	1.1	.29	1,260	1.71	36.4	178	0	81	1,820	8.1
May 9-11----------	24.0	--	12	.12	34	11	374	6.6	452	0	568	4.5	.5	3.5	.31	1,240	1.69	80.4	129	0	86	1,800	8.1
May 12-27---------	9.39	--	6.9	.03	26	21	524	6.7	500	19	790	13	.6	1.0	.43	1,660	2.26	42.1	153	0	88	2,350	8.4
May 28-31---------	38.3	--	21	.06	25	9.8	333	6.6	392	0	508	7.5	.6	4.1	.18	1,110	1.51	115	103	0	87	1,670	7.9
June 2-5----------	138.3	--	16	.04	18	4.1	246	4.9	338	0	310	3.5	.5	5.2	.16	782	1.06	292	62	0	89	1,190	8.2
June 6------------	102	--	15	.06	91	47	482	8.8	290	0	1,180	11	.4	3.4	.19	1,980	2.69	545	421	183	71	2,720	8.1
June 7-9----------	46.0	--	15	.04	52	25	352	9.2	290	10	720	7.5	.5	6.4	.16	1,340	1.82	166	231	0	76	1,920	8.3
June 10-13--------	16.3	--	----	----	59	31	387	7.2	386	---	765	10	---	.1	----	-----	----	--------	276	0	75	-----	---
June 14-18--------	14.6	--	10	.05	32	19	333	6.3	393	0	553	7.0	.5	3.0	.21	1,160	1.58	45.7	160	0	81	1,720	8.1
June 19-----------	31	--	15	.10	31	7.2	240	6.6	258	0	378	4.0	.6	7.6	.13	854	1.16	71.5	107	0	82	1,260	8.0
June 20-30--------	48.5	--	14	.04	42	21	295	6.5	301	0	570	6.0	.5	2.8	.17	1,110	1.51	145	193	0	76	1,610	7.8

See footnotes at end of table, p. 42.

Table 7.--Mineral constituents and related physical measurements, Moreau River at Bixby, March 1949 to September 1951--Continued

[Analytical results in parts per million except as indicated]

Date of collection	Mean discharge (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
October 1950 to September 1951--Continued [Analyses for periods that exceed 1 day were made of samples composited by discharge]																							
July 1-2, 1951----	10	--	----	----	46	24	261	6.2	245	---	555	8.0	---	0.3	----	-----	----	--------	214	13	72	-----	---
July 3-4----------	112.5	--	15	0.04	21	6.7	174	5.3	249	0	246	3.0	0.4	3.2	0.11	614	0.84	187	80	0	81	930	7.8
July 5------------	88	--	15	.20	15	3.6	107	4.2	194	0	122	2.0	.6	2.3	.07	386	.52	91.7	53	0	80	547	7.5
July 6-9----------	81.5	--	13	.03	46	20	208	7.0	197	0	488	5.5	.5	3.5	.13	902	1.23	198	196	34	69	1,310	7.6
July 10-26--------	7.14	--	9.4	.03	39	27	285	7.4	246	0	623	9.0	.5	3.2	.24	1,120	1.52	21.6	207	5	74	1,660	8.0
July 27-31--------	.54	--	8.2	.04	22	23	418	7.9	275	17	775	12	.2	1.9	.41	1,420	1.93	2.07	151	0	85	2,090	8.5
Aug. 1-11---------	2.15	--	8.4	.04	25	19	408	8.6	280	10	770	12	.6	2.5	.36	1,400	1.90	8.13	142	0	85	2,050	8.2
Aug. 12-16--------	357.6	--	14	.20	27	7.9	124	4.9	197	0	193	5.0	.4	5.0	----	490	.67	473	100	0	72	744	7.8
Aug. 17-31--------	20.2	--	12	.04	34	13	180	6.4	209	0	340	4.0	.2	2.0	.18	716	.97	39.1	139	0	73	1,060	7.6
Sept. 1-30--------	14.6	--	13	.04	22	7.1	237	5.6	348	0	290	4.5	.4	2.6	.21	764	1.04	30.1	84	0	85	1,150	7.9
Weighted average 4/----------	9/ 23.7	--	12	0.09	33	13	246	5.2	6/ 308	---	402	6.8	0.5	6.5	0.19	885	1.20	56.6	136	0	79	1,300	---
Estimated weighted average 7/------	--------	--	----	----	33	14	250	5.2	-----	---	-----	----	---	---	----	-----	----	--------	---	--	79	1,300	---

1 Mean for day.
2 Not included in weighted average.
3 Ponded--no flow.
4 Weighted average for period sampled only.
5 Mean discharge for water year is 97.0 cfs.
6 Includes carbonate as bicarbonate.
7 On basis of complete water year.
8 Mean discharge for water year is 216 cfs.
9 Mean discharge for water year is 21.9 cfs.

Table 8.--Mineral constituents and related physical measurements, Moreau River near Faith, April 1941 to September 1949

[Analytical results in parts per million except as indicated]

Date of collection	Mean discharge (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
April 1941 to September 1946																							
Apr. 16, 1941 1/---	2/ 300	--	----	----	19	5.2	168	----	304	--	190	2.1	---	0.6	----	542	----	-------	68	0	82	850	7.4
Sept. 19, 1942 1/--	2/ 4	--	----	----	52	11	200	----	---	--	-----	----	---	---	----	832	----	-------	175	---	71	1,270	7.7
Nov. 6 1/----------	2/ 10	--	----	----	29	18	439	----	---	--	-----	----	---	---	----	1,410	----	-------	148	---	87	2,100	8.3
Apr. 14, 1943 1/---	2/ 51	--	----	----	46	23	138	----	---	--	-----	----	---	---	----	634	----	-------	208	---	59	910	7.9
June 14 1/---------	2/ 2,740	--	----	----	17	3.8	102	----	---	--	-----	----	---	---	----	270	----	-------	260	---	79	560	7.5
July 9 1/----------	2/ 219	--	----	----	27	10	104	----	---	--	-----	----	---	---	----	460	----	-------	110	---	67	690	7.3
May 7, 1945 1/-----	2/ 28	--	----	----	57	10	59	----	247	--	107	12	---	.1	----	432	----	-------	187	0	41	1,690	8.4
Nov. 29------------	1	--	4.9	0.04	32	25	638	8.4	844	0	855	16	0.5	.5	----	2,000	2.72	-------	183	0	88	2,780	7.8
June 5, 1946-------	2/ 367	--	----	.05	86	22	211		160	0	598	7.0	.3	.2	----	1,010	1.37	-------	305	174	60	1,290	7.8
June 26------------	2/ 192	--	----	.10	35	14	117		148	0	260	4.0	.3	.6	----	521	.71	-------	145	24	64	755	7.4
July 16------------	2/ 21.1	--	----	.05	97	42	225		200	9	685	10	.5	.9	----	1,170	1.59	-------	415	236	54	1,520	8.3
Sept. 5------------	2/ 1.31	--	----	.05	41	37	586		408	0	1,130	10	.6	3.2	----	2,010	2.73	-------	254	0	83	2,770	8.2
October 1946 to September 1947 [Analyses for periods that exceed 1 day were made of samples composited by equal volume]																							
Oct. 2, 1946-------	13	--	----	0.00	34	13	198		230	0	359	4.0	0.4	0.6	----	745	1.01	26	138	0	76	987	7.4
Mar. 26, 1947------	2,010	--	12	1.0	24	10	51	7.4	92	0	126	8.0	.4	.8	0.09	287	.39	1,560	101	26	55	436	7.5
Apr. 9-18----------	424	41	7.0	.10	22	9.2	274	29	141	0	575	7.0	.2	2.0	.19	962	1.31	1,100	93	0	82	1,300	7.4
Apr. 19-28---------	90	43	6.0	.10	22	5.7	294	4.0	222	0	507	8.0	.2	2.0	.19	960	1.31	233	78	0	88	1,390	7.8
Apr. 29-May 9------	44	52	5.0	.07	24	10	448	18	355	0	756	12	.4	2.0	.37	1,450	1.97	274	101	0	89	1,880	8.1
May 10-19----------	23	56	4.0	.07	24	12	474	21	380	12	764	13	.4	2.0	.37	1,520	2.07	94	109	0	88	2,010	8.2
May 20-31----------	16	52	4.0	.05	20	11	503	21	378	20	784	15	.5	2.0	.37	1,570	2.14	68	95	0	90	2,130	8.3
June 1-10----------	39	60	4.0	.03	43	34	423	10	380	20	775	16	.5	.4	----	1,520	2.07	160	247	0	78	2,190	8.7
June 11-20---------	56	61	22	.03	61	43	420	14	332	18	900	14	.6	.2	----	1,660	2.26	251	329	27	72	2,380	8.6
June 21------------	2,720	--	9.0	.18	17	5.9	53	8.4	122	0	88	.5	.1	.8	.13	283	.38	2,080	67	0	60	435	8.4
June 21, 6:00 p.m.	-----------	--	7.0	.16	25	5.5	50	7.2	130	0	90	2.0	.1	.8	.14	272	.37	-------	85	0	54	449	8.1
June 25------------	4,900	--	9.0	.10	63	27	115	15	116	0	416	5.5	.3	1.2	.15	713	.97	9,430	268	173	47	1,100	8.2
July 1-10----------	126	69	19	.10	78	36	238	19	238	22	583	6.0	.3	.6	.23	1,120	1.52	381	343	111	58	1,550	8.3
July 11------------	544	--	6.0	.01	116	43	253		244	0	770	8.0	.4	4.0	.30	1,320	1.80	1,940	466	266	54	1,860	8.4
July 11-20---------	149	70	19	.01	40	17	193	17	200	28	365	4.0	.2	2.0	.16	755	1.03	304	170	0	69	1,140	8.2
July 21-31---------	21	70	21	.05	41	23	290	18	339	4	514	7.0	.3	.8	.34	1,090	1.48	62	197	0	74	1,580	8.3
Aug. 1-10----------	7.9	73	14	.01	43	34	394	19	305	32	758	12	.4	.6	.47	1,460	1.99	31	247	0	76	2,070	8.3
Aug. 11-20---------	9.7	66	10	.01	42	29	425	11	291	28	760	11	.3	.8	.44	1,460	1.99	38	224	0	80	2,070	8.3
Aug. 21-31---------	1.8	65	6.0	.05	46	36	453	18	312	32	912	14	.3	.8	.49	1,670	2.27	8.4	263	0	78	2,360	8.3
Sept. 1-10---------	1.3	59	7.0	.00	50	45	586	22	308	32	1,210	18	.5	.6	.57	2,120	2.88	8.5	310	5	79	2,930	8.3
Sept. 11-30--------	1.1	50	7.6	.04	52	49	708	18	395	11	1,460	26	.9	.0	.62	2,530	3.44	7.6	331	0	81	3,090	8.3

See footnotes at end of table, p. 46.

Table 8.--Mineral constituents and related physical measurements, Moreau River near Faith, April 1941 to September 1949--Continued

[Analytical results in parts per million except as indicated]

Date of collection	Mean discharge (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
October 1947 to September 1948																							
[Analyses for periods that exceed 1 day were made of samples composited by equal volume Oct. 1, 1947, to Mar. 13, 1948, and by discharge Mar. 18 to Sept. 30, 1948]																							
Oct. 1-11, 1947----	4.5	51	7.6	0.04	52	49	708	18	395	11	1,460	26	0.9	0.0	0.62	2,530	3.44	31	331	0	81	3,090	8.3
Oct. 12-18---------	43	49	13	.07	42	21	492	7.2	409	8	872	17	.8	.9	.45	1,680	2.28	195	191	0	84	1,960	8.2
Oct. 30-Nov. 30----	18	34	12	.02	38	23	569	4.8	652	24	793	18	.7	.6	.48	1,810	2.46	88	189	0	86	2,600	8.3
Dec. 1-31----------	8.6	32	12	.02	56	33	642	3.2	806	12	942	19	.7	1.5	.45	2,130	2.90	49	275	0	83	2,880	8.2
Dec. 16 3/---------	1.0	32	13	.24	65	34	695		904	28	960	18	.5	.8	----	2,270	3.09	6.1	302	0	83	3,070	8.3
Jan. 1-7, 1948-----	1.9	32	18	.03	53	48	799	9.6	858	0	1,280	24	.8	2.0	.56	2,660	3.62	14	330	0	84	3,290	8.1
Jan. 8-12----------	7.4	33	18	.02	38	47	858	5.6	848	39	1,340	27	.9	1.5	.41	2,800	3.81	56	288	0	86	3,760	8.4
Jan. 13-Feb. 20----	2.0	32	16	.03	86	40	718	10	824	22	1,200	26	.6	.9	.36	2,520	3.43	14	379	0	80	3,320	8.2
Feb. 19 3/---------	1.0	32	7.5	.30	13	3.5	39		87	0	50	1.0	.2	6.9	----	192	.26	.5	47	0	64	158	6.5
Feb. 21-26---------	137	32	9.6	.25	12	4.4	91	12	166	0	109	3.5	.4	4.9	.00	370	.50	137	48	0	76	505	7.4
Feb. 27-28---------	380	33	9.4	.60	15	4.5	58	1.6	116	0	81	1.0	.6	2.9	----	300	.41	308	56	0	68	342	7.7
Feb. 29-Mar. 2-----	250	32	9.3	.30	15	3.0	52	5.6	100	0	82	2.0	.4	2.1	.21	262	.36	177	50	0	66	238	7.6
Mar. 3-6-----------	123	32	9.5	.15	28	6.3	59	2.4	124	0	117	2.5	.5	2.4	----	340	.46	113	96	0	56	470	7.4
Mar. 7-13----------	36	32	12	.15	30	11	108	5.2	174	0	203	6.0	.1	3.0	.00	490	.67	48	120	0	63	702	7.0
Mar. 14------------	900	34	7.0	.22	14	2.8	38		81	0	59	.0	.0	1.4	----	202	.27	491	46	0	64	265	6.6
Mar. 15------------	1,400	32	7.5	.20	15	1.8	20		72	0	26	.0	.0	1.5	----	138	.19	522	45	0	49	182	6.7
Mar. 16, 8:15 a.m.-	1,800	32	7.5	.18	17	1.8	15		64	0	28	.0	.0	1.3	----	142	.19	690	50	0	40	161	7.5
Mar. 16, 6:00 p.m.-	1,800	32	12	.60	16	5.0	69		146	0	86	.0	.0	2.0	.05	298	.41	1,450	60	0	71	396	7.0
Mar. 17, 8:00 a.m.-	1,040	32	10	.28	14	4.5	48		104	0	70	.0	.0	1.7	----	224	.30	629	53	0	66	304	6.9
Mar. 17, 3:00 p.m.-	1,040	32	7.0	.60	12	4.0	47		82	0	75	.0	.0	2.9	.01	204	.28	573	46	0	68	252	7.3
Mar. 18-21---------	1,200	32	9.4	.34	33	6.7	50	4.0	81	0	118	8.0	.2	2.6	.00	284	.39	920	110	44	44	370	6.9
Mar. 22-23---------	925	32	10	1.1	43	13	71	6.0	94	0	219	8.0	.2	2.0	----	414	.56	1,030	161	84	48	590	7.4
Mar. 24-25---------	450	32	11	.82	64	26	135	6.0	98	0	415	28	.2	2.1	----	726	.99	882	267	187	52	1,010	7.9
Mar. 26-31---------	255	33	11	.00	50	30	158	4.8	121	0	476	9.0	.3	1.0	.00	806	1.10	555	248	149	57	1,120	8.1
Apr. 1-9-----------	83	36	9.2	.07	70	35	214	7.6	227	0	562	9.0	.3	1.4	.16	1,010	1.37	226	319	133	59	1,450	8.1
Apr. 10-30---------	139	47	22	.06	62	32	220	4.0	196	10	560	9.5	.3	2.6	.20	1,020	1.39	383	286	109	62	1,500	8.5
May 1-31-----------	60	55	14	.06	95	71	330	2.8	236	12	1,010	14	.5	1.5	----	1,670	2.27	271	529	316	57	2,230	8.5
May 24 3/----------	17	60	5.0	.00	95	88	514		343	5	1,350	15	.7	.5	.03	2,240	3.05	103	599	310	65	2,650	8.2
June 1-30----------	314	63	22	.90	47	19	167	4.4	165	0	386	5.0	.5	2.1	.14	710	.97	602	195	60	64	1,130	7.8
June 4 3/----------	372	61	10	.02	22	5.0	100		144	0	164	1.6	.1	2.1	----	395	.54	397	75	0	74	567	7.6
June 8 3/----------	15	67	9.0	----	27	6.5	135		208	0	202	3.8	.1	1.9	----	505	.69	20	94	0	76	720	7.7
July 1-31----------	95	69	21	.30	47	19	166	4.0	199	0	364	5.0	.5	1.9	.14	708	.96	182	195	32	64	1,110	8.1
July 19 3/---------	120	70	13	.14	28	6.0	154		197	0	246	6.0	.6	1.1	----	580	.79	188	94	0	78	841	7.9
Aug. 1-31----------	26	65	20	.20	27	11	286	4.4	344	12	406	8.0	.5	2.1	----	944	1.28	66	113	0	84	1,470	8.4
Aug. 4 3/----------	8.0	61	15	.00	33	20	296		388	0	460	7.0	.6	.1	.34	1,030	1.40	22	165	0	80	1,520	8.0
Sept. 1-30---------	.04	56	7.8	.02	25	23	515	10	390	17	904	16	.8	1.0	.43	1,710	2.33	.2	157	0	87	2,620	8.5

Weighted average 4/	105	--	15	0.45	42	18	151	4.3	5/169	--	344	6.8	0.3	2.1	----	669	0.91	190	179	40	60	970	---
October 1948 to September 1949 [Analyses for periods that exceed 1 day were made of samples composited by discharge]																							
Oct. 8-31, 1948----	4.0	41	7.8	0.02	35	26	628	8.4	567	26	944	22	0.8	1.1	0.65	1,980	2.69	21	194	0	87	2,980	8.5
Nov. 1-30----------	20	--	12	.02	25	13	456	6.0	582	22	518	13	.7	2.5	.09	1,360	1.85	73	116	0	89	2,100	8.5
Dec. 1-31----------	3.1	33	14	.02	46	31	889	8.0	1,140	31	1,040	24	.6	2.7	.02	2,660	3.62	22	242	0	88	3,800	8.3
Jan. 1-20, 1949----	.5	32	25	.01	22	64	1,350	10	1,620	0	1,820	36	1.2	.8	1.2	4,140	5.63	6	318	0	90	5,460	7.9
Mar. 4-------------	6/0	--	48	.02	25	17	296	8.0	336	14	452	11	.2	1.5	.18	1,040	1.41	0	132	0	82	1,600	8.4
Mar. 5-------------	50	--	51	.03	12	5.2	29	4.8	88	0	40	3.0	.2	1.6	.08	220	.30	30	52	0	52	248	7.8
Mar. 6, 10:00 a.m.-	300	--	44	.05	13	4.2	41	4.0	96	0	60	1.0	.2	1.4	.04	228	.31	7/153	50	0	62	271	7.8
Mar. 6, 12:00 m.---	300	36	11	----	14	8.7	21	4.8	82	0	44	4.0	.8	2.0	----	182	.25	-------	71	4	37	258	7.2
Mar. 6, 5:00 p.m.--	300	36	8.6	----	10	8.7	23	.8	86	0	34	1.0	.8	3.6	----	156	.21	-------	61	0	45	219	7.2
Mar. 7, 7:00 a.m.--	1,500	33	8.7	----	14	9.2	35	1.6	106	0	58	1.0	.8	1.3	----	188	.26	7/774	73	0	51	276	7.2
Mar. 7, 12:00 m.---	1,500	34	10	----	13	9.6	28	1.6	98	0	48	1.0	.8	.8	----	166	.23	-------	72	0	45	242	7.3
Mar. 7, 2:00 p.m.--	1,500	--	49	.02	14	5.2	32	6.0	100	0	44	2.0	.2	1.5	.00	218	.30	-------	56	0	52	248	7.9
Mar. 8, 8:00 a.m.--	2,200	32	9.1	----	13	9.2		8.0	74	0	20	2.0	.8	1.7	----	120	.16	7/701	70	9	20	159	7.0
Mar. 8, 1:20 p.m.--	2,200	--	5.0	.07	4.0	4.8		21	53	0	25	2.0	.3	2.0	.00	122	.17	-------	30	0	61	145	7.5
Mar. 8, 2:00 p.m.--	2,200	--	10	.04	9.9	1.7	19	5.2	61	0	24	1.8	.2	1.9	.14	112	.15	-------	32	0	52	164	7.6
Mar. 8, 5:00 p.m.--	2,200	34	8.1	----	11	7.9	11	1.6	68	0	24	1.0	.8	1.0	----	116	.16	-------	60	4	27	152	7.0
Mar. 9, 9:00 a.m.--	1,700	34	7.8	----	9.2	9.2		8.3	65	0	20	1.0	.8	1.3	----	104	.14	7/514	61	8	23	133	7.0
Mar. 9, 2:00 p.m.--	1,700	--	14	.02	7.9	3.2	21	4.4	45	0	23	15	.2	1.7	.00	120	.16	-------	32	0	55	172	7.4
Mar. 9, 5:00 p.m.--	1,700	34	7.0	----	10	7.9		8.7	60	0	22	1.0	.6	2.0	----	112	.15	-------	58	9	25	130	6.8
Mar. 10, 9:00 a.m.-	1,000	33	9.0	----	9.0	9.6	10	4.8	65	0	26	.4	.6	1.1	----	106	.14	7/324	62	9	24	130	7.0
Mar. 10, 2:00 p.m.-	1,000	--	31	.04	13	4.0	16	5.6	72	0	20	6.8	.2	1.5	.00	136	.18	-------	49	0	38	179	7.9
Mar. 10, 5:00 p.m.-	1,000	34	9.2	----	12	7.9	12	5.6	76	0	22	1.0	.6	1.4	----	118	.16	-------	63	1	27	158	7.2
Mar. 11, 8:30 a.m.-	800	32	9.0	----	14	9.2	36	4.8	86	0	74	.0	.6	1.7	----	204	.28	7/570	73	2	50	315	7.0
Mar. 11, 2:00 p.m.-	800	--	26	.16	16	2.8	83	4.0	113	0	129	5.4	.2	1.5	.06	326	.44	-------	52	0	76	484	8.0
Mar. 11, 5:00 p.m.-	800	34	9.7	----	16	7.4	53	5.6	114	0	94	.0	.4	1.4	----	262	.36	-------	71	0	60	399	7.1
Mar. 12, 8:30 a.m.-	600	33	9.8	----	12	6.1	35	4.8	86	0	56	.0	.6	1.5	----	170	.23	7/284	55	0	55	260	7.0
Mar. 12, 5:00 p.m.-	600	36	10	----	16	6.6	28	2.4	98	0	48	.0	.6	1.2	----	180	.24	-------	67	0	47	270	7.0
Mar. 13------------	500	32	8.5	----	13	6.6	29	2.4	80	0	56	.0	.6	1.4	----	154	.21	208	60	0	50	226	7.0
Mar. 14------------	400	32	9.5	----	17	7.9	21	4.0	92	0	46	.0	.6	1.6	----	182	.25	197	75	0	37	264	7.0
Mar. 15------------	350	32	9.1	----	14	7.4	25	4.8	90	0	44	.0	.4	1.6	----	178	.24	168	66	0	43	263	7.0
Mar. 16------------	300	32	10	----	16	7.0	35	3.2	94	0	58	.0	.6	1.5	----	186	.25	151	69	0	51	276	7.0
Mar. 17------------	270	32	9.2	----	16	8.3	32	4.0	90	0	66	.0	.6	1.3	----	182	.25	133	74	0	47	265	7.0
Mar. 18------------	240	32	8.3	----	24	10	50	3.2	106	0	124	3.0	.4	1.2	----	308	.42	200	101	14	51	463	7.1
Mar. 19------------	220	32	11	----	20	9.0	57	2.4	110	0	126	.0	.4	.8	----	297	.40	176	87	0	58	452	7.1
Mar. 20------------	200	34	6.0	----	18	7.2	45	.8	108	0	86	1.0	.3	.9	----	234	.32	126	75	0	56	362	7.1
Mar. 21------------	200	34	11	----	19	7.2	44	2.4	118	0	78	1.0	.2	.5	----	232	.32	125	77	0	54	352	7.2
Mar. 22------------	300	34	10	----	13	5.2	36	3.2	92	0	60	1.0	.3	1.1	----	174	.24	141	54	0	58	264	7.0
Mar. 23------------	2,120	36	11	----	16	6.1	20	4.0	94	0	34	.0	.4	.9	----	161	.22	922	65	0	39	246	7.2
Mar. 24------------	4,160	34	14	----	23	8.1	36	4.0	112	0	78	1.0	.4	.7	----	222	.30	2,490	91	0	45	333	7.3
Mar. 25, 8:30 a.m.-	3,810	--	11	----	22	8.5	35	2.4	84	0	94	.0	.2	.4	----	209	.28	7/2,010	90	21	45	327	7.1
Mar. 25, 4:30 p.m.-	3,810	36	12	----	19	7.9	29	1.6	96	0	62	1.0	.5	.6	----	181	.25	-------	80	1	43	283	7.3
Mar. 26, 7:30 a.m.-	3,120	34	12	----	29	13	50	4.8	84	0	160	.0	.4	.2	----	312	.42	7/2,530	126	57	45	484	7.3
Mar. 26, 12:30 p.m.	3,120	35	11	----	31	12	45	5.6	94	0	140	1.0	.3	.6	----	299	.41	-------	127	50	42	459	7.4
Mar. 26, 5:00 p.m.-	3,120	35	9.6	----	30	14	36	4.0	96	0	124	.0	.4	.9	----	288	.39	-------	133	54	36	436	7.3
Mar. 27, 8:00 a.m.-	2,720	34	9.4	----	22	12	36	5.6	88	0	114	.0	.4	.6	----	262	.36	7/1,900	105	33	41	398	7.2

See footnotes at end of table, p. 46.

Table 8.--Mineral constituents and related physical measurements, Moreau River near Faith, April 1941 to September 1949--Continued

[Analytical results in parts per million except as indicated]

Date of collection	Mean discharge (cfs)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	ph
October 1948 to September 1949--Continued [Analyses for periods that exceed 1 day were made of samples composited by discharge]																							
Mar. 27, 5:00 p.m.-	2,720	36	11	----	24	11	32	4.0	104	0	94	.0	0.4	1.0	----	256	0.35	-------	106	21	39	385	7.2
Mar. 28, 7:30 a.m.-	3,070	34	9.8	----	22	10	39	2.4	100	0	96	.0	.4	.7	----	258	.35	7/2,170	96	14	46	389	7.2
Mar. 28, 5:00 p.m.-	3,070	36	11	----	27	10	41	5.6	114	0	106	.0	.4	.9	----	266	.36	-------	109	16	44	395	7.3
Mar. 29------------	3,070	34	13	0.10	32	10	56	5.6	100	0	154	.0	.4	1.6	----	338	.46	2,800	121	39	49	489	7.4
Mar. 30------------	2,470	36	11	.01	32	6.5	58	4.8	96	0	159	.0	.0	.9	----	347	.47	2,310	107	28	53	492	7.2
Mar. 31-Apr. 1-----	1,480	38	10	.01	35	11	63	4.8	102	0	174	1.0	.4	.8	----	368	.50	1,470	133	49	50	543	7.3
Apr. 2-10----------	1,010	41	12	.01	40	16	77	1.2	104	0	232	3.0	.2	1.0	0.16	452	.61	1,230	166	81	50	659	7.3
Apr. 11-18---------	462	47	14	.01	44	20	118	2.8	136	0	304	3.0	.3	1.6	.36	592	.80	738	193	81	57	851	7.8
Apr. 12 3/---------	575	50	11	.01	33	14	104	4.0	113	0	262	3.6	.2	1.0	.14	505	.69	784	140	47	61	735	7.6
Apr. 19-30---------	108	51	14	.01	64	33	200	1.6	230	0	496	4.4	.4	1.3	.25	964	1.31	281	295	106	59	1,340	7.8
May 1-12-----------	91	54	18	.10	50	20	274	3.2	308	18	504	6.5	.4	1.3	.41	1,050	1.43	258	208	0	74	1,530	8.6
May 13-June 2------	27	59	11	.08	51	35	385	3.2	388	21	728	12	.4	1.1	.62	1,440	1.96	105	272	0	75	2,080	8.5
June 3-30----------	12	63	7.4	.10	28	28	466	4.0	418	37	760	14	.4	1.0	.22	1,560	2.12	51	185	0	84	2,280	8.7
July 1-Aug. 9------	1.1	67	12	.02	20	45	1,070	18	770	49	1,680	34	1.1	.4	.90	3,320	4.52	10	235	0	90	4,400	8.7
Sept. 7-30---------	6/0	50	30	1.2	19	1.0	341	12	332	0	480	14	1.0	2.9	.30	1,070	1.46	0	52	0	92	1,510	7.2
Weighted average 4/	152	--	12	----	29	12	72	3.4	5/122	--	168	2.0	0.4	1.1	----	374	0.51	153	122	22	55	546	---

1 Samples collected and analyzed by the U. S. Bureau of Reclamation.
2 Discharge at time of sampling.
3 Not included in weighted average.
4 Weighted average for period sampled only.
5 Includes carbonate as bicarbonate.
6 Ponded--no flow.
7 Mean for day.

Table 9.--Mineral constituents and related physical measurements, Moreau River near Eagle Butte, April 1941 to September 1951

[Analytical results in parts per million except as indicated]

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Apr. 17, 1941 1/	300	---	---	32	7.7	202	---	359	0	259	6.0	---	1.2	---	754	---	112	0	78	1,090	7.2
Oct. 10 1/	20	---	---	50	14	210	---	334	0	358	11	---	8.7	---	954	---	183	0	69	1,340	8.0
Dec. 2 1/	20	---	---	116	31	288	---	280	0	811	16	---	6.2	---	1,460	---	418	0	57	1,910	7.9
Jan. 22, 1942 1/	20	---	---	230	85	892	---	414	0	2,420	58	---	6.2	---	4,190	---	930	0	66	4,650	7.6
Mar. 18 1/	10	---	---	33	11	258	---	350	0	409	15	---	5.0	---	970	---	129	0	76	1,390	7.9
Apr. 9 1/	20	---	---	60	10	78	---	---	---	---	---	---	---	---	496	---	193	---	47	710	7.5
June 3 1/	150	---	---	60	18	155	---	---	---	---	---	---	---	---	792	---	226	---	60	1,160	7.3
July 20 1/	185	---	---	18	4.9	81	---	---	---	---	---	---	---	---	366	---	63	---	73	510	7.4
Nov. 7 1/	8	---	---	111	32	366	---	---	---	---	---	---	---	---	1,660	---	411	---	66	2,210	8.1
Apr. 4, 1943 1/	700	---	---	70	20	288	---	---	---	---	---	---	---	---	1,180	---	260	---	71	1,690	7.9
Apr. 20 1/	66	---	---	76	23	167	---	---	---	---	---	---	---	---	826	---	283	---	54	1,180	7.9
July 6 1/	3,200	---	---	38	8.0	78	---	---	---	---	---	---	---	---	382	---	130	---	59	570	7.8
July 8 1/	1,580	---	---	32	6.4	56	---	---	---	---	---	---	---	---	206	---	106	---	53	470	7.7
Nov. 30, 1945	82	4.0	0.04	129	60	838	12	668	0	1,780	34	0.5	.3	---	3,190	4.34	568	21	76	4,060	7.7
June 6, 1946	626	---	.05	95	33	174		144	0	596	8.0	.4	.6	---	979	1.33	373	255	50	1,300	7.3
June 26	468	---	.05	70	22	132		145	0	404	5.0	.4	6.0	---	725	.99	265	146	52	975	8.0
July 16	46	---	.05	97	41	250		197	0	745	10	.5	1.2	---	1,240	1.69	411	249	57	1,610	7.9
Aug. 6	11.4	---	.05	102	44	365		186	0	1,010	16	.5	.9	---	1,630	2.22	435	282	65	2,060	8.1
Aug. 28	39	---	.05	40	17	180		202	0	367	7.0	.4	4.0	---	728	.99	170	4	70	1,000	8.0
Sept. 17	93.6	---	.00	23	9.0	256		400	6	296	2.0	.5	.0	---	829	1.13	94	0	85	1,090	8.2
Oct. 8	57	---	.00	47	16	223		202	0	474	5.0	.3	.2	---	890	1.21	183	17	72	1,130	8.2
Mar. 24, 1947	10,600	11	.15	31	6.3	40	3.2	140	0	66	6.0	.8	1.0	0.17	239	.33	103	0	47	372	7.4
Apr. 16	701	9.5	.10	63	32	167	10	130	0	514	13	1.2	1.5	.14	896	1.22	288	181	57	1,220	7.7
May 5	68	9.0	.02	88	36	217	20	237	8	613	12	.4	.7	.32	1,120	1.52	368	161	54	1,660	8.2
June 18	132	4.0	.01	58	18	207	21	213	7	477	12	.4	2.0	.30	918	1.25	219	32	65	1,420	8.5
Sept. 10	2/0	3.5	.00	87	20	510		237	0	1,080	62	.5	.8	.47	1,880	2.56	279	85	79	2,300	7.7
July 1, 1948	241	12	.00	41	17	146		155	0	332	12	.0	.8	.18	642	.87	172	45	65	896	7.5
July 20	1,680	12	.00	45	12	81		156	0	198	1.0	.4	.8	.11	460	.63	162	34	52	652	7.8
Aug. 10	10	8.2	.00	57	19	192		228	0	422	8.0	.5	.2	.06	876	1.19	220	33	66	1,200	7.5
Aug. 31	2.4	6.6	.00	37	16	354		384	0	572	11	.6	.6	.34	1,190	1.62	158	0	83	1,720	7.8
Mar. 8, 1949	3,280	7.6	.05	34	3.3	38		118	0	78	1.0	.1	3.0	.06	234	.32	99	2	46	349	7.6
Mar. 22	610	10	.03	32	3.5	63		129	0	116	1.0	.3	2.4	---	294	.40	95	0	59	456	7.5
Mar. 27	9,010	10	.02	60	7.2	27		119	0	130	1.0	.3	1.9	---	304	.41	179	81	24	481	7.6
May 4	366	13	.02	28	15	186		235	0	320	5.0	.3	2.6	---	696	.95	132	0	75	1,040	7.6
May 26	40	12	.01	65	32	331		326	0	696	13	.7	.8	---	1,310	1.78	294	27	71	1,890	8.0
July 14	8.0	6.2	.02	120	41	581		224	0	1,450	26	.5	1.2	---	2,340	3.18	468	284	73	3,100	8.0
Apr. 7, 1950	12,200	20	.02	55	7.2	53		154	0	143	3.0	.3	1.0	.05	376	.51	167	41	41	539	7.9

See footnotes at end of table, p. 48.

Table 9.--Mineral constituents and related physical measurements, Moreau River near Eagle Butte, April 1941 to September 1951--Continued

[Analytical results in parts per million except as indicated]

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Apr. 20, 1950	6,350	8.6	0.04	38	4.4	50		136	0	94	8.0	0.2	0.1	----	270	0.37	113	1	49	409	7.5
June 21	99	9.9	.10	64	29	387		305	0	810	18	.4	1.3	----	1,470	2.00	279	29	75	2,080	8.0
Aug. 9	8	----	----	---	----	518	13	---	--	-----	----	---	---	----	2,280	3.10	480	--	69	3,000	---
Sept. 19	31	6.7	.02	85	32	511		256	0	1,160	24	.6	1.1	----	1,950	2.65	344	134	76	2,710	7.7
Dec. 21	1.2	16	.04	237	79	920		743	0	2,150	47	.8	.8	----	3,820	5.20	917	308	69	4,630	7.7
Apr. 3, 1951	356	10	.10	31	6.5	104		168	0	180	3.0	---	2.3	----	438	.60	104	0	69	677	8.1
Apr. 25	32	----	----	---	----	319	--	360	0	655	14	---	---	----	-----	----	---	---	70	1,860	7.7
June 19	447	11	.02	57	13	147		170	0	350	4.0	.4	5.3	0.16	682	.93	196	57	62	997	7.2
Aug. 20	165	----	----	---	----	133	--	213	8	178	2.6	---	---	----	-----	----	---	---	77	731	8.4
Sept. 10	112	----	----	---	----	128	--	188	0	258	5.0	---	---	----	-----	----	---	---	65	840	7.4

1 Samples collected and analyzed by the U. S. Bureau of Reclamation.
2 Ponded--no flow.

Table 10.--Mineral constituents and related physical measurements, Moreau River at Promise, October 1941 to September 1951

[Analytical results in parts per million except as indicated]

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Oct. 10, 1941 1/	40	----	----	66	16	143	----	151	414	10	---	8.7	----	794	----	232	0	54	1,110	8.0
Dec. 2 1/	40	----	----	172	37	283	----	256	974	20	---	5.0	----	1,730	----	582	0	50	2,200	7.8
Jan. 22, 1942 1/	40	----	----	372	87	573	----	364	2,220	41	---	4.3	----	3,800	----	1,290	0	47	4,260	7.4

Mar. 16 1/	10	----	----	148	27	228	----	158	840	19	---	16	----	1,520	----	484	0	49	1,810	7.5
Apr. 9 1/	60	----	----	41	7.8	81	----	---	-----	----	---	----	----	430	----	136	---	57	640	7.7
June 9 1/	2,500	----	----	49	9.4	67	----	---	-----	----	---	----	----	484	----	162	---	47	640	7.6
Aug. 4 1/	170	----	----	80	14	110	----	---	-----	----	---	----	----	650	----	257	---	48	940	7.0
June 15, 1943 1/	7,880	----	----	89	15	90	----	---	-----	----	---	----	----	664	----	284	---	41	950	7.8
Nov. 30, 1945	87	11	0.02	78	33	87	3.0	250	290	12	0.3	1.6	----	655	0.87	330	125	36	939	8.1
June 3, 1946	448	----	.00	100	25	140		172	486	4.0	.4	2.0	----	875	1.19	352	211	46	1,160	8.2
Mar. 24, 1947	5,160	8.8	.05	55	12	73	6.2	152	210	5.5	.1	1.8	0.15	457	.62	187	62	45	695	8.0
Mar. 26	12,400	7.8	.10	32	6.2	49	5.0	118	110	3.5	.1	2.5	.03	274	.37	105	9	49	435	8.0
Apr. 17	689	12	.08	88	34	178	14	146	593	16	1.2	1.8	----	1,010	1.37	360	240	53	1,420	7.5
May 6	93	5.0	.12	112	37	203	19	239	653	14	.4	.8	.10	1,160	1.58	432	236	49	1,700	7.7
June 18	503	19	.02	99	21	103	20	146	433	7.0	.4	.6	.14	791	1.06	333	213	38	1,130	8.0
Sept. 9	2.0	10	.01	207	61	429		260	1,400	19	.4	.8	.38	2,260	3.07	767	554	55	2,850	8.4
June 10, 1948	141	15	.08	27	9.7	160		210	261	6.2	.4	2.0	.21	598	.81	107	0	76	858	7.6
June 30	430	13	.00	78	28	171		110	540	19	.5	.6	.18	905	1.23	310	220	54	1,220	7.2
July 22	870	11	.00	43	11	63		162	148	.2	.4	1.3	.40	392	.53	152	19	47	579	7.7
Aug. 11	21	12	.00	97	26	194		222	554	8.0	.3	1.4	.19	1,000	1.36	349	167	55	1,440	7.3
Aug. 31	6.7	9.1	.00	83	31	363		264	852	14	.6	.0	.35	1,480	2.01	334	118	70	2,060	7.4
Mar. 8, 1949	4,600	9.9	.02	48	7.7	49		108	158	1.5	.1	3.2	.05	345	.47	152	63	41	503	7.6
Mar. 22	1,070	8.0	.02	16	7.9	39		83	84	.2	.2	2.2	.00	214	.29	73	5	54	321	7.5
Apr. 12	1,620	8.3	.01	46	12	64		113	196	4.0	.3	1.9	.07	422	.57	165	72	46	575	7.8
Apr. 7, 1950	13,400	22	.02	45	4.2	54		142	120	3.0	.2	1.0	.05	320	.44	130	14	47	469	7.9
June 22	86	13	.02	100	31	381		273	915	19	.4	.9	----	1,590	2.16	377	153	69	2,110	7.9
Aug. 10	6	----	----	---	----	478	13	---	-----	----	---	----	----	2,460	3.35	716	---	59	3,060	---
Sept. 19	10	12	.02	204	53	442		244	1,400	20	.6	.5	.20	2,250	3.06	727	527	57	2,850	7.8
Jan. 15, 1951	1.4	14	.10	376	78	527		505	1,840	53	.4	.5	.24	3,140	4.27	1,260	846	47	3,580	7.7
Apr. 2	600	6.6	.30	45	5.7	82		146	176	5.5	.3	3.1	.15	434	.59	136	16	58	636	7.3
July 6	223	11	.02	67	15	246		249	525	6.5	.4	2.1	----	996	1.35	228	24	70	1,440	7.4
Aug. 21	237	----	----	---	----	124	--	210	193	3.2	---	----	----	-----	----	-----	---	71	739	7.9
Sept. 11	99	----	----	---	----	112	--	155	248	4.3	---	----	----	-----	----	-----	---	62	771	7.3

1 Samples collected and analyzed by the U. S. Bureau of Reclamation.

Table 11.--Monthly and annual summary of water and sediment discharges, Moreau River at Bixby

Month	Water discharge (cfs-days)	Runoff (acre-ft)	Suspended sediment					
			Load (tons)	Daily load (tons)			Concentration (ppm)	
				Mean	Maximum	Minimum	Weighted mean	Maximum daily
Apr. 28-30, 1949	90	179	19.6	-------	-------	-------	-------	-------
May	861	1,710	a 3,900	126	1,300	0.5	1,680	4,970
June	194.7	386	11.4	.4	.8	(t)	22	40
July	54.1	107	3.5	.1	.3	0	24	52
August	0	0	0	0	0	0	-------	-------
September	26.5	53	2.8	.09	.7	0	39	74
Apr. 28 to Sept. 30	1,226.3	2,440	a 3,940	25	1,300	0	1,190	4,970
October	291.8	579	481	16	259	(t)	611	2,400
November	121.6	241	30	1	-------	-------	91	-------
December	66.4	132	12	.4	-------	0	67	-------
January 1950	0	0	0	0	0	0	-------	-------
February	0	0	0	0	0	0	-------	-------
March	3,035	6,020	3,790	122	763	0	463	1,300
April	64,679	128,300	880,500	29,400	169,000	43	5,040	7,470
May	8,816	17,490	102,400	3,300	24,000	-------	4,300	7,120
June	888	1,760	836	28	180	-------	349	1,390
July	435.8	864	51	1.6	-------	-------	43	-------
August	400	793	3,400	110	2,660	(t)	3,150	6,020
September	286.9	569	5,630	188	4,050	(t)	7,270	21,500
Water year 1949-50	79,020.5	156,748	997,100	2,730	169,000	0	4,670	21,500
October	197.1	391	110	3.5	29	1	207	665
November	158.2	314	46	1.5	-------	-------	108	-------
December	93	184	a 36	1.2	-------	(t)	143	-------
January 1951	108.3	215	b 28	.9	-------	(t)	96	-------
February	25.7	51	b 4	.1	-------	(t)	58	-------
March	1,543.5	3,060	a 5,437	175	1,170	(t)	1,310	2,000
April	524.6	1,040	400	13	102	-------	282	758
May	472.7	938	7,625	246	5,100	-------	5,970	21,500
June	1,534.0	3,040	12,688	423	2,150	-------	3,060	5,870
July	783.1	1,550	7,687	248	2,000	(t)	3,640	7,250
August	2,114.5	4,190	44,965	1,450	18,600	(t)	7,880	10,100
September	436.7	866	2,893	96	1,260	-------	2,450	6,020
Water year 1950-51	7,991.4	15,840	81,920	224	18,600	-------	3,800	21,500

a Includes estimated loads for a few days.
b Includes estimated loads for many days.
t Sediment discharge less than 1 ton.

Table 12.--Monthly and annual summary of water and sediment discharges, Moreau River near Faith

Month	Water discharge (cfs-days)	Runoff (acre-ft)	Suspended sediment: Load (tons)	Suspended sediment: Daily load (tons)			Suspended sediment: Concentration (ppm)	
				Mean	Maximum	Minimum	Weighted mean	Maximum daily
August 15-31, 1946----	112.8	224	615	36	550	0	2,020	5,660
September------------	1,928.5	3,830	31,500	1,050	8,630	.1	6,050	13,000
Aug. 15 to Sept. 30---	2,041.3	4,050	32,120	683	8,630	0	5,830	13,000
October---------------	7,135	14,150	88,620	2,860	25,300	2.8	4,600	10,600
November-------------	2,725	5,400	13,530	451	5,390	1.5	1,840	3,180
December-------------	269	534	38	1.2	2.3	.1	53	111
January 1947----------	1,820	3,610	990	32	242	.1	201	308
February-------------	16,975	33,670	94,670	3,380	45,000	2.2	2,070	3,790
March----------------	30,025	59,550	216,000	6,970	65,500	1.2	2,660	3,730
April----------------	10,043	19,920	88,870	2,960	21,600	11	3,280	9,200
May------------------	784	1,560	104	3.3	17	.9	49	114
June-----------------	25,324	50,230	553,700	18,500	131,000	1.7	8,100	11,700
July-----------------	3,241	6,430	20,460	660	10,500	2.7	2,340	5,120
August---------------	196.6	390	228	7.4	100	.1	430	2,930
September------------	35.1	70	1	.05	.3	0	15	278
Water year 1946-47----	98,572.7	195,500	1,077,000	2,950	131,000	0	4,050	11,700
October---------------	508.1	1,010	2,750	89	1,250	0.2	2,000	5,860
November-------------	549	1,090	155	5.2	18	1.8	105	210
December-------------	268	532	88.4	2.8	14	0	122	172
January 1948----------	67	133	17.1	.6	3.0	0	94	135
February-------------	1,940	3,850	517	18	97	0	99	610
March----------------	15,420	30,590	a 21,100	681	2,960	.4	507	1,250
April----------------	3,677	7,290	73,350	2,440	24,200	1.1	7,390	16,500
May------------------	1,868	3,710	9,770	315	2,110	1.7	1,940	4,280
June-----------------	9,435	18,710	214,700	7,160	57,900	1.6	8,430	14,400
July-----------------	2,944	5,840	23,800	768	3,150	1.0	2,990	5,930
August---------------	816.9	1,620	7,380	238	1,840	.3	3,350	8,700
September------------	1.2	2.4	.1	---------	.1	0	31	50
Water year 1947-48----	37,494.2	74,380	353,600	966	57,900	0	3,490	16,500
October---------------	97.0	192	101	3.3	77	0	382	2,370
November-------------	602	1,190	2,180	72.7	1,210	1.7	1,340	7,210
December-------------	95	188	b 20	.6	1.9	------	78	------
January 1949----------	10	20	b 1	.03	---------	0	37	------
February-------------	0	0	0	0	0	0	------	------
March----------------	37,450	74,300	389,800	12,600	60,900	0	3,860	7,350
April----------------	15,274	30,300	117,000	3,900	15,200	12	2,840	5,010
May------------------	1,590	3,150	6,180	199	2,200	1.0	1,440	5,170
June-----------------	410.1	813	103	3.4	50	.5	93	439
July-----------------	45.7	91	6.1	.2	1.7	0	49	229
August---------------	0	0	0	0	0	0	------	------
September------------	6.7	13	b 10	.3	---------	0	550	------
Water year 1948-49----	55,580.5	110,300	a 515,400	1,410	60,900	0	3,430	7,350

a Includes estimated loads for a few days.
b Includes estimated loads for many days.

Table 13.--Particle-size analyses of suspended sediment, Moreau River at Bixby

[Methods of analyses: B, bottom-withdrawal tube; N, in native waters; W, in distilled water; P, pipette; C, chemically dispersed; S, sieve; M, mechanically dispersed]

Date	Time	Water discharge (cfs)	Suspended sediment													Methods of analysis
			Concentration of sample (ppm)	Concentration of suspension analyzed (ppm)	Percent finer than indicated size, in millimeters											
					0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.000	2.000	
Mar. 24, 1949-----	1:00 p.m.	2,710	3,460	1,870	10	20	53	58	70	79	86	95	97	-----	-----	BN
Do----------------	1:00 p.m.	2,710	3,460	1,900	32	41	49	58	69	76	86	93	95	-----	-----	BW
Apr. 13-----------	2:00 p.m.	298	1,740	2,060	55	72	86	94	-----	98	99	100	-----	-----	-----	BW
Do----------------	2:00 p.m.	298	1,740	2,100	-----	5	15	-----	-----	98	98	100	-----	-----	-----	BN
May 4-------------	2:00 p.m.	85	5,130	1,770	24	47	84	91	96	98	100	-----	-----	-----	-----	BW
May 5-------------	2:15 p.m.	79	1,150	780	48	74	-----	99	99	99	99	100	-----	-----	-----	BW
May 6-------------	2:15 p.m.	50	3,920	1,510	21	28	85	100	-----	-----	-----	-----	-----	-----	-----	BW
Do----------------	2:15 p.m.	50	3,920	1,420	11	12	15	45	-----	97	98	100	-----	-----	-----	BN
Mar. 7, 1950------	2:20 p.m.	212	1,160	3,370	-----	89	-----	93	-----	95	-----	-----	-----	-----	-----	PWCM
Apr. 3------------	4:45 p.m.	2,370	6,120	10,600	-----	29	-----	39	-----	67	88	99	100	-----	-----	SPWCM
Apr. 4------------	3:10 p.m.	2,390	2,950	1,760	28	33	37	41	51	63	76	91	-----	-----	-----	BWCM
Do----------------	3:10 p.m.	2,390	2,950	1,690	21	22	26	34	45	59	75	95	-----	-----	-----	BN
Apr. 5------------	11:15 a.m.	2,460	3,870	7,260	-----	45	-----	58	-----	74	92	99	100	-----	-----	SPWCM
Apr. 7------------	11:50 a.m.	7,540	6,060	11,000	-----	44	-----	60	-----	78	-----	-----	-----	-----	-----	SPWCM
Apr. 8------------	10:00 a.m.	5,720	3,890	7,740	-----	55	-----	68	-----	80	-----	-----	-----	-----	-----	SPWCM
Apr. 12-----------	11:30 a.m.	702	2,520	7,330	-----	64	-----	78	-----	85	-----	-----	-----	-----	-----	SPWCM
Apr. 14-----------	2:45 p.m.	2,520	5,630	3,590	38	44	50	56	64	73	83	94	-----	-----	-----	BWCM
Do----------------	2:45 p.m.	2,520	5,630	3,460	5	8	40	46	60	74	86	95	-----	-----	-----	BN
Apr. 15-----------	11:10 a.m.	8,860	7,400	14,000	-----	44	-----	62	-----	77	89	99	100	-----	-----	SPWCM
Apr. 18-----------	10:00 a.m.	2,360	6,370	11,000	-----	48	-----	62	-----	72	79	93	100	-----	-----	SPWCM
Apr. 19-----------	10:20 a.m.	1,200	4,820	8,880	-----	45	-----	57	-----	64	69	77	85	96	100	SPWCM
Apr. 20-----------	10:20 a.m.	605	3,350	6,840	-----	65	-----	79	-----	86	89	92	93	97	100	SPWCM
Apr. 21-----------	5:10 p.m.	336	2,380	1,380	72	81	89	94	97	98	99	100	-----	-----	-----	BWCM
Do----------------	5:10 p.m.	336	2,380	1,440	4	8	30	-----	97	98	98	99	-----	-----	-----	BN
Apr. 27-----------	10:00 a.m.	165	564	1,390	-----	87	-----	95	-----	100	-----	-----	-----	-----	-----	PWCM
May 11------------	9:50 a.m.	1,380	6,100	13,400	-----	57	-----	74	-----	87	-----	-----	-----	-----	-----	SPWCM
Mar. 24, 1951-----	1:15 p.m.	69	1,470	3,360	-----	91	-----	97	-----	99	-----	-----	-----	-----	-----	PWCM
Mar. 27-----------	9:45 a.m.	163	1,780	2,100	80	88	91	95	97	99	-----	-----	-----	-----	-----	PWCM
Do----------------	9:45 a.m.	163	1,780	2,100	1	4	80	94	95	98	-----	-----	-----	-----	-----	PN
Mar. 29-----------	5:00 p.m.	117	992	997	75	83	90	96	98	99	99	100	-----	-----	-----	BWCM
Apr. 5------------	1:00 p.m.	34	249	249	75	86	90	93	97	98	98	99	100	-----	-----	BWCM
June 19-----------	8:00 p.m.	61	11,000	8,260	-----	93	-----	-----	-----	-----	-----	-----	-----	-----	-----	PWCM
June 22-----------	6:00 p.m.	108	7,170	4,430	-----	96	-----	-----	-----	-----	-----	-----	-----	-----	-----	PWCM
July 4------------	9:30 a.m.	128	2,940	2,100	-----	90	-----	96	-----	98	-----	-----	-----	-----	-----	PWCM
Aug. 12-----------	9:30 a.m.	590	8,520	4,670	-----	73	-----	85	-----	94	-----	-----	-----	-----	-----	SPWCM
Do----------------	6:30 p.m.	680	17,800	7,030	-----	82	-----	96	-----	100	-----	-----	-----	-----	-----	SPWCM
Aug. 13-----------	1:30 p.m.	1,040	7,260	5,440	-----	81	-----	92	-----	98	-----	-----	-----	-----	-----	SPWCM
Aug. 14-----------	12:20 p.m.	151	8,900	3,500	-----	94	-----	98	-----	100	-----	-----	-----	-----	-----	SPWCM
Sept. 1-----------	1:00 p.m.	58	5,490	4,280	-----	94	-----	100	-----	-----	-----	-----	-----	-----	-----	SPWCM

Date	Time	Water discharge (cfs)	Concentration of sample (ppm)	Concentration of suspension analyzed (ppm)	0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.000	2.000	Methods of analysis
Sept. 2----------	9:00 a.m.	100	7,360	5,760	-----	95	-----	99	-----	100	-----	-----	-----	-----	-----	SPWCM
Sept. 3----------	5:00 p.m.	45	3,220	2,600	90	95	97	99	100	-----	-----	-----	-----	-----	-----	BWCM

Table 14.--Particle-size analyses of suspended sediment, Moreau River near Faith

[Methods of analyses: B, bottom-withdrawal tube; N, in native waters; W, in distilled water]

Date	Time	Water dis- charge (cfs)	Suspended sediment													Methods of analysis
			Concen- tration of sample (ppm)	Concentration of suspension analyzed (ppm)	Percent finer than indicated size, in millimeters											
					0.002	0.004	0.008	0.016	0.031	0.062	0.125	0.250	0.500	1.000	2.000	
Feb. 17, 1947-----	3:00 p.m.	4,320	5,200	8,810	34	38	48	58	68	82	94	99	100	-----	-----	BN
Feb. 20----------	1:20 p.m.	772	787	850	23	38	80	84	88	91	93	96	100	-----	-----	BN
Mar. 26----------	3:05 p.m.	1,610	2,190	4,500	36	40	49	58	65	74	81	89	100	-----	-----	BN
June 25----------	12:15 p.m.	5,090	9,040	7,890	25	30	36	43	50	66	78	86	92	-----	-----	BW
Mar. 17, 1948-----	2:15 p.m.	926	494	1,390	77	87	92	95	97	98	98	99	100	-----	-----	BW
Mar. 19----------	1:00 p.m.	996	422	470	52	70	-----	92	93	96	98	99	100	-----	-----	BN
Do-------------	1:00 p.m.	996	422	450	74	84	90	95	96	97	98	99	100	-----	-----	BW
Mar. 24----------	12:00 m.	386	1,190	924	48	63	79	92	97	98	99	100	-----	-----	-----	BW
Mar. 30----------	11:45 a.m.	171	801	848	2	12	51	-----	-----	98	99	100	-----	-----	-----	BN
Apr. 27----------	5:30 p.m.	101	2,120	1,580	2	5	16	-----	-----	99	100	-----	-----	-----	-----	BN
May 11-----------	10:45 a.m.	64	853	751	10	14	21	-----	-----	99	-----	-----	-----	-----	-----	BN
June 18----------	6:00 a.m.	628	8,180	1,710	-----	78	87	88	91	92	94	96	98	-----	-----	BW
June 19----------	6:00 a.m.	870	9,420	1,540	-----	5	15	-----	76	82	88	95	98	-----	-----	BN
Do-------------	12:30 p.m.	673	8,740	1,830	58	68	81	86	92	94	96	98	99	-----	-----	BW
June 23----------	3:45 p.m.	602	3,860	2,590	1	4	28	-----	-----	94	96	98	100	-----	-----	BN
July 4-----------	5:00 a.m.	411	9,620	3,720	46	60	71	78	82	86	93	96	99	-----	-----	BW
Do-------------	11:00 a.m.	429	3,920	1,480	44	58	70	80	86	89	94	97	99	-----	-----	BW
Do-------------	6:00 p.m.	340	4,940	1,890	48	65	78	88	92	94	96	98	99	-----	-----	BW
July 7-----------	9:30 a.m.	194	5,120	4,530	-----	1	2	22	-----	98	100	-----	-----	-----	-----	BN
July 15----------	6:00 a.m.	230	4,260	3,420	3	9	-----	-----	89	93	94	98	100	-----	-----	BN
Do-------------	1:00 p.m.	276	3,840	3,000	6	11	-----	-----	94	95	96	99	100	-----	-----	BN
July 19----------	4:40 p.m.	188	8,720	6,030	54	71	87	93	99	99	100	-----	-----	-----	-----	BW
Nov. 5-----------	8:00 a.m.	73	9,200	1,870	77	89	98	100	-----	-----	-----	-----	-----	-----	-----	BW
Nov. 6-----------	8:00 a.m.	35	3,560	1,360	90	98	99	-----	-----	-----	-----	-----	-----	-----	-----	BW
Nov. 9-----------	4:40 p.m.	24	575	550	86	93	96	97	100	-----	-----	-----	-----	-----	-----	BW
Mar. 24, 1949-----	12:00 m.	3,620	3,850	1,550	8	20	57	66	76	86	92	96	98	-----	-----	BN
Do-------------	12:00 m.	3,620	3,850	1,750	36	45	55	66	77	86	93	98	99	-----	-----	BW
Apr. 12----------	11:40 a.m.	575	1,990	1,260	52	69	79	87	91	94	95	99	100	-----	-----	BW
Do-------------	11:20 a.m.	575	1,990	2,450	49	67	82	88	93	95	97	99	100	-----	-----	BW
Do-------------	11:20 a.m.	575	1,990	2,340	2	5	14	-----	-----	96	97	99	100	-----	-----	BN
May 1------------	7:00 a.m.	171	6,800	1,450	60	81	91	97	100	-----	-----	-----	-----	-----	-----	BW
May 2------------	6:30 a.m.	102	1,850	1,520	66	93	99	99	100	-----	-----	-----	-----	-----	-----	BW
May 3------------	6:00 a.m.	104	1,170	963	57	86	96	98	100	-----	-----	-----	-----	-----	-----	BW
May 4------------	6:30 a.m.	136	4,710	1,990	72	91	98	100	-----	-----	-----	-----	-----	-----	-----	BW
Do-------------	6:30 a.m.	136	4,710	1,880	3	4	4	-----	-----	-----	-----	-----	-----	-----	-----	BN

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