Geology and Water Resources of the Bitterroot Valley, Southwestern Montana

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1889

Prepared in cooperation with the Montana Bureau of Mines and Geology, Butte, Montana

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By R. G. McMURTREY, R. L. KONIZESKI, M. V. JOHNSON, *and* J. H. BARTELLS

With a section on CHEMICAL QUALITY OF WATER

By H. A. SWENSON

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A detailed study of the availability of water for future development in the Bitterroot Valley

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CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY AND WATER RESOURCES OF THE BITTERROOT VALLEY, SOUTHWESTERN MONTANA

By R. G. McMurtrey, R. L. Konizeski, M. V. Johnson, and J. H. Bartells

ABSTRACT

The Bitterroot Valley is a Late Cretaceous structural basin that was partly filled at its deepest point by more than 1,640 feet of Tertiary sediments. These sediments grade valleyward from coarse colluvial deposits along the edges of the valley to fine-grained deposits and then to coarse channel deposits of the ancestral Bitterroot River near the center of the valley. Beneath the flood plain and low terraces of the present Bitterroot River, about 40 feet of Quaternary alluvium overlies the Tertiary sediments.

Each spring and summer, at rates greatly exceeding discharge, water infiltrates to the ground-water reservoir in the Tertiary and Quaternary rocks. During the fall and winter, water is released from storage. Net recharge in the spring of 1958 and 1959 was about 90,000 and 82,000 acre-feet, respectively. Net discharge during the rest of each year was about 90,000 and 76,000 acre-feet, respectively. Some surface water available for recharge during high runoff each spring is rejected. During the 1958 and 1959 water years, total surface-water inflow was about 1.7 million and 2.0 million acre-feet, respectively. Consumptive use during these water years was about 450,000 and 400,000 acre-feet, respectively. More pumping from the ground-water reservoir would provide additional storage space for peak runoff and would increase the potential consumptive use in the valley.

Additional wells, capable of yielding more than 250 gpm (gallons per minute), can be constructed on the flood plain of the Bitterroot River and on some of the adjacent low terraces, especially those east of the river. Near Corvallis, on a low terrace, wells capable of yielding 1,000 gpm or more can be constructed. Wells capable of yielding 50 to 250 gpm can be constructed on many of the alluvial fans of the tributary streams. In the remaining area, wells will generally yield only enough water for domestic and stock use.

From the hydrologic standpoint, the best use of ground water for irrigation is conjunctive use with surface water. Surface water is adequate early in the season and can be distributed throughout the area. As shortages occur, ground water can be used in areas where it is available in sufficient quantity, allowing the surface water to be used in areas of shortage where ground water is not available.

Water in the Bitterroot Valley is of satisfactory chemical quality for domestic, stock, municipal, and most industrial uses. Surface water is softer, as a rule, and contains less dissolved solids than the ground water. Streams heading in the Sapphire Mountains are more mineralized than those heading in the Bitterroot Mountains. Bitterroot River water in October 1955 was about twice as mineralized at Florence, near the outlet of the valley, as it was at Darby, near the inlet, but the difference is not significant in relation to the usefulness of the water.

INTRODUCTION

A cooperative program for the evaluation of the ground-water resources in Montana was begun in July 1955 by the U.S. Geological Survey and the Montana Bureau of Mines and Geology. The appraisal of the water resources of the Bitterroot Valley was one of the first projects started under the cooperative agreement. The main objectives were to determine (1) character and extent of the water-bearing materials; (2) occurrence, direction of movement, and availability of ground water; (3) annual, seasonal, and long-term fluctuations of the water table; (4) surface-water and ground-water inflow to and outflow from the valley in space and time; (5) areas from which substantial supplies of ground water of good quality can be obtained; and (6) chemical quality of the water.

LOCATION AND EXTENT

The Bitterroot Valley extends from near Darby to Florence and is bounded on the east by the Sapphire Mountains and on the west by the Bitterroot Mountains. The valley is about 45 miles long, averages about 7 miles wide, and includes about 300 square miles (fig. 1).

In 1955 and 1956, geologic and hydrologic data were collected east of the river. In 1957, the study area was expanded to include the western part of the valley, and the scope of the investigation was expanded to include surface-water inflow and outflow.

WELL-NUMBERING SYSTEM

The wells described in this report are assigned numbers on the basis of their location within the U.S. Bureau of Land Management's system of land subdivision. The well number shows the location of the well by township, range, section, and position within the section (fig. 2). The first letter of the well number gives the quadrant of the meridian and base-line system in which the well is located. The first numeral of the well number denotes the township, the second the range, and the third the section in which the well is located. Lowercase letters following the section number show the location of the well within the quarter section and the quarter-quarter section, respectively. Lowercase letters are assigned to the quarter or quarter-quarter

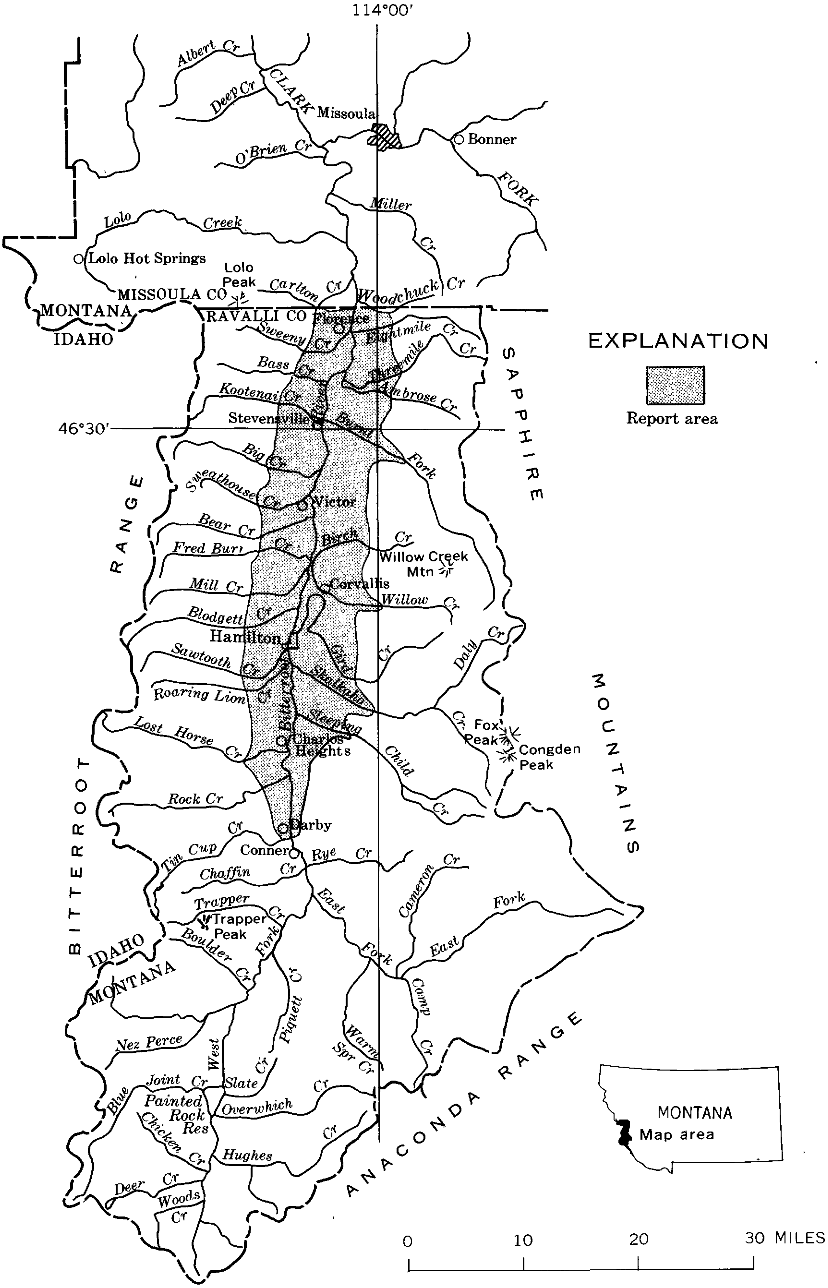

FIGURE 1.—Location of principal drainage features and the report area.

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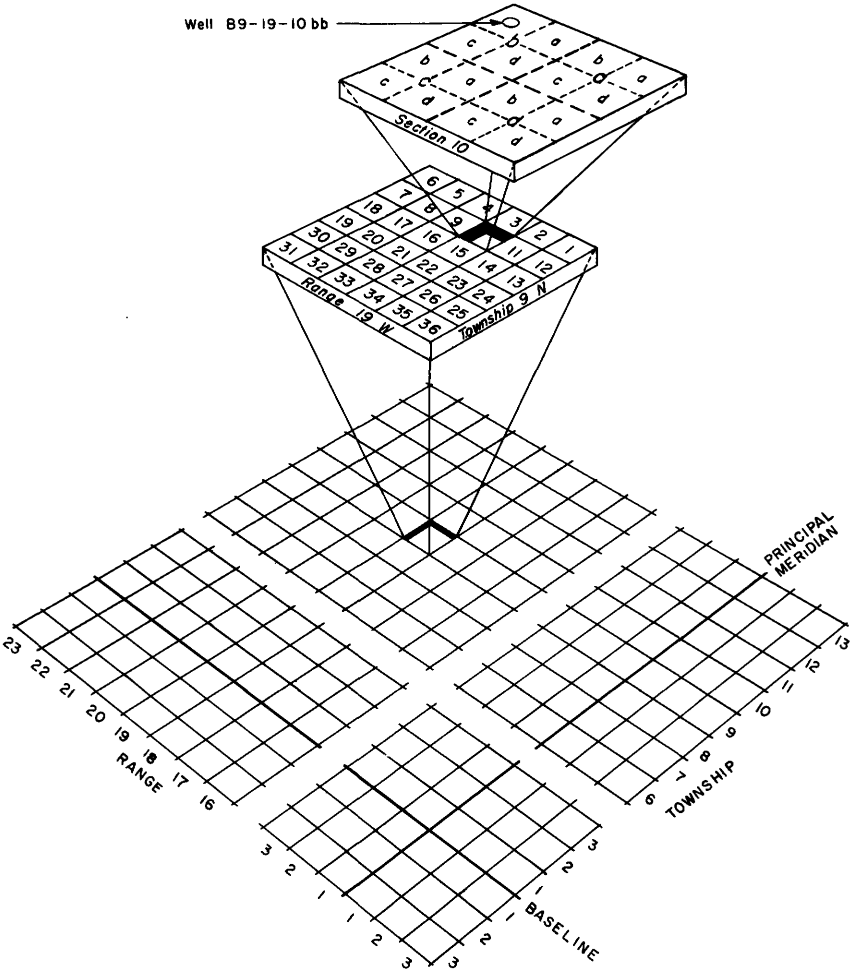


FIGURE 2.—Well-numbering system.

sections in a counterclockwise order beginning with "a" in the northeast quadrant. Suffix serial numbers, assigned in the order that the wells were inventoried, are added to the well numbers when more than one well was inventoried in a quarter-quarter section. Springs are numbered in the same manner.

PREVIOUS INVESTIGATIONS

Lindgren (1904) gave a generalized geological description of the Bitterroot Valley. Douglass spent considerable time during 1889, 1901, and 1905, searching for vertebrate fossils to date the Tertiary sediments in the valley. His conclusions were published in 1909 and have been cited by most of the later workers as a basis for their own Tertiary correlations. Langton (1935) and Ross (1950) described the regional stratigraphy and the rocks peripheral to the valley. Pardee wrote several papers (1910, 1940, 1942) relating to Lake Missoula of Pleistocene age, and a paper (1950) summarizing the late Cenozoic history of the northern Rocky Mountains and describing parts of the Bitterroot Valley.

The U.S. Soil Conservation Service (1947) prepared a report that furnishes data relating to water use, defines problems of water use and distribution, and predicts problems associated with prospective developments. McMurtrey and Konizeski (1956, 1959) reported progress on this investigation from September 1955 to September 1956 and summarized geologic and ground-water data collected from September 1955 to August 1958.

ACKNOWLEDGMENTS

Appreciation is expressed to the residents of the valley who gave information about their wells, permitted measurements to be made in their wells, and allowed access to their land. Special thanks are given to those who acted as observers for precipitation stations established for this investigation. Valuable information was furnished by the well drillers in the area.

The cooperation and assistance of the following organizations and officials contributed to the success of the investigation: U.S. Forest Service, U.S. Soil Conservation Service, U.S. Weather Bureau, University of Montana, Ravalli County Improvement Association, Ravalli County Rural Development Association, Ravalli County Agent, Valley Water Co. at Hamilton, and officials of the towns of Stevensville and Darby.

GEOGRAPHY

CLIMATE

The Bitterroot Valley is characterized by mild winters, cool summers, light precipitation, and very little wind. Wide deviations from average precipitation are common. During 1912–59, the annual precipitation at Stevensville averaged 12.75 inches and ranged from 7.07 inches (1935) to 20.83 inches (1927). Average monthly precipitation at Stevensville ranges from 0.66 inch in August to 1.74 inches in June (fig. 3). More than 25 percent of the yearly precipitation is generally in May and June. Precipitation is considerably greater in the Bitterroot Mountains than in either the Sapphire Mountains or the valley.

Large daily and seasonal fluctuations in temperature are common. Average monthly temperatures at Stevensville range from a high of 65.8°F in July to a low of 23.1°F in January (fig. 3). The average

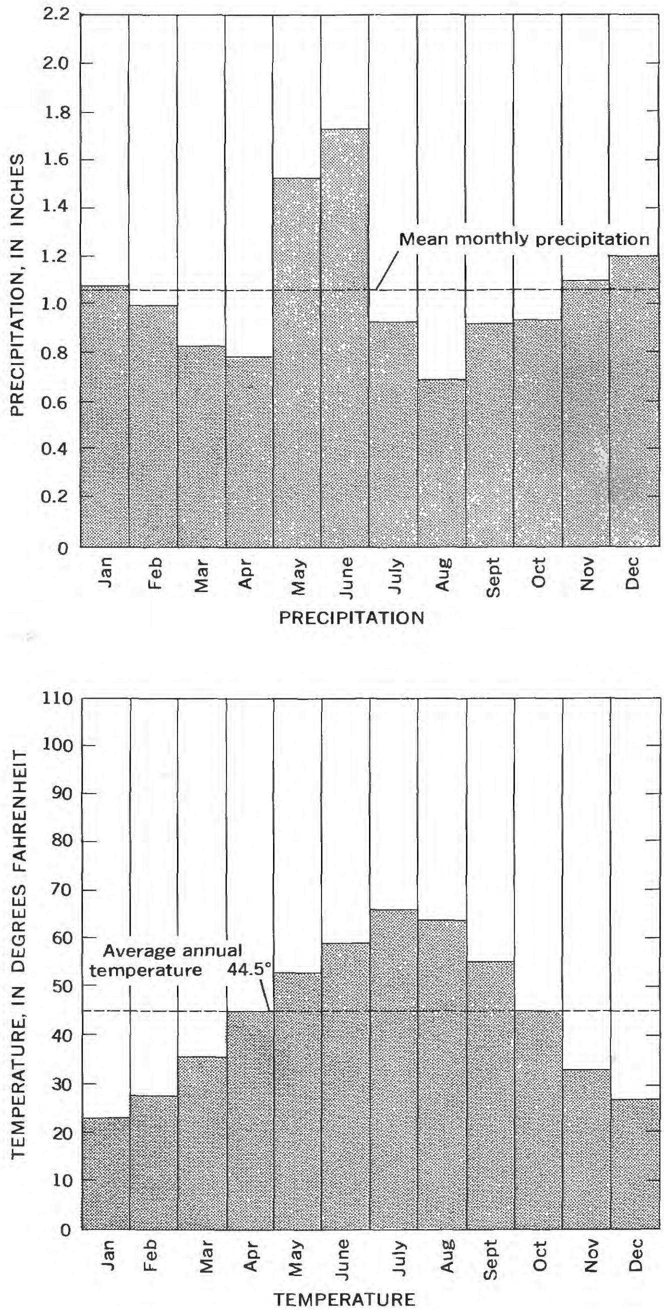


FIGURE 3.—Average monthly precipitation and temperature at Stevensville.

annual temperature is 44.5°F. Other temperature data are shown in the following tabulation:

	Stevensville	*Hamilton*
Mean minimum	30.2°F	33.2°F
Mean maximum	58°F	59.2°F
Highest recorded	102°F	103°F
Lowest recorded	−37°F	−39°F
Length of growing season	113 days	130 days
Average date of last killing frost	May 25	May 16
Average date of first killing frost	Sept. 15	Sept. 23

HISTORY AND INDUSTRY

The earliest report of the Bitterroot Valley is from the journal of Lewis and Clark, who traveled down the valley from Lost Trail Pass to Lolo in September 1805. Settlement of the valley began in 1841 when Father DeSmet and Father Ravalli established St. Mary's mission at the present site of Stevensville. In the 1860's, discovery of gold in western Montana and northern Idaho and the subsequent demand for agricultural products stimulated settlement.

Irrigation began in 1846 when Father Ravalli diverted water from Burnt Fork to irrigate a garden. The earliest decreed right was in 1852 from Burnt Fork for land northwest of Stevensville. The first irrigation canal supplying more than one person was built by James Hedges in 1883 and is still in use. The longest irrigation canal (75 miles) was built in 1905 and is now operated by the Bitterroot Irrigation District.

Agriculture in the Bitterroot Valley is predominantly irrigation farming. Dry farming is limited to a small area on the western slope of the Sapphire Mountains. The principal crops are forage crops, sugar beets, potatoes, small grains, and fruit. In addition, most farms have beef or dairy cattle. More than half the farm units are smaller than 50 acres.

According to the Montana State Engineer (1958), about 104,000 acres is irrigated in the valley; about 25,000 acres is supplied from the Bitterroot River, and the other 79,000 acres is supplied from tributary streams.

Lumber is the chief industry in the valley. The surrounding forest lands are estimated by the U.S. Forest Service to have an annual sustained yield of 12 million board feet of ponderosa pine, 14 million board feet of Douglas-fir, and 35 million board feet of lodgepole pine. Other industries include a fluorite mine, the harvest and sale of about 25,000 Christmas trees, a cheese factory, a creamery, livestock-commission yards, and a canning factory. The Rocky Mountain Laboratory, a research unit of the U.S. Department of Public Health, Education, and Welfare, is located at Hamilton. During the summer, the tourist trade is important.

TOPOGRAPHY

The Bitterroot Valley is one of many north-south-trending troughs in the Northern Rocky Mountains physiographic province (Fenneman, 1931, p. 220). It separates the rugged Bitterroot Mountains on the west from the more subdued Sapphire Mountains on the east. The Bitterroot Mountains are characterized by aretes, cirques, glacial lakes, and other prominent glacial features. The serrated crest of the mountains is about 10 miles west of the valley axis but is 2 to 5 miles east of the drainage divide. Summit altitudes along the crest increase from 9,075 feet at Lolo Peak in the north to 10,131 feet at Trapper Peak in the south.

The remarkably uniform front of the Bitterroot Mountains (fig. 4) is a series of triangular spurs separated by narrow steep-walled canyons. These canyons, which are remarkably straight and approximately parallel to each other, head in glacial cirques west of the crest of the mountains. The canyons are U-shaped in cross section, but the northernmost ones have deep V-shaped gorges in their lower courses (fig. 5). The uniformity of the triangular spurs is interrupted by glacial scour at altitudes above 7,000 feet and by local pediments between 6,000 and 7,000 feet. The surface of a pediment between Bass Creek and Sweeney Creek, if projected eastward, is about 1,500 feet above the central part of the valley (fig. 6). Remnants of a wave-cut bench of ancient glacial Lake Missoula (Pardee, 1910) occur at and below an altitude of 4,200 feet.

The Sapphire Mountains are characterized by moderately rounded profiles. Much of the surface is underlain by thin rocky soil, but bedrock crops out along the steeper slopes. Most of the summits are at altitudes below 8,500 feet, but Fox and Congdon peaks attain altitudes of 8,788 and 8,870 feet. The front of the mountains is very irregular. It borders the east side of the Bitterroot River from the confluence of the East Fork and West Fork to Skalkaho Creek, then recedes about 3 miles eastward. North of Woodchuck Creek at the Missoula County line, the front borders the river again. Relief is generally abrupt south of Skalkaho Creek and more subdued to the north.

The most striking topographic features within the valley are the great terraces that extend gently downward from the mountains (fig. 7). They have been modified by dissection and aggradation, but they generally slope into the valley at dips ranging from 4° or 5° near the margins of the valley to less than 1° near the center of the valley.

FIGURE 4.—Eastern front of the Bitterroot Mountains.

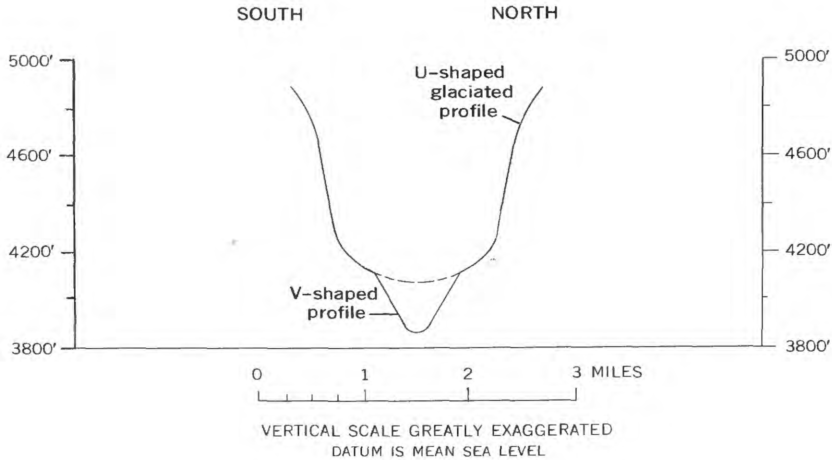


FIGURE 5.—Diagrammatic north-south profile across Kootenai Creek, showing glaciated canyon modified by postglacial (interlacustrine) stream erosion.

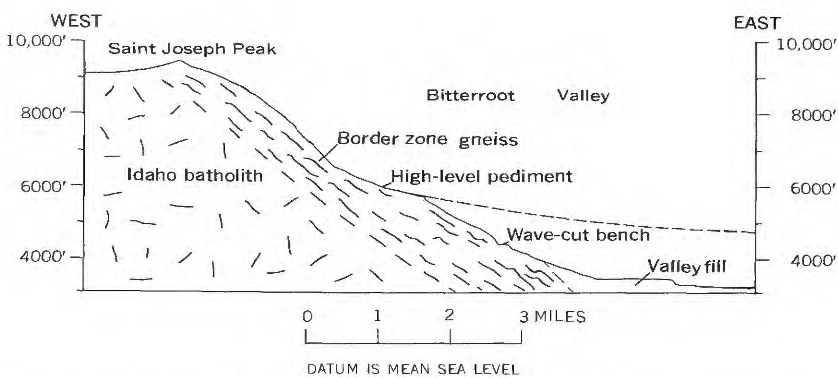


FIGURE 6.—Diagrammatic profile across eastern front of Bitterroot Mountains, showing high-level pediment between Bass and Sweeney Creeks, and remnants of a wave-cut bench.

Between Florence and Charlos Heights, their general north-south gradient is about the same as that of the Bitterroot River. For this report, terraces with their lowest points at altitudes of more than 3,300 feet are classified as high terraces and the others as low terraces.

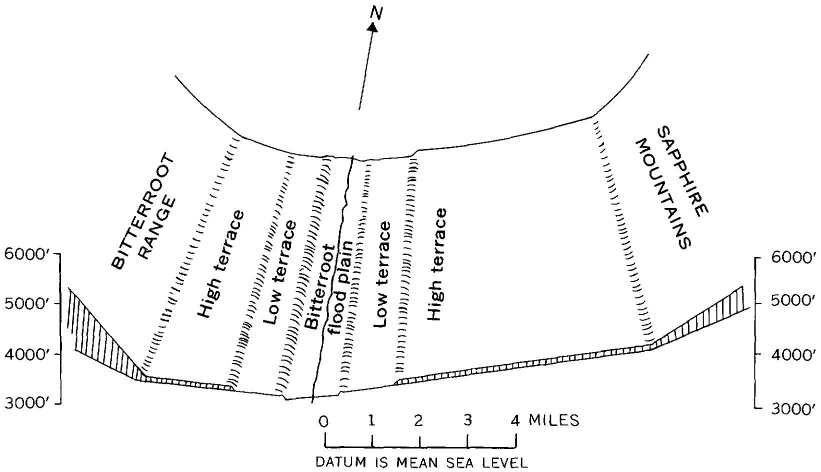


FIGURE 7.—Physiographic diagram of terraces north of Burnt Fork and Big Creek.

The high terraces have a maximum east-west width of about 6 miles but average about 3 miles. They are incised by the flat-floored valleys of the major perennial tributary streams. The high terraces on the east side of the valley have uniform topography and generally end in scarps 50 to 150 feet high. Those on the west side of the valley are greatly modified by dissection and sometimes end in low rounded bluffs that merge gently with the low terraces, making it difficult to define their boundaries.

The valley floors of most of the tributary streams are flat or slightly convex in cross section and are relatively wide for the size of the present streams. The flood plains usually coalesce with the low terraces along the wide flood plain of the Bitterroot River. Some of the tributary valleys are modified by moraines and glaciofluvial material near the base of the Bitterroot Mountains.

DRAINAGE

The Bitterroot River and its tributaries drain about 2,800 square miles. The master stream is formed by the confluence of the East Fork and West Fork of the Bitterroot River near Conner (fig. 1). Its altitude decreases from 3,832 feet near Darby to 3,273 feet near Florence. The gradient is about 20 feet to the mile between Darby and Hamilton and about 10 feet to the mile between Hamilton and Florence.

Between Darby and Florence, the Bitterroot River is joined by five major tributary streams from the Sapphire Mountains and 20 from the Bitterroot Mountains. In the Bitterroot Mountains, the approximate ratio of total length of stream to gradient per unit length of stream decreases from about 10 miles long by 600 feet of drop per mile in the north, to about 15 miles long by 300 feet of drop per mile in the south.

In the mountains, all of the major tributary streams flow on or close to bedrock. In the Bitterroot Valley, they flow over loose, unconsolidated sediments, and large volumes of water are lost by seepage. During the growing season, much of the remaining water is diverted for irrigation, and the lower courses of the streams are dry.

GEOLOGY

STRATIGRAPHY AND HYDROLOGIC CHARACTER OF ROCKS

The Sapphire Mountains are formed mostly of Precambrian sedimentary rocks and partly of Cretaceous intrusive rocks and associated metamorphic rocks. The Bitterroot Mountains are formed mostly of Cretaceous intrusive rocks and associated masses of metamorphosed Precambrian rocks. Early Tertiary volcanic rocks occur locally along the edge of the mountains and within the valley. Since its Late Cretaceous origin, the valley has been partly filled, at its deepest point, by more than 1,680 feet of sediments derived mostly by weathering and erosion of the mountains and to a lesser extent by accumulation of volcanic ejecta.

Hydrologically, the Precambrian sediments, the Cretaceous intrusives and metamorphics, and the early Tertiary volcanics can be considered together because they have similar abilities to store and transmit water. In general, these rocks are hard and dense and yield water only from fractures. An exception seems to be the Newland Limestone (p. 41), which transmits water through solution cavities. Fractures related to structural movement are common in the hard dense rocks, and most wells intersect enough fractures to yield 1 to 10 gpm (gallons per minute) initially. Because the amount of water stored in each fracture is small, well yields soon diminish unless the fractures are recharged by surface water or by seepage from the overlying unconsolidated rocks. Although the average permeability is small, the rocks are exposed over large areas, and their aggregate effect is important. Water released from these rocks sustains the flow of many springs and the base flow of streams.

The hydrologic properties of the Tertiary sediments and of the Quaternary rocks are discussed with the geologic description of these units. Table 1 is a summary of the water-bearing characteristics of the rocks in the Bitterroot Valley. The distribution of the rocks is shown on plate 1.

TABLE 1.—*Water-bearing properties of rocks in the Bitterroot Valley*

System	Series	Formation	Description	Water-bearing properties
Quaternary	Holocene	Alluvium	Stream-deposited clay, silt, sand, gravel, and boulders reworked from older Cenozoic deposits.	Alluvium is the most productive aquifer in area; yield of wells is somewhat variable but adequate for domestic and stock needs; along the Bitterroot River the yield is sufficient for irrigation, municipal, or industrial wells.
	Pleistocene	Glaciofluvial, glaciolacustrine, talus, and fan deposits.	Unsorted morainal and talus deposits ranging in size from clay to boulders; and stratified to poorly stratified glaciofluvial, glaciolacustrine, and fan deposits.	Yields of wells are generally adequate for domestic and stock needs but vary with degree of sorting and thickness of water-bearing zones.
Tertiary		Colluvium	Poorly sorted coarse angular sand and gravel.	Not known to yield water to wells.
		Flood-plain and channel deposits.	Silt and clay flood-plain deposits, and sand and gravel channel deposits, tuffaceous in places.	Yields small supplies adequate for stock and domestic wells from saturated channel sand and gravel. Fine-grained deposits are not known to yield water to wells.
Pre-Tertiary		Undifferentiated Precambrian and Cretaceous rocks.	Dense, relatively impermeable sedimentary, metamorphic, and igneous rocks marginal to and underlying the Bitterroot Valley.	Small supplies yielded to wells from joints and from weathered surficial material.

PRECAMBRIAN ROCKS

The oldest rocks exposed along the margins of the Bitterroot Valley are Precambrian sedimentary rocks assigned to the Ravalli Group and Newland Limestone of the Belt Supergroup. Rocks of the Ravalli Group crop out over large areas east of the valley between Eight Mile Creek and Birch Creek and in a narrow zone along the west side of the valley from the Ravalli County line south of Sweeney Creek. These rocks are mostly dark-gray quartzites and quartzitic argillites. Rocks of the Newland Limestone crop out over large areas east of the valley between Soft Rock Creek and Gird Creek, as small inliers at Chaffin Butte, and on the west side of the valley near the mouths of Big Creek and Sweathouse Creek. These rocks are mostly dark-bluish-gray argillaceous limestones and limy argillites. Belt rocks also probably underlie much of the valley fill.

CRETACEOUS ROCKS

Cretaceous rocks marginal to the Bitterroot Valley are components of either the Idaho batholith, its associated masses, or its border zone. They have been described in detail by Lindgren (1904), Langton (1935), Ross (1936, 1947, 1950), Anderson (1952), Chapman, Gottfried, and Waring (1955), Larsen and Schmidt (1958), and Larsen and others (1958).

IDAHO BATHOLITH AND ASSOCIATED MASSES

The Bitterroot Mountains west of Montana are underlain by granitic rocks of the Idaho batholith. These rocks are mostly gray quartz monzonite with small stocks of granodiorite and anorthite. Outlying masses also occur on the mountain slopes east of the Bitterroot Valley between Threemile and Ambrose Creeks and between Willow and Sleeping Child Creeks.

BORDER-ZONE GNEISS

Ross (1950, p. 153–154, 158) stated that "the border-zone gneiss comprises only the eastern ends of the spurs of the Bitterroot Range * * * and includes only the rock that has a distinctly laminated or stratiform character * * *." The principal minerals are quartz, potash feldspar, sodic plagioclase, biotite, other micas, and some myrmekite. It averages about 2,000 feet thick over its entire north-south extent (S. L. Groff, written commun., 1954).

Ross, Andrews, and Witkind, (1955) showed a large mass of border-zone gneiss (injection gneiss of Ross, 1950, p. 151) east of the Bitterroot Valley between Sleeping Child Creek and Darby. Similar rocks also crop out on the low foothills between Chaffin and Tin Cup Creeks and along many of the high terrace scarps between Chaffin and Roaring Lion Creeks.

TERTIARY ROCKS

VOLCANIC ROCKS

Tertiary volcanic rocks crop out locally on the high terraces near the mouths of the Sweeney Creek and Sweathouse Creek canyons in sec. 16, T. 10 N., R. 20 W., and sec. 33, T. 8 N., R. 21 W., and on both sides of the Bitterroot River between Lost Horse Creek and Chaffin Creek. In some areas, they intrude the border-zone gnesiss and older rocks, and fragments of them are included in the Pliocene strata along Blodgett Creek in sec. 15, T. 6 N., R. 21 W. Their composition ranges from acidic to basic. Welded tuffs near the mouth of Sweeney Creek canyon include angular fragments of Belt and granitic rocks.

SEDIMENTARY ROCKS

Unconsolidated to semiconsolidated Tertiary sedimentary rocks constitute most of the valley fill. They are referred to in this report as Tertiary strata. The various pre-Tertiary bedrock inliers, the irregular eastern margins of the valley, and the drilling data indicate that the Tertiary strata rest on a surface of moderate to high relief formed on Precambrian Belt rocks and Cretaceous border-zone rocks. However, gravimetric work by M. H. Manghnani (oral commun., 1959) under the supervision of the Department of Geology, University of Montana, indicates a basal cross-valley profile near Florence of very low relief. Except on the high terraces along the east side of the valley, the Tertiary strata are mostly overlain by Quaternary alluvium (pl. 1).

The total thickness of the exposed Tertiary section is apparently represented in the Threemile Creek–Ambrose Creek area. The maximum measured thickness is 227 feet in sec. 25, T. 10 N., R. 19 W. (See stratigraphic section below.) However, a test well drilled in 1922 by the Bitterroot Oil Co. in sec. 6, T. 6 N., R. 20 W., reportedly bottomed in unconsolidated sediments at 1,450 feet (Vine and Erdmann, 1952, p. 6). The top 30 or 40 feet of the well penetrated Quaternary alluvium, the remainder Tertiary strata. Field relationships indicate that strata penetrated by the oil well are lower in the section than exposures in sec. 25, T. 10 N., R. 19 W., thus, the cumulative thickness of Tertiary strata is at least 1,640 feet. Gravimetric work by M. H. Manghnani indicates a probable thickness of 2,000±200 feet near the center of the valley east of Florence (oral commun., 1959).

Section of Tertiary strata measured along a bluff in sec. 25, T. 10 N., R. 19 W.

	Feet
Silt and clay, buff; contains much mica; weathers into nodules	17
Sand, buff	10
Sand, buff, arkosic, well-sorted, well-bedded	8
Sand, buff, arkosic; contains pebbles up to 1 in. in diameter and is cemented with clay and some volcanic ash	5
Sand, buff, arkosic, medium-sorted, well-bedded	10
Covered	65
Clayey silt, buff, thin-bedded; weathers into nodules	5
Ash, gray, thin-bedded	6
Sand, buff, arkosic	30
Covered	20
Clayey silt, buff, thin-bedded; weathers into nodules; contains enough ash to give beds a pale-gray appearance from the distance. These beds dip from 1° to 5° valleyward and to the north. The dip decreases valleyward and is consistently a little less than that of the terrace	22
Sand, buff, arkosic; contains some ash and poorly sorted pebbles up to ¼ in. in diameter, cemented by clay and silt	23
Clayey silt, buff; contains some ash	6
Total	227

The Tertiary strata are mostly detritus from the mountains but also contain volcanic ejecta. Coarse colluvial deposits along the base of the mountains grade valleyward into fine-grained alluvial-fan deposits that in turn interfinger with flood-plain deposits of silt and paludal clay with intercalated lenses of channel sand and some gravel (fig. 8).

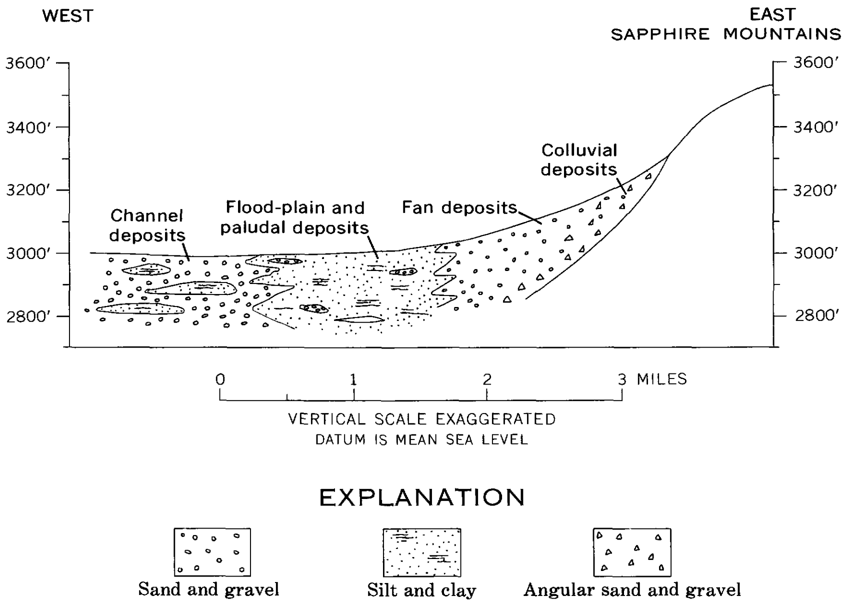


FIGURE 8.—Diagrammatic section across east side of Bitterroot Valley, showing east-west distribution of Tertiary sediments.

Channel deposits of the ancestral Bitterroot River constitute most of the section in the central areas of the valley. This pattern of distribution is complicated by local variations and is interrupted by extensions of channel deposits toward the mouths of the various tributary canyons (fig. 9). Extensive deposits of volcanic ash are interbedded with the Tertiary sediments. The complete east-west distribution of the depositional types of Tertiary strata is not encompassed in any single or continuous series of outcrops.

Douglass (1909, p. 265) described the east-west distribution of Tertiary strata east of Stevensville as follows:

Here then we have near the mountains sand composed of quartz and feldspar caused by the decomposition in place of granitic rock. A little farther away toward the west is the same kind of sand, little or not at all water worn, but mixed with other material and forming the high benchland. Still farther to the west nearer the river, are similar sands, perhaps slightly water worn, mixed with lighter colored material.

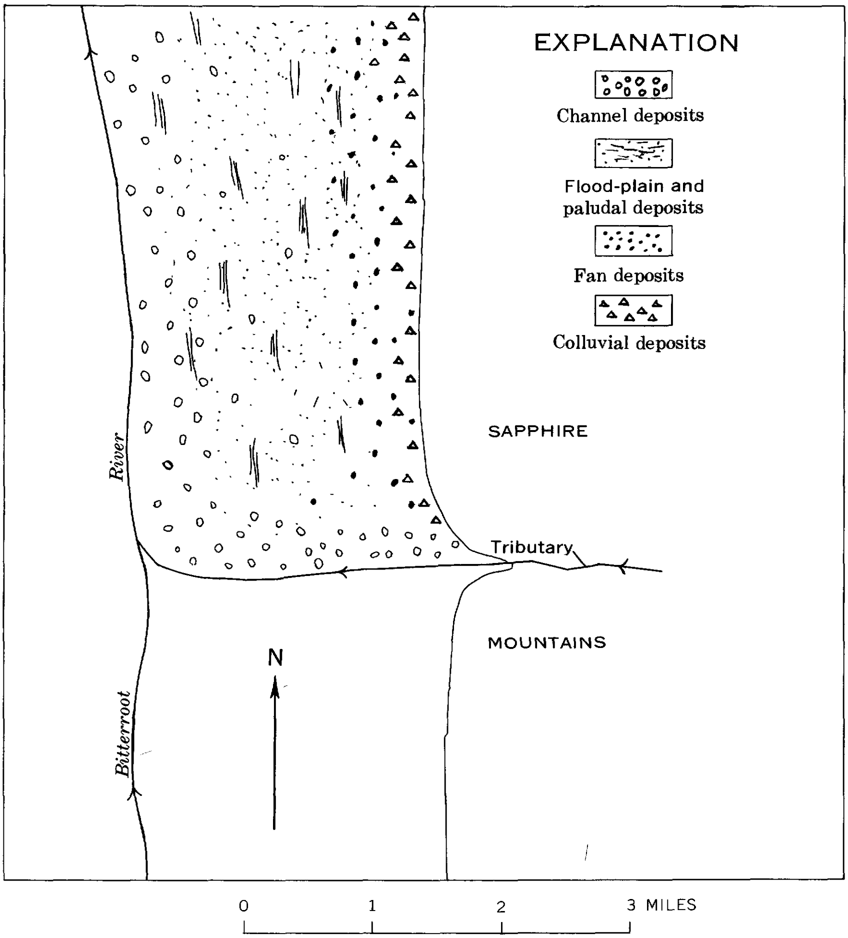


FIGURE 9.—Distribution of Tertiary detritus in front of tributary canyon.

Tertiary strata near the mountains and in the central and western areas of the valley are mostly overlain by Quaternary alluvium. However, Tertiary colluvium crops out on the high terrace scarps east of Threemile Creek and north of Woodchuck Creek in secs. 5 and 25, T. 10 N., R. 19 W. The colluvium that crops out east of Threemile Creek consists of loose freshly weathered feldspar and quartz derived in place at the foot of an associated mass of the Idaho batholith. These deposits grade westward into unconsolidated alluvial fans of moderately weathered arkosic sand and intercalated beds of volcanic ash. The outcrops near Woodchuck Creek are transitional between locally derived deposits and fan deposits and consist of bedded deposits of angular fragments of quartzitic argillite up to 4 inches in diameter and of quartz and feldspar, cemented by a silty clay matrix.

Most of the exposed Tertiary flood-plain deposits on the east side of the valley consist of semiconsolidated silt with some intercalated lenses of bentonitic clay. Two clay samples (table 2) taken from the Ambrose Creek drainage in sec. 16, T. 9 N., R. 19 W. (sample 16), and from the white cliff outcrops in sec. 6, T. 10 N., R. 19 W. (sample 22), had similar chemical characteristics and were relatively high in aluminum.

TABLE 2.—*Chemical analyses, in percent, of Tertiary clay from the Bitterroot Valley*

[Sahinen and others (1958, table 4, p. 37)]

Sample	SiO_2	Al_2O_3	Fe	CaO	MgO	Na_2O	K_2O	TiO_2
16	59.2	20.1	3.4	1.5	0.5	1.6	2.7	0.4
22	60.6	19.1	2.9	1.4	1.6	2.7	2.8	.15

In a few localities, the flood-plain silt contains angular fragments of locally derived bedrock and a few lime concretions along the bedding planes. The lime was evidently derived from solution of the Newland Limestone east of the valley. Some silt along the west side of the valley near Victor contains monazite. In 1953, the U.S. Bureau of Mines conducted extensive exploratory operations in order to estimate the potential reserves (Holt, 1964).

The Tertiary channel deposits are relatively unconsolidated but form the white cliffs as much as 140 feet high. The channel deposits are typically crossbedded and are well-rounded grains of quartz and fragments of granite, border-zone gneiss, and argillaceous rocks. The average grain size generally decreases from boulders up to 10 inches in diameter near the mouths of the tributary canyons to fine gravel and sand near the center of the valley.

Fifty feet of channel deposits are exposed in borrow pits and gullies on the margins of the high terrace above Skalkaho Creek in sec. 4, T. 5 N., R. 20 W. Some intercalated lenses are slightly cemented with manganese. Because the manganese occurs on the bedding planes, it is believed to be of primary origin. Turbulence of the transporting water may have caused oxidation and precipitation.

At least five beds of volcanic ash are exposed in 16 localities on the east side of the valley. A single bed is exposed on the north bank of Lick Creek on the west side of the valley in sec. 29, T. 4 N., R. 21 W.

The ash is mostly intercalated with flood-plain silt. It is generally horizontally bedded and was apparently deposited in an aqueous environment; however, some ash is crossbedded and may have been windblown. Small concentrically banded pellets of ash, 3 to 6 mm (millimeters) in diameter, occur on some of the bedding planes. Local variations in chemistry and lithology of the ash do not allow intravalley correlation.

The Tertiary sediments are predominantly brown and gray, but some are black and various shades of yellow, green, and red. The colluvial deposits and flood-plain silt range from dark brown to light gray. The brown coloration results from weathering of included iron-bearing rock and mineral fragments. The variation from dark to light is a function of the amount of incorporated (iron-free) ash.

The volcanic ash ranges from medium dark gray to light gray, and the color is related to the size of shards and to the amount of devitrification. Most of the channel sand and gravel is light gray. One exception is the brick-red basal 38 feet of the white cliffs between Woodchuck Creek and Eightmile Creek in sec. 6, T. 10 N., R. 19 W. (See stratigraphic section below.) The color of these sediments is apparently caused by oxidation of iron by percolating ground water.

The paludal clay ranges from green, to brown, to yellow, to bluish gray, to black. These colors result partly from the proportion of bentonite (green to white), to flood-plain silt (brown), to carbon (black). A bluish cast often prevails in moist conditions, and because of this, much of the clay, regardless of its true color, is described in drillers' logs as blue clay.

Section of Cenozoic strata measured along Bitterroot River at white cliffs in sec. 6, T. 10 N., R. 19 W.

	Ft	*In*
Quaternary:		
Sand, gray, slope wash; bedded parallel to surface slope	1	0
Soil, brownish-black	1	0
Gravel, angular; average diameter is 3 in		3
Tertiary:		
Clay, buff, well-bedded; contains some 1 in.-thick lenses of carbonaceous materials; grades upward to silt	5	6
Sand, gray, washed, channeled; contains a few clay and pebble lenses from 1 to 3 in. thick and up to 30 ft long. Bedding dips 3° to the southeast and is parallel to bedding in the whole outcrop	3	6
Sand, grit, and pebbles, gray, well-bedded; contains thin limonitic stained lenses	7	4
Clay, buff, thin-bedded; grades downward into silt, and then into fine gray sand at bottom	5	6
Sand, gray, well-bedded; mostly of granitic derivation	3	6
Sand, gray, well-bedded, channeled; contains some lenses of grit and pebbles to 1 in. in diameter	14	3
Clay, carbonaceous; weathers into blocky rubble	1	6

428-135 O—71——4

Section of Cenozoic strata measured along Bitterroot River at white cliffs in sec. 6 T. 10 N., R. 19 W.—Continued

	Ft	In
Tertiary—Continued		
Sand, buff; contains much silt and clay	2	6
Clay, buff, blocky, well-bedded; grades downward into silty clay to clayey silt; separated from underlying sand by 1 in. of reddish clay	8	0
Sand and grit, gray, well-bedded, channeled; contains gravel to 1 in. in diameter and a few thin lenses of clay	32	0
Sand and gravel, red, hematitic, poorly sorted, interbedded, lenticular, channeled; staining follows the bedding	15	6
Sand, gray, channeled; with thin red hematitic lenses, many of which go across the bedding and give the whole section a reddish cast. This sand was apparently gray at the time of deposition, and the iron stain was caused by percolating water from adjacent beds	9	0
Sand, grit, and gravel, ferruginous, crossbedded, channeled; contains syngenetic and epigenetic iron stain and one 2-ft lense of unstained gray sand	14	0
Sandy grit and gravel; gray with much iron stain that gives the section a reddish cast; channeled and lenticular. Mostly covered by talus	30	0
	154	4

The age of the Tertiary strata was first estimated by Earl Douglass in 1909. On the basis of "a small piece of tooth of a Mastodon * * * the lower portion of the Ulna-radius of a fairly large Procamelus, * * *" and "a few fragments of bones and teeth, some of the latter of which belonged to the high-toothed type of later Miocene horses, * * *" (Douglass, 1909, p. 265), he assigned a Miocene age to "a portion at least of the upper beds * * *." He also stated: "there are, however, beds which lie lower and are exposed—one or two hundred feet in thickness—in a bend of the Bitterroot River, 12 to 15 miles below Stevensville. These beds I believe to be Oligocene, though no characteristic fossils were found in them."

Since Douglass' explorations, local residents collected two fossil vertebrate assemblages from the Threemile Creek and Ambrose Creek areas. These were presented to the Montana State University and have since been lost. However, Dr. C. F. Deiss, who was with the Department of Geology at that time (1935), stated (written commun., 1956) that "The bones were so fragmentary that identification [age] was a guess as to Pliocene."

During the 1956 field season of this investigation, the Tertiary strata on the east side of the valley were carefully prospected for fossils. A stratigraphically definitive mammalian assemblage was collected from outcrops along the drainages of Threemile, Ambrose, and Willoughby

Creeks, and from a small arroyo immediately north of Willow Creek. It included eight specimens of the following species: *Tardontia* cf. *occidentale*, *Mammut* (*Pliomastodon*) cf. *P. matthewi*, *Pliohippus interpolatus*, *Teleoceras* cf. *T. fossiger*. On the basis of this assemblage and the regional structure, Konizeski (1958, p. 346) assigned on early Pliocene (Clarendonian) age to all of the exposed Tertiary strata on the east side of the Bitterroot Valley.

The lithology (see stratigraphic section below) and structural relationships of the exposed Tertiary beds west of the Bitterroot River suggest that they are equivalent to the better known Pliocene strata on the east side of the valley. An abandoned coal mine and two prospects about 3 miles northwest of Darby in sec. 3, T. 4 N., R. 21 W., were examined in 1958. No fossils were found, but semi-indurated plant beds, probably correlative with the coal mine strata, crop out on the north bank of Lick Creek in sec. 29, T. 4 N. R. 21 W. They are interbedded with volcanic ash and underlie semiconsolidated buff-colored silt similar to the Pliocene flood-plain silt exposed on the east side of the Bitterroot Valley. From them were collected specimens of *Micrhystridium*, *Botryococcus*, Dinoflagellata? and *Selaginella* (age indeterminate); and *Metasequoia occidentalis* (Paleocene to middle Miocene), *Glyptostrobus* sp. (Lower Cretaceous to Holocene), and *Alnus relata* (Miocene). On the basis of the stratigraphically ambiguous assemblage and because these beds underlie younger, probably Pliocene, strata, these beds are believed to be of Miocene, or perhaps late Oligocene, age.

Section of Tertiary strata measured along north bank of Blodgett Creek in sec. 15, T. 6 N., R. 21 W.

	Ft	*In*
Sand, gray, lenticular	1	2
Silt, gray; includes thin limonitic lenses	1	2
Sand, ferruginous	0	3
Clay, buff but greenish on joint faces, blocky	2	0
Sand, limonitic, micaceous	0	3
Clay, light-gray, well-bedded; contains greenish lenses	1	6
Sand, limonitic, well-sorted, well-bedded, lenticular	6	0
Sand, gray, silty	0	3
Sand, limonitic, coarse; grades laterally into grit and gravel	0	6
Clay; bluish gray when wet; cream colored to light gray when dry; thin bedded; forms resistant beds	0	10
Sand, limonitic, well-bedded	1	2
Clay; bluish gray when wet; cream colored to light gray when dry; thin bedded; forms resistant beds	0	10
Sand, gray, arkosic, well-sorted, lenticular	0	4
Sand, limonitic, coarse, well-sorted, lenticular	0	6
Clay, blue-gray to cream-colored, well-bedded; contains hackberry seeds	1	0

Section of Tertiary strata measured along north bank of Blodgett Creek in sec. 15, T. 6 N., R. 21 W.—Continued

	Ft	In
Sand, light-gray, arkosic, well-sorted, lenticular	0	10
Clay and silt; blue gray when wet; cream colored to gray when dry; micaceous; soapy-slippery feel when wet; excellent unit bedding but intraunit bedding hard to see; forms resistant beds that weather into nodules	3	0
Grit and gravel, gray, angular; in limonitic sand and clay matrix	4	0
	25	7

Because few wells have been drilled into the Tertiary sediments, little is known of their hydrologic properties (table 10). Wells drilled normally penetrate less than 400 feet into these sediments; thus, the major part has not been tested. Study of the outcrops, however, allows some tentative generalities to be made about the water-bearing characteristics. Colluvium along the mountain fronts is poorly sorted and unlikely to yield large quantities of water to wells. No wells are known to tap the colluvium, but test drilling may locate water-bearing beds because the degree of sorting changes rapidly within short distances and because the colluvium can be recharged by streams from the mountains. The fine-grained alluvial fan deposits and flood-plain deposits are not known to yield water to wells and are relatively impermeable. These deposits impede the movement of water and act as confining beds. Channel deposits of the ancestral Bitterroot River are permeable and yield adequate amounts of water to domestic and stock wells. Most of the wells in the valley tap relatively silt-free sand and gravel lenses in the channel deposits. Most of the lenses are thin, and, even though relatively permeable, one lens may have a small yield. Yields of wells in the channel deposits could probably be substantially increased by drilling 300 or 400 feet into the deposits and gravel packing the entire water-bearing section.

QUATERNARY ROCKS

Quaternary alluvium averages about 40 feet thick over much of the valley. It lies on an irregular erosion surface cut mostly on lower Pliocene strata. Early to middle Pleistocene alluvium caps the ends of the high terraces on the east side of the valley and mantles most of the high terraces on the west side of the valley. Late Pleistocene to Holocene alluvium underlies the low terraces and the Bitterroot flood plain. Moraines partly block the mouths of many of the tributary canyons on the west side of the valley.

Except for the morainal deposits, the alluvium is generally best sorted in the eastern and southern areas of the valley. The alluvium consists of stream-transported detritus from the Sapphire Mountains, glacial debris from the Bitterroot Mountains, and reworked Cenozoic fill. This material was deposited in a wide variety of rapidly changing fluvial, glaciofluvial, and glaciolacustrine environments. Thus, the various sedimentary types overlap, interfinger, and intergrade both laterally and vertically.

The alluvium beneath high terraces on the east side of the valley is mostly well-rounded gravel, sand, and silt deposited in alluvial and lacustrine environments. The sorting generally increases and grain size decreases with increased distance from the mouths of the major tributary canyons. These relationships are best illustrated in the exposures along the high terrace scarps that border the flood plain of Burnt Fork (fig. 10).

About 40 feet of bedded lacustrine deposits are exposed in roadcuts on the west end of the high terrace between Eightmile Creek and Threemile Creek in secs. 18, 19, 30, T. 10 N., R. 19 W. The beds dip west at a low angle and pinch out to the east at the contact with Pliocene flood-plain silt. These Quaternary deposits are mostly fine well-sorted sand and some gravel; however, clay and silt also occur in areas immediately adjacent to the Pliocene flood-plain silt. Well-developed foreset beds and other deltaic features are exposed in a gravel pit in sec. 1, T. 9 N., R. 20 W. (fig. 11).

A unique deposit of Quaternary alluvium crops out on the east-west ridge between Dry Creek and Soft Rock Creek where well-rounded granitic boulders 10 feet or more in diameter are set in a gravel matrix. The distribution, lithology, and orientation of the material suggest that it was transported by outwash streams flowing from glaciers on the slopes of Willow Creek Mountain, an outlying mass of the Idaho batholith, 5 miles east of the valley (Alden, 1953, pl. 1).

The alluvium beneath most of the high terraces on the west side of the valley was derived from the glacial deposits in the Bitterroot Mountains. Talus occurs in a narrow belt along the heads of the high terraces at the base of the steep mountain slopes.

The Bitterroot River and its tributaries have cut below the level of the high terraces and partly drained the alluvium beneath the terraces. Wells tapping the alluvium yield adequate amounts of water for domestic and stock use. Springs issue along the contact between the alluvium and Tertiary sediments. The most successful wells tap depressions in the surface of the Tertiary sediments where the zone of saturation is thicker than average. Recharge from irrigation keeps the alluvium from becoming completely drained.

Glaciofluvial deposits are mostly outwash fans of angular to well-rounded fragments of granitic rocks and of border-zone gneiss. Grain size ranges from silt to boulders, which may be more than 20 feet in

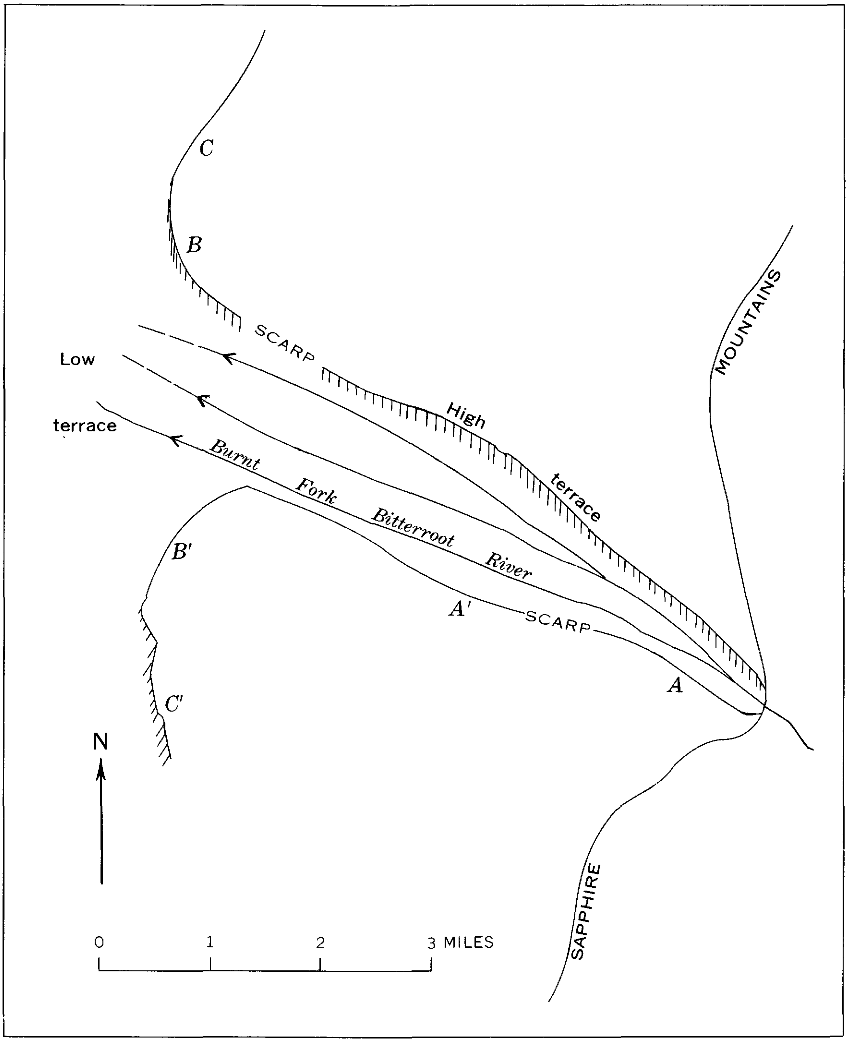


FIGURE 10.—Gradational distribution of Quaternary alluvium in Burnt Fork area. *A*, heterogeneous mixture of well-rounded to subrounded boulders, cobbles, gravel, sand, silt, and clay; exposed in borrow pit in sec. 9, T. 8 N., R. 19 W. *A'*, lithology similar to *A* but somewhat better sorted; exposed in sec. 6, T. 8 N., R. 19 W. *B*, moderately well sorted, well-bedded, and well-rounded gravel, sand, and some silt; exposed in gravel pit in sec. 13, T. 9 N., R. 20 W. *B'*, lithology and distribution as in *B*; exposed in sec. 2, T. 8 N., R. 20 W. *C*, well-sorted, well-bedded sand; exposed in pit in sec. 13, T. 9 N., R. 20 W. *C'*, lithology and distribution as in *C*; exposed along irrigation ditch in sec. 15, T. 8 N., R. 20 W.

diameter. In general, the material is coarsest near the base of the mountains and finest on the valleyward ends of the high terraces; however, there is much local variation and lateral lensing. The wide

FIGURE 11.—Deltaic deposits of glacial Lake Missoula, sec. 1, T. 9 N., R. 20 W.

range in grain size and lateral lensing cause the water-bearing characteristics to vary greatly within short distances. In general, however, sorting and permeability are lowest near the base of the mountains and increase valleyward.

Glaciolacustrine deposits are mostly well-sorted well-bedded sand containing small amounts of silt, grit, and pea gravel. Fifty feet of well-sorted lacustrine sand and a few pebbles is exposed in a pit in sec. 36, T. 7 N., R. 21 W. Twenty feet of fine well-sorted lacustrine sand is exposed in sec. 9, T. 7 N., R. 21 W. The predominately fine grained glaciolacustrine deposits are poorly permeable. The deposits are mostly above river level and are generally drained.

The low terraces are developed on about 40 feet of late Pleistocene to Holocene fluvial gravel, sand, and silt. On the east side of the valley, this alluvium is mostly material eroded from the Sapphire Mountains and is partly reworked older Cenozoic fill.

The distribution of alluvium along Eightmile Creek is typical of the east side tributaries. This alluvium is about 40 feet of angular fragments of argillite in a matrix of weathered monzonite and silt. These materials grade north from the creek into sand which includes angular fragments of argillite. South of the creek, the alluvium grades into a rich deep soil of clay and silt.

The low terraces on the west side of the valley are formed on late Pleistocene to Holocene alluvium. Huge outwash fans head below the mouths of the major tributary canyons, extend down the stream valleys, and generally coalesce below the eastern margins of the intervening high terraces. These fans are material derived mostly from moraines in the tributary canyons. The constituents grade from boulders and gravel near the heads of the fans to gravel, coarse sand, silt, and clay at their outer, valleyward margins.

The flood plain of the Bitterroot River is formed on about 40 feet of Quaternary alluvium. The alluvium was derived mostly from the low terraces and is well-rounded gravel and sand which contains a small amount of silt and clay. It is generally better sorted in the southeast and finer grained in the northwest.

The alluvium beneath the low terraces and the flood plain of the Bitterroot River has the greatest water-transmitting and storing capacity of any aquifer in the valley. Properly constructed and developed wells in the flood plain are capable of supplying more than 250 gpm. Except near Corvallis, wells located on the low terraces or along the tributaries supply less water because the saturated thickness is slightly less and because the average permeability of the deposits is less. Near Corvallis, permeability is greater than average, and wells are capable of yielding 1,000 gpm or more. Wells on the low terraces and along the tributary streams are adequate for domestic and stock use. Test drilling in these areas might locate places of greater permeability than average (because of variations in sorting) where wells could produce enough water for supplemental or for limited irrigation. The alluvium is almost completely saturated and hydraulically connected with the streams. Thus, pumping large quantities of water will cause the streamflow to diminish.

Moraines occur at altitudes ranging from 3,700 feet to 5,200 feet near the mouths of the major tributary canyons south of Big Creek and within the lower canyons of several of the major tributary streams north of Big Creek. The moraines on Roaring Lion Creek are perhaps the best developed in the valley. A lateral moraine extends valleyward from a bedrock spur on the south side of the canyon. From this moraine, five terminal moraines extend northward partly blocking the mouth of the canyon. Roaring Lion Creek is deflected north of these terminal moraines. The relatively undissected nature of most of the moraines indicates a late Pleistocene age.

Till comprising the moraines contains large amounts of clay and is poorly permeable. No wells are known to obtain water from the till.

Large boulders up to 25 feet in diameter are scattered over the terraces on the west side of the valley and on the east side of the valley south of Spooner Creek. Their locations suggest transportation by ice rafting as well as by streams. No moraines occur on the east side of the valley.

Thin soils mantle most of the valley. Their extremely variable composition reflects the lithology of the underlying and bordering source rocks. Most of the soils on the east side of the valley are derived from Pliocene sediments. Conversely, most of the soils along the Bitterroot flood plain and the west side of the valley are derived from relatively young unweathered Quaternary deposits. Because of these relationships, the soils on the east side of the valley are generally well developed and fertile and produce good crops when adequately irrigated, while those on the Bitterroot flood plain and the west side of the valley are generally less well developed and less fertile.

STRUCTURE

REGIONAL

The Bitterroot Valley has been described (Pardee, 1950, p. 389–390) as part of a system of north-south trending Northern Rocky Mountain structures. Lindgren (1904, p. 48) stated that it "is an extremely well marked and probably very deep depression almost coextensive with the range, and that borings would probably show it to be a structural depression without outlet * * *." Ross (1950, fig. 56) depicted the valley as a structural trough on the flanks of the Idaho batholith.

The eastern front of the Bitterroot Mountains (west side of the valley) is uniform in regional aspect but complex in detail. It is a dip slope formed on, and partly transecting, the stratiform structure of the border-zone gneiss (figs. 12, 13). The attitude of the gneiss varies locally, but it strikes about N. 15° E. between Darby and Victor, and N. 30° E. between Victor and Florence. In contrast, the eastern front of the mountains strikes about due north from Darby to Victor, and about N. 35° E. between Victor and Florence. The 15°–30° east dip of the mountain front is about equivalent to that of the border-zone gneiss.

The traces of four echelon faults are clearly visible on the mountain front between Florence and Victor. Movement along them was recorded as late as 1898 (Lindgren, 1904, p. 49). The faults strike from about N. 35° E. in the south, to N. 15° E. in the north, and range in dip from about 45° E. to vertical. The shear zone of the fault near Big Creek is more than a quarter of a mile wide. The shear zone near Gash Creek is more than 150 feet wide, and the fault has more than 50 feet of throw. Stream gradients increase where the streams cross the faults. The

428–135 O—71——5

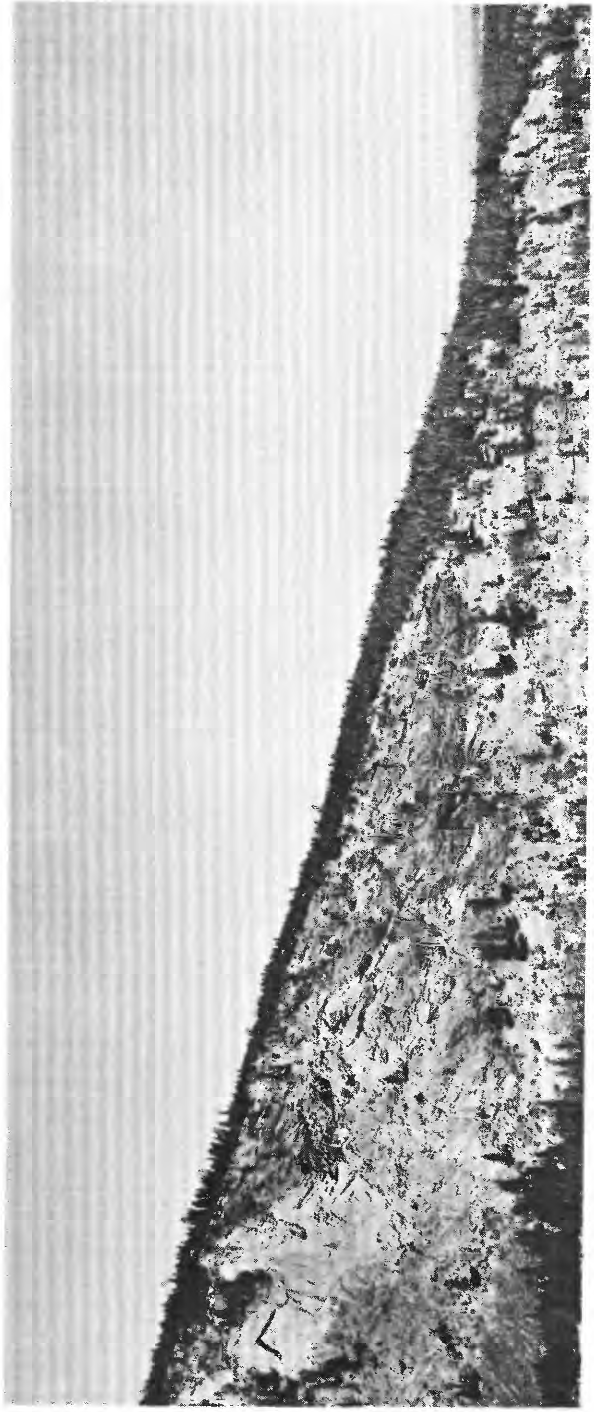


FIGURE 12.—Stratiform border-zone gneiss near mouth of Blodgett Creek canyon.

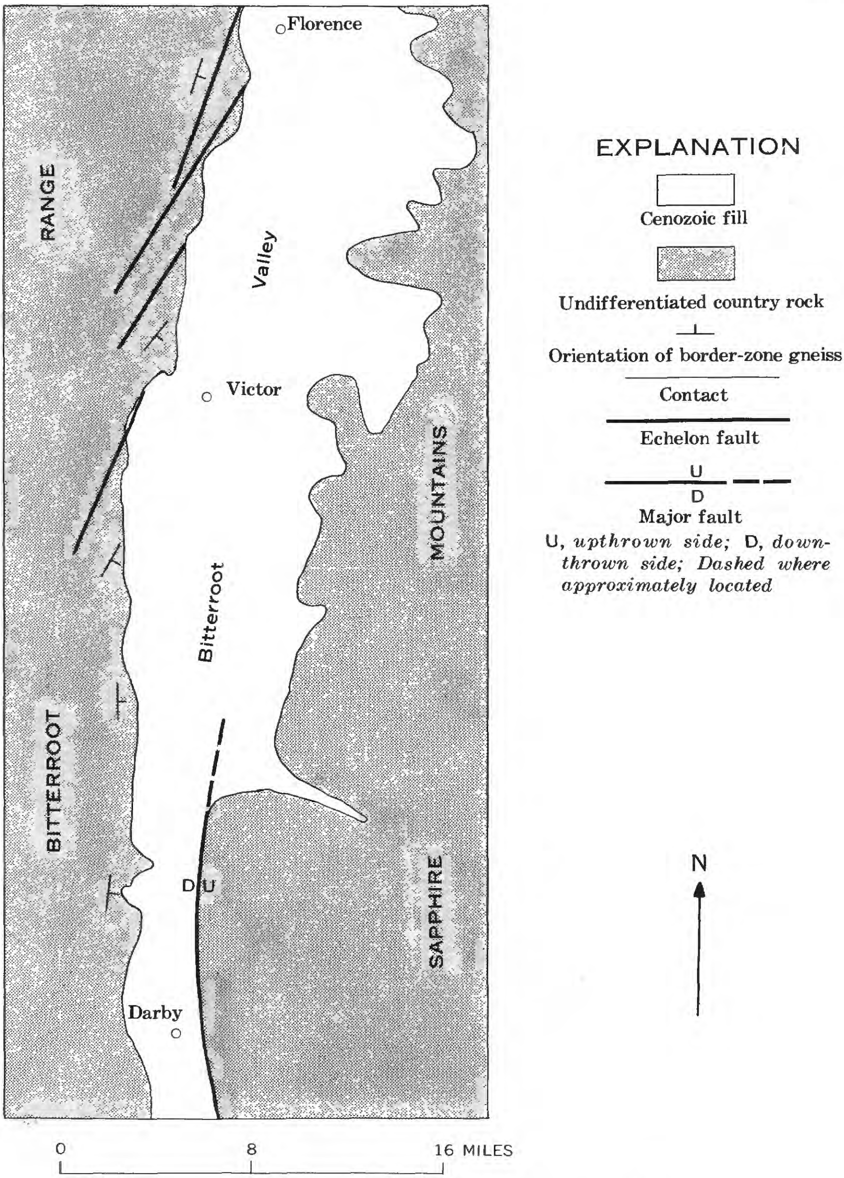


FIGURE 13.—Structures marginal to Bitterroot Valley.

mountain front between Skalkaho Creek and Darby ends in a series of great triangular spurs above the Bitterroot River. Tertiary volcanic rocks exposed on the ends of these spurs dip 10°–20° S. and are greatly faulted and jointed. Similar rocks across the river along U.S. Highway 93 in sec. 15, T. 4 N., R. 21 W., are apparently part of the same section that has been downfaulted at least 200 feet, suggesting that the stream follows a major fault (fig. 14). The abrupt eastward recession of the Sapphire Mountain front for 3 miles along the south side of Skalkaho Creek may be fault controlled also. All of the exposed volcanic rocks within the valley occur along fault zones.

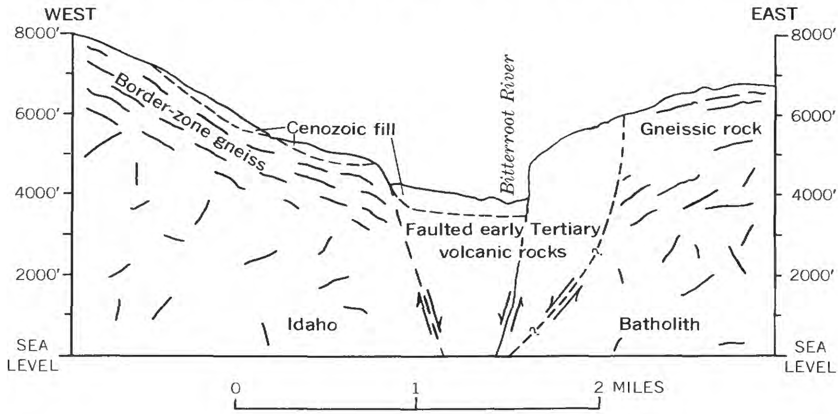


FIGURE 14.—Diagrammatic section across Bitterroot Valley south of Skalkaho Creek.

INTRAVALLEY

The strike of the exposed Pliocene strata is generally about the same as and the dip is a few degrees greater than, that of the high terraces. Conversely, the older Tertiary strata in the valley are variously oriented. It appears, therefore, that the dip of the Pliocene strata is about the same as it was when the strata were deposited and that the folding, faulting, and reversal of dip in the older Tertiary strata are due to pre-Pliocene orogeny. Only two exceptions to the regional dip of the Pliocene strata have been recorded in the Bitterroot Valley.

Bedrock extends valleyward beneath the high terrace immediately north of Skalkaho Creek in secs. 9, 16, T. 5 N., R. 20 W. Lapping onto this bedrock is 60 feet of Pliocene flood-plain silt and ashy, bentonitic clay, which dips about 30° W. The dip may have been a primary depositional feature on the steeply dipping bedrock surface or may have been caused by secondary slumping of the clay.

The other exception is at the white cliffs where the exposed Pliocene strata dip about 3° S. Because this locality is near the middle of the valley, orientation could not be primary. The only plausible alternative is that the dip was reversed by folding or faulting. The stresses that caused the tilting may be related to the echelon faults west of the area.

SUMMARY OF GEOLOGIC HISTORY

ORIGIN OF BITTERROOT VALLEY

The age of the Idaho batholith has been estimated by lead-alpha methods (Chapman and others, 1955; Larsen and Schmidt, 1958; Larsen and others, 1958). Larsen, Gottfried, Jaffe, and Waring concluded that it is early Late Cretaceous and that it was intruded in a short time, not more than a few million years. Ross (1950, p. 170) described the huge slab of border-zone gneiss that forms the western wall of the valley as "a part of the [Beltian] rocks that were invaded * * * and domed during the intrusion * * *." The structural relationships show that the Bitterroot Valley became a marginal trough during the intrusion. It is equally clear, however, that the valley has been modified by later structural movement and by erosion. As indicated by Ross (1950. fig. 56), a considerable thickness of border-zone gneiss and overlying Belt rocks has been eroded from above the batholith. Also, it is evident that most of the overlying Belt rocks and much of the easily erodable border-zone gneiss must have been stripped from the eastern flanks of the batholith (west wall of the valley).

Anderson (1952, p. 255) concluded that the Idaho batholith was introduced by multiple emplacement. Larsen, Gottfried, Jaffe, and Waring (1958, p. 51) dated the batholith as about 108–109 million years but stated that "within the general areas of the Idaho batholith are bodies of igneous rock that are much younger—probably Laramide in age." Faults along the eastern margins of the batholith may be related in part to these later intrusions.

The main basin of the Bitterroot Valley is apparently a synclinal warp interrupted on the west by relatively minor fault zones. The rocks south of Skalkaho Creek were faulted perhaps during emplacement of the Idaho batholith. The faulted Tertiary volcanic rocks along lines of structural weakness marginal to the valley indicate recurrent tectonic activity. However, the undisturbed valley fill shows that either postdepositional (post early Pliocene) movement has been relatively slight or the floor of the valley has moved as a single unit with only minor local variations.

The high-level pediments and stream deposits along the eastern front of the mountains are apparently related to the early Tertiary valley floor. The modern intravalley terraced topography is the result of late Tertiary and Quaternary erosion and deposition.

CENOZOIC HISTORY

The Cenozoic history of the Bitterroot Valley may be summarized as follows:

1. Erosion of Belt rocks and border-zone gneiss probably both from within and marginal to the newly formed early Tertiary structural trough (Bitterroot Valley) along the east side of the Idaho Batholith.
2. Deposition of a great but unknown thickness of early-middle Tertiary fill on a valley floor of pre-Tertiary bedrock, accompanied by intermittent local extrusions of lava and volcanic ejecta along marginal zones of structural weakness.
3. Development of one or more pre-Pliocene erosion surfaces cut across early-middle Tertiary sediments and into bedrock marginal to the valley.
4. Deposition of early Pliocene sediments and volcanic ejecta in environments ranging valleyward from colluvial, to fan, to flood plain, to channel.
5. Development of an uneven erosion surface (high terrace) on Pliocene sediments. This surface was similar to the present floor of the valley.
6. Erosion and deposition during the Pleistocene shaped the modern intravalley topography.

TERTIARY HISTORY

The several pre-Tertiary inliers show that much of the original surface of deposition was quite irregular. The abundance of bedded ash, that may be of Miocene age, exposed along Lick Creek is evidence of extensive volcanic activity, and the interbedded channel sand and lignitic shale show that the environments of deposition ranged from fluvial to paludal. A floral assemblage suggests a moderately moist, temperate climate.

High pediments on the eastern slopes of the Bitterroot Mountains may be remnants of an ancient pre-Pliocene erosion surface. If so, their altitude, more than 1,500 feet above the floor of the valley, indicates the removal of an equivalent amount of early to middle Tertiary sediments.

At least 227 feet and probably many times that amount of sediments were deposited in the Bitterroot Valley in early Pliocene time. However, erosion and deposition were accompanied by fallout of volcanic ejecta and probably by local emplacement of lava in the fault zones.

The predominance of fine-grained early Pliocene sediments indicates low regional relief. However, the coarser colluvium and channel deposits near the mouths of some tributary streams show considerable local relief. The color change from predominantly gray in the Miocene strata to mostly buff in the Pliocene probably results from some regional, perhaps climatic, change. The Pliocene biota is not sufficiently well known to draw significant environmental interpretations from it.

In late Pliocene or early Pleistocene time the ancestral Bitterroot River eroded a broad valley into the Tertiary sediments and formed a base level for the tributaries. Because most of the early Pliocene strata are undisturbed, it appears that the change from a depositional to an erosional cycle was caused by some regional, perhaps climatic, change rather than by structural movement. The relationship (see "Intravalley") of the beveled Pliocene strata and the overlying Pleistocene alluvium shows that the topography was similar to the present.

QUATERNARY HISTORY

The highlands were deeply weathered at the end of the Tertiary Period; erosion in the Quaternary Period was probably rapid at first and then slower as the weathered material was stripped from the bedrock. Glacial debris accumulated in the west part of the valley, stream deposits in the east part.

During the maximum stages of Pleistocene glaciation, the Clark Fork was ponded by lobes of the Cordilleran ice sheets (Bretz and others, 1956, p. 1047), and the Bitterroot Valley became an embayment of glacial Lake Missoula. As the waters of the ancient lakes rose, deltas formed at the mouths of the tributary streams. Later, huge moraines developed upstream from the deltaic deposits on the west side of the valley, and the combination of outwash fans and lacustrine deposits subdued the irregular late Pliocene to early Pleistocene topography.

During a mid-Pleistocene interglacial (interlacustrine) interval, the Bitterroot River and its tributaries eroded their present valleys into the early Pleistocene alluvium and Tertiary fill along the traces of the Pliocene drainage system. During later stages of glaciation, small moraines developed at the mouths of many tributary canyons along the west side of the valley.

The glacial Lake Missoula existed as late as 6,000 years ago (C. Malough, oral commun., 1958). As the lake drained, wave-cut benches were formed during periods of temporary stability (Eakins and Honkala, 1952). Deep V-shaped notches were subsequently eroded into the lower courses of many of the U-shaped glaciated canyons on the west side of the valley. The drainage of the lake was followed by emplacement of large outwash fans on the flood plains of the tributary streams.

WATER RESOURCES

SURFACE WATER

The surface- and ground-water systems are closely interrelated in the Bitterroot River basin. After entering the basin as precipitation, water may interchange between systems several times and leave as either streamflow, underflow, or water vapor. Because surface water plays an important part in the economy and life of the basin, the quantity and the distribution in time and space of surface water must be known to properly plan for full development and proper management of the basin's water resources.

Although the streamflow records for most of the area are short, they define some of the characteristics of streams and could be extended by correlation with streams that have long-term records.

The distribution of runoff reflects the pronounced influence of the high, rugged Bitterroot Range. The pattern of runoff is typical of mountain areas where the spring runoff from snowmelt is often augmented by late spring or early summer rains. About 55 percent of the runoff in the Bitterroot River occurs during May and June. Autumn precipitation often causes an increase in runoff before the low flows of winter. The west-side streams show greater seasonal fluctuations than the east-side streams or the main stem of the Bitterroot River (figs. 15–18). Runoff from the foothills and the valley floor is relatively minor. The valley outflow is modified in quantity and pattern by extensive irrigation.

The Bitterroot River basin is subdivided into the following areas (fig. 19): A, upper Bitterroot River; B, west side; C, east side; D, valley floor between the gaging stations near Darby and near Florence (the study area); and E, lower Bitterroot River. A comparison of annual inflow and outflow from the areas is shown in figure 20. The total inflow is the sum of the flows of the west-side and east-side tributaries and the Bitterroot River above Darby; the outflow is the flow of the Bitterroot River near Florence. The location of stream-gaging stations is shown in figure 19.

UPPER BITTERROOT RIVER AREA

The drainage basin of the Bitterroot River above the gaging station near Darby, about 3 miles downstream from the confluence of the West and East Forks, is 1,049 square miles. The average annual runoff for the 22-year period (water years 1938–59) was 11.7 inches (653,600 acre-feet).

The basin of the West Fork Bitterroot River contains 644 square miles and is bounded on the west and south by the Bitterroot Range.

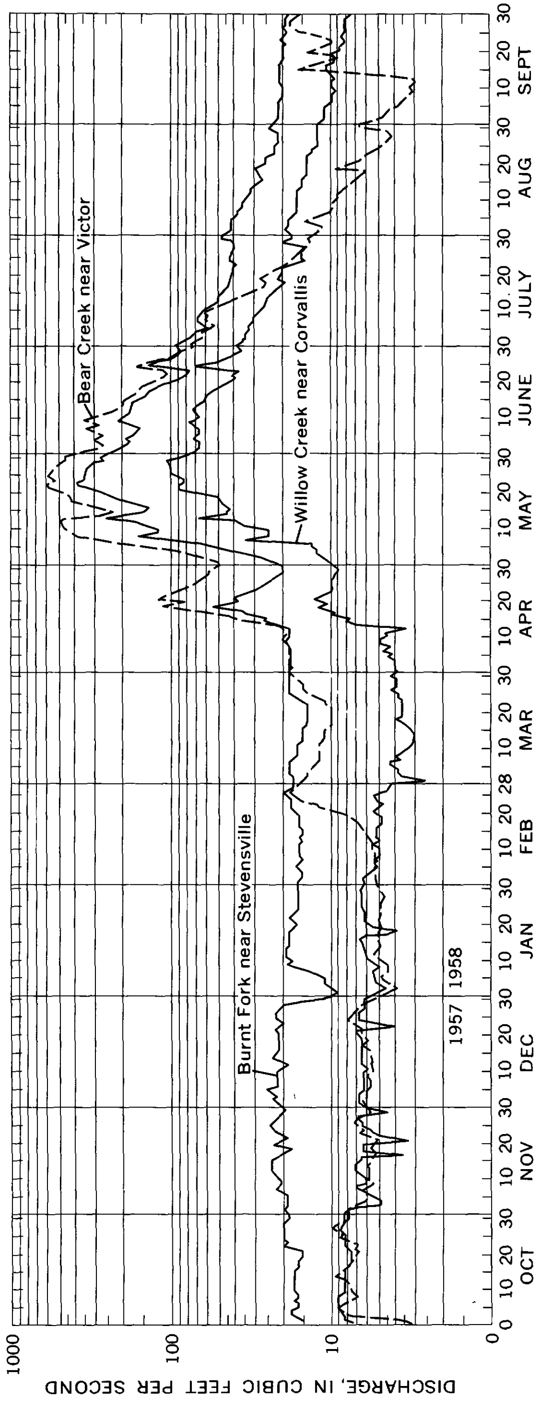


FIGURE 15.—Hydrographs of typical Bitterroot River tributaries, 1958 water year.

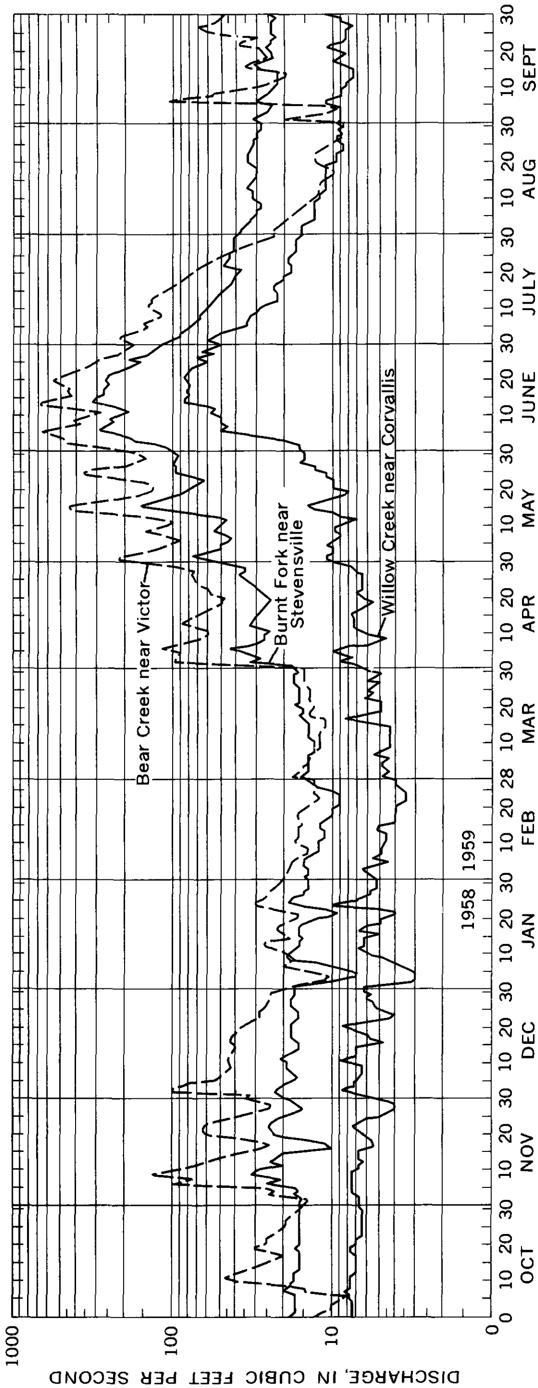


FIGURE 16.—Hydrographs of typical Bitterroot River tributaries, 1959 water year.

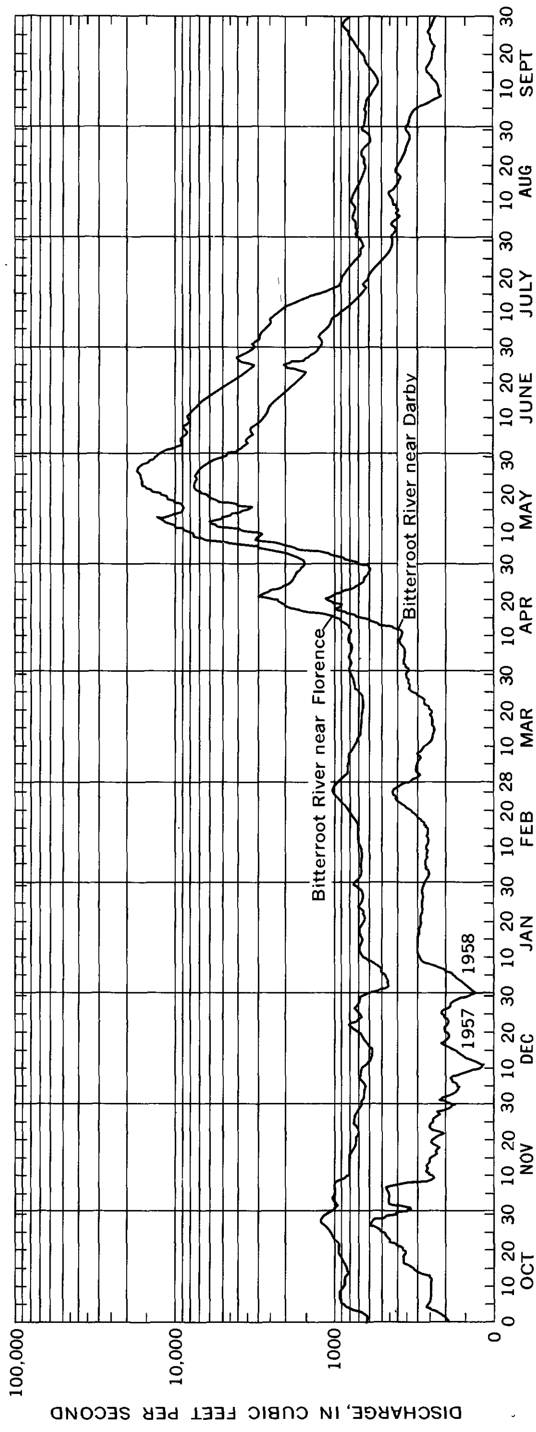


FIGURE 17.—Hydrographs of Bitterroot River near Florence and near Darby, Mont., 1958 water year.

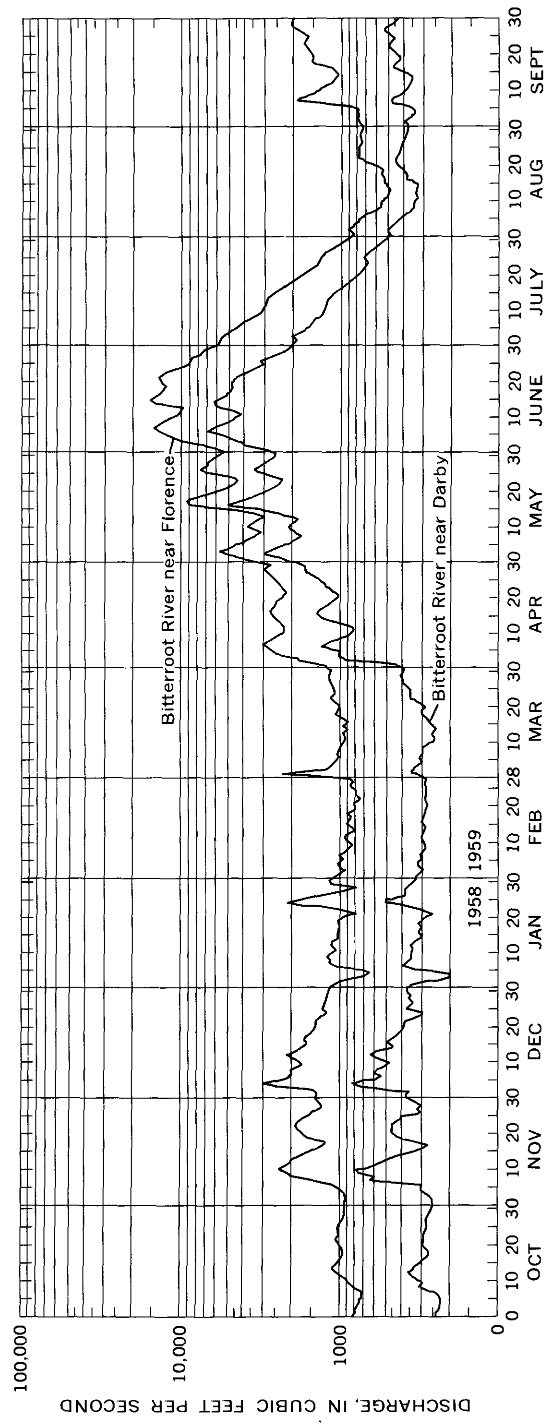


FIGURE 18.—Hydrographs of Bitterroot River near Florence and near Darby, Mont., 1959 water year.

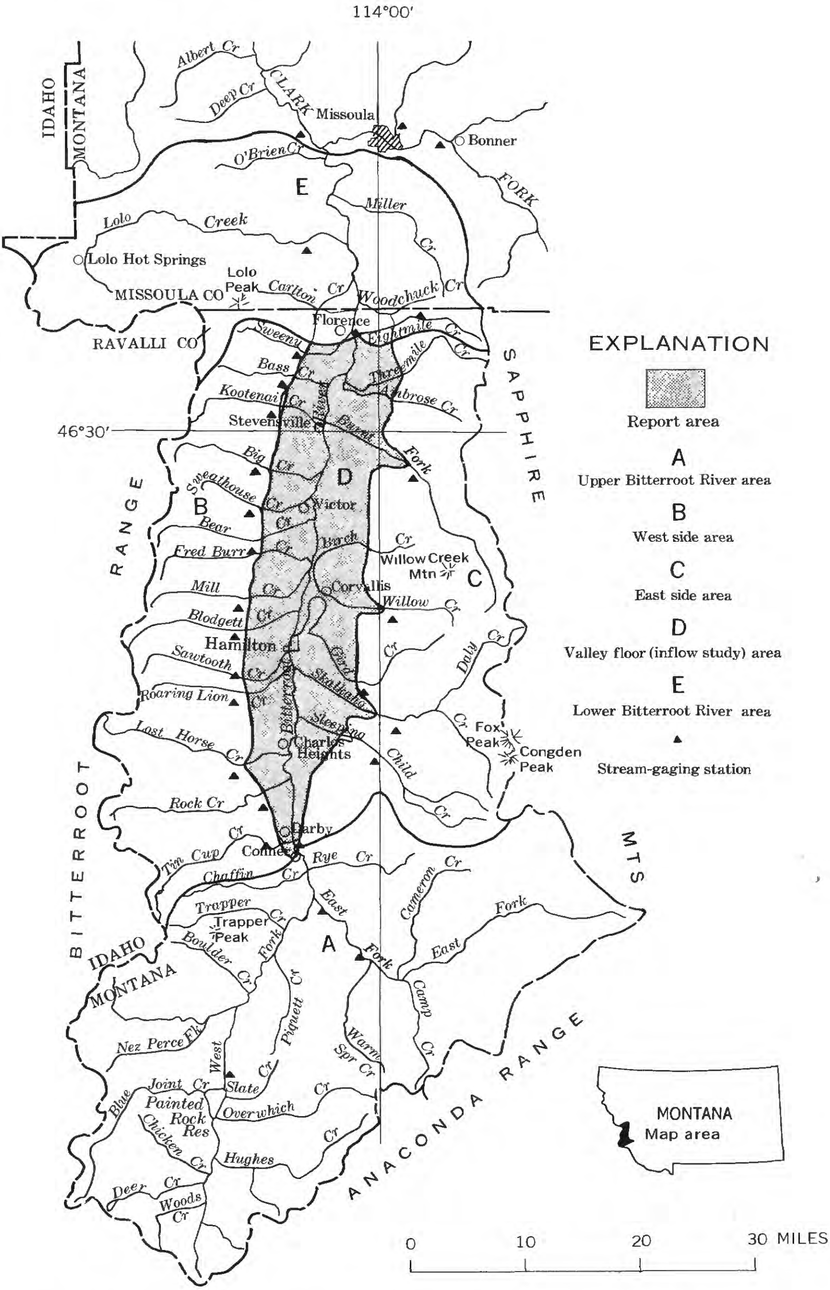


FIGURE 19.—Subareas of Bitterroot River basin and location of stream-gaging stations.

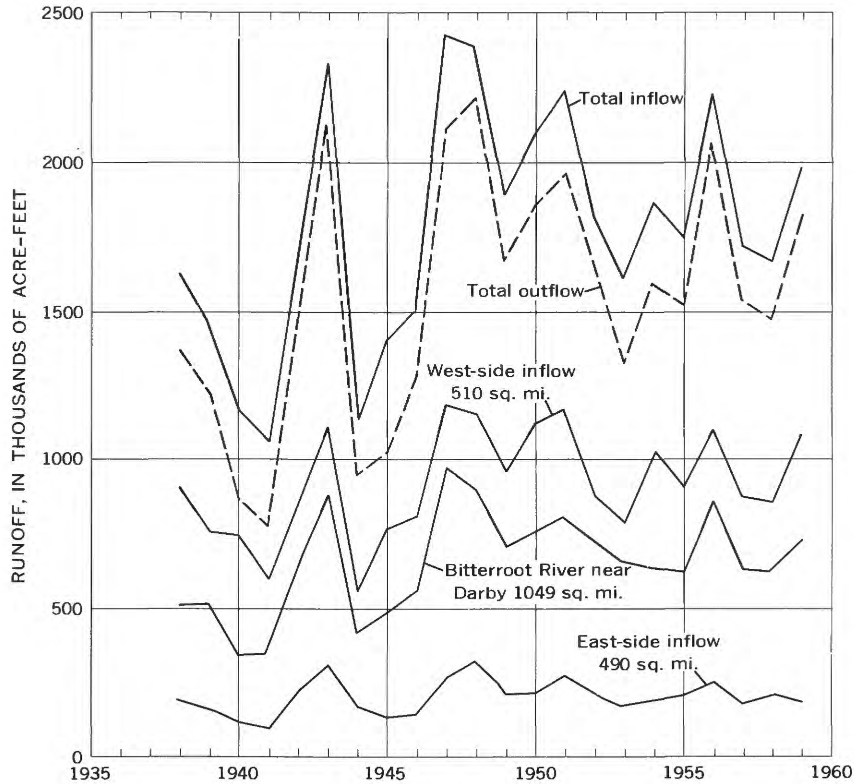


FIGURE 20.—Yearly inflow to, and outflow from study area.

Drainage basins of its western tributaries are more affected by moist Pacific air masses and have a higher runoff than other streams in the West Fork basin. The area tributary to Painted Rocks Lake has an average annual runoff of about 12.6 inches, and the West Fork basin has about 14.6 inches. Painted Rocks Lake, a reservoir completed in 1940 primarily for storage of irrigation water for the valley, has a capacity of 31,700 acre-feet. Up to the present (1968), few firm water-purchase contracts have been consummated. Only a small amount of land along the West Fork is irrigable, with diversions for only about 600 acres.

The basin of the East Fork Bitterroot River, which is somewhat smaller than the West Fork basin, contains 405 square miles. It is bounded on the east by the Sapphire Mountains and on the south by the Anaconda Range. For 1937–57, the average annual runoff half a mile above the confluence with the West Fork was 8.6 inches. Tributary streams flow through narrow canyons of steep gradient in their upper reaches and then enter mountain valleys with hay meadows and small farms. About 3,000 acres of land upstream from or in the vicinity of Sula is irrigated.

WEST-SIDE AREA

The west-side area contains 510 square miles. The mountains rise sharply from the valley floor, and the streams flow through steep narrow canyons. Heavy precipitation is induced as the moist Pacific air masses rise over the high Bitterroot Mountains. The average annual runoff in this area during 1938–59 was 33.6 inches (915,000 acre-feet). Except for the May–June high-water period, nearly all the west-side streamflow is diverted during the irrigation season. High runoff is uniformly distributed throughout the area, except for Bass and Sweeney Creeks, which have a smaller unit runoff that may be caused by precipitation shadows in the lee of mountains to the west.

Lake Como on Rock Creek, with a usable capacity of 34,800 acre-feet, is the only major reservoir in the area. Runoff during May and June is adequate for annual refill. About 17,400 acres on the east side of the Bitterroot Valley are irrigated from the Bitterroot River Irrigation District Canal, which carries water from Rock Creek to 8 miles northeast of Stevensville. About 11,400 acre-feet of water (as determined by the U.S. Bureau of Reclamation in 1942) is stored behind low dams at the outlets of several high mountain lakes in the Bitterroot Range. The water is released in late July and August when runoff is inadequate for downstream demands.

EAST-SIDE AREA

The Sapphire Mountains form the eastern boundary of this area, which contains 490 square miles. The average annual runoff for 1938–59 was 7.8 inches (202,700 acre-feet). The three principal streams (Sleeping Child Creek, Skalkaho Creek, and Burnt Fork) originate at higher altitudes in the Sapphire Mountains than the other streams. Their basins comprise 46 percent of the east-side drainage, but they contribute more than 70 percent of the runoff, or about 12 inches per year.

Willow and Gird Creeks drainage basins make up 10 percent of the area and contribute about 10 percent of the total runoff. They originate at lower altitudes in the Sapphire Mountains and, in their upper reaches, are underlain by the Newland Limestone. The streamflow pattern of these two streams differs from the principal streams in that Willow and Gird Creeks have smaller diurnal fluctuations and a more gradual recession from peak flows. This difference is attributable to relatively high permeability of the limestone, in which water may be temporarily stored and eventually discharged into streams. The remaining 44 percent of the east-side area consists of rolling foothills. The streams are short and ephemeral and contribute about 20 percent of the runoff.

During the irrigation season, the flow of the east-side streams is diverted. A total storage of about 870 acre-feet has been developed in small natural lakes in the basins of Skalkaho Creek, Willow Creek, and Burnt Fork.

VALLEY-FLOOR AREA

The valley-floor area, which contains 305 square miles, is adjacent to the Bitterroot River between the gaging stations near Darby and near Florence. The pervious soils and extensive farming generally prevent surface runoff, except during storms of high intensity or during snowmelt while the ground is frozen. Seepage losses are high from many of the tributary streams as they enter this area, and canals divert the remaining flow. Numerous canals supply water to about 100,000 acres. During the irrigation season, the flow of the Bitterroot River varies greatly from point to point because of extensive diversions, entrance of tributary streams, and return flow from irrigation. Critical low flows are confined to the Grantsdale-Victor reach. The Bitterroot River is a gaining stream through the valley-floor area. Graphs of inflow and outflow (figs. 21–23) illustrate the variations in streamflow.

LOWER BITTERROOT RIVER BASIN

The lower part of the basin, from Florence to the mouth, contains 496 square miles. Lolo Creek, entering from the west, is the major tributary. Eightmile and Miller Creeks are the major tributaries from the east and are entirely diverted during the irrigation season. Lolo Creek has a broad flood plain and is subject to seepage loss between the mouth of the canyon and the Bitterroot River. Water is diverted from Clark Fork for irrigation in the lower Bitterroot River basin.

STREAMFLOW RECORDS

Collection of streamflow records in the Bitterroot River basin began in 1898. The records were few and intermittent for many years. A better distributed and sustained collection began in 1938; the periods of record are listed in table 3. The streamflow records are published in Water-Supply Papers 1316 and 1736 (U.S. Geol. Survey, 1955, p. 335–350; 1964, p. 242–256).

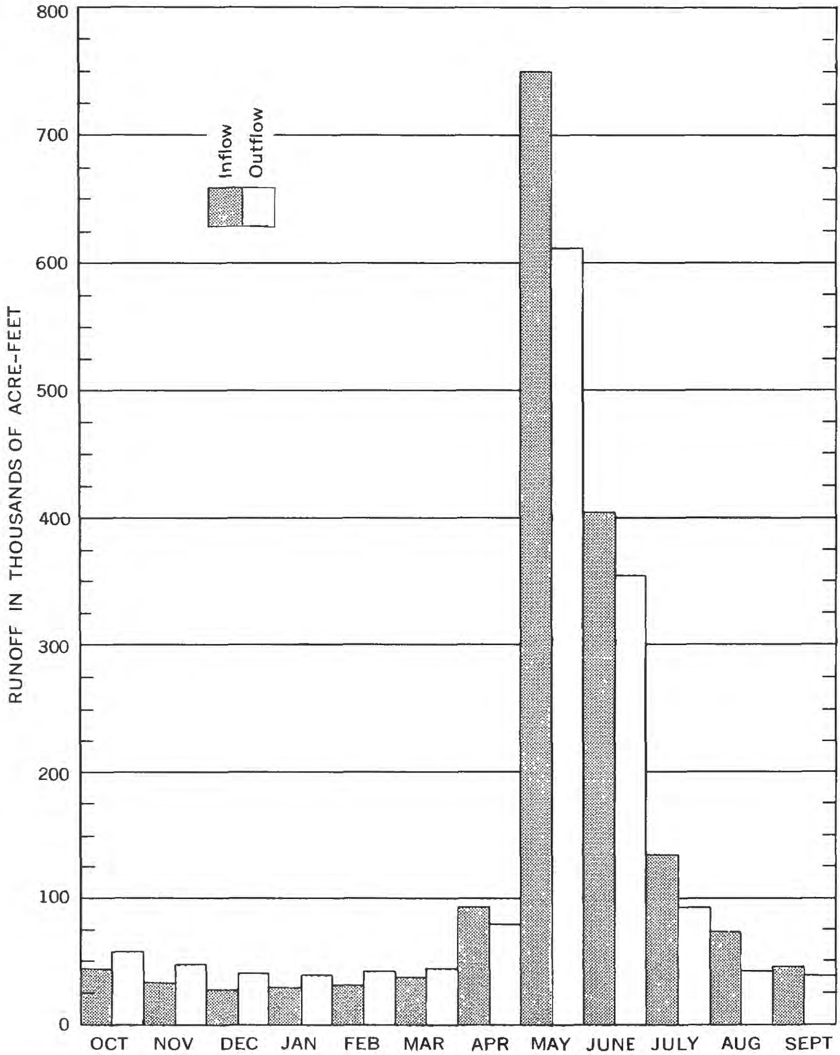


FIGURE 21.—Monthly inflow and outflow for 1958 water year.

More intensive record collection began in October 1957 and continued through September 1959. Four previously discontinued stations were reestablished, and three new gaging stations were established. Miscellaneous measurements were made at about monthly intervals at 15 sites on tributary streams to estimate monthly runoff. These measurements were published in Water-Supply Paper 1636 (U.S. Geol. Survey, 1960, p. 211–224). Since 1929, records have been collected on the Clark Fork above and below Missoula. The flow of the

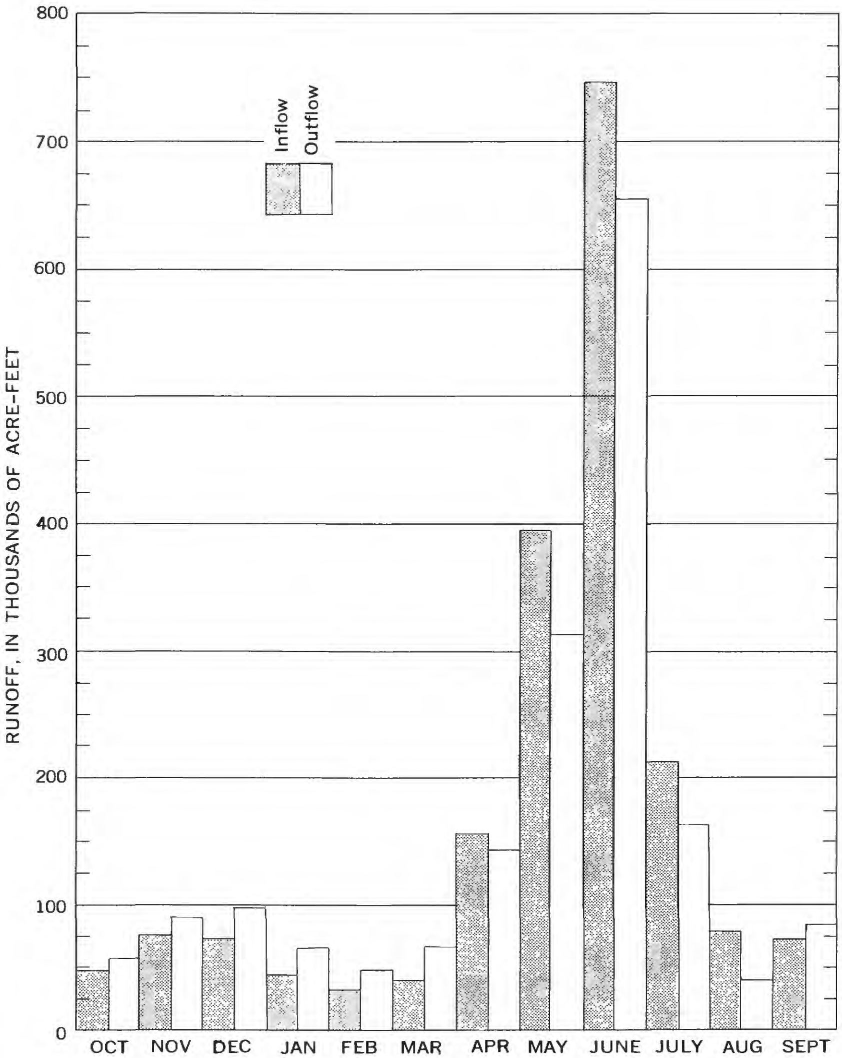


FIGURE 22.—Monthly inflow and outflow for 1959 water year.

Bitterroot River at its mouth is the difference in flow at these two points with minor correction for intervening small tributaries and diversion.

In evaluating and computing the flow characteristics of streams, it is advantageous to have a common base period. For this study, suffi-

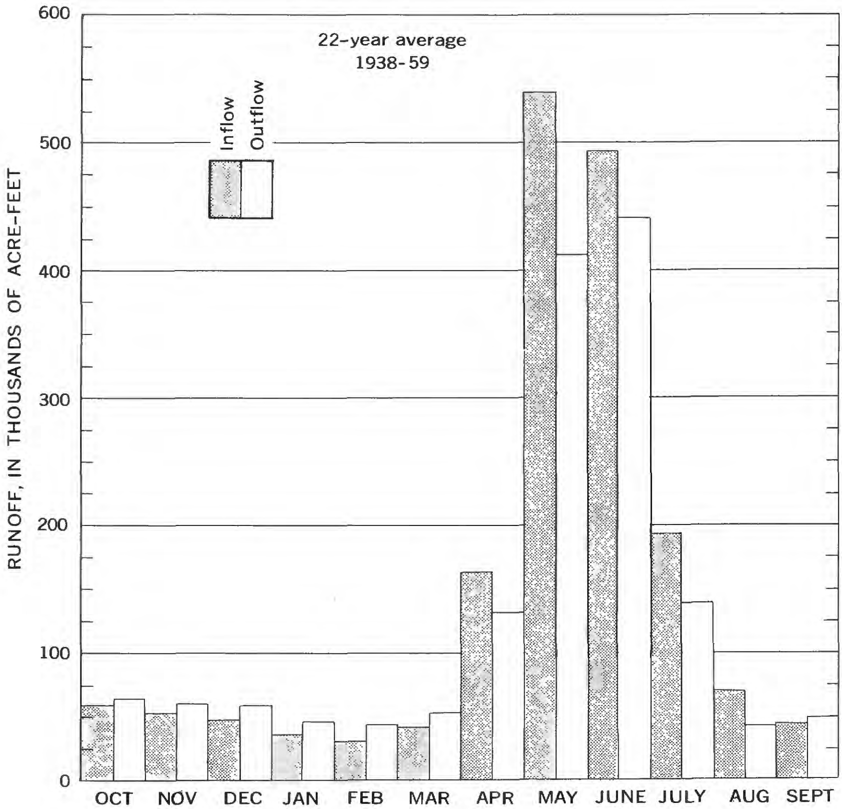


FIGURE 23.—Average monthly inflow and outflow, 1938–59.

cient data were available to use the period October 1, 1937, to September 30, 1959 (water years 1938–59). Some individual gaging-station records are extended for the full period by statistical correlation with nearby stations. Monthly inflow by areas, total inflow, and outflow at Florence for the base period are listed in tables 4–8. A summary of the annual inflow to and outflow from the study area is given in table 9.

Flow-duration curves show the percentage of time that the discharge of a stream has equaled or exceeded a specified amount. Flow-duration curves were constructed for Bear Creek near Victor using mean daily flows (fig. 24) and for the Bitterroot River near Florence using average monthly flows (fig. 25).

TABLE 3.—*Gaging stations in or related to the Bitterroot Valley*

Gaging station	Drainage area (sq mi)	Period of record	Type of record [1]
Clark Fork above Missoula	5,999	Mar. 1929–	a
Rattlesnake Creek at Missoula	79.7	June–Dec. 1899; Apr. 1958– .	a
Missoula Irrigation District Canal at Missoula		Apr. 1958–Sept. 1960	b
Orchard Homes Canal at Missoula		Apr. 1958–Sept. 1960	b
Flynn ditch at Missoula		Apr. 1958–Sept. 1960	b
Grass Valley ditch near Missoula		Apr. 1958–Sept. 1960	b
Bitterroot River:			
West Fork Bitterroot River Reservoir near Conner	317	June 1940–	c
West Fork Bitterroot River near Conner	317	Apr. 1941–	a
West Fork Bitterroot River near Darby	552	Sept. 1910–Aug. 1916	a
East Fork Bitterroot River near Conner	381	Apr. 1956–	a
East Fork Bitterroot River at Conner	405	Oct. 1910–Aug. 1915; Apr. 1937–Sept. 1957.	a
Bitterroot River near Darby	1,049	Apr. 1937–	a
Tin Cup Creek near Darby	33.4	Oct. 1957–Sept. 1959	d
Burke Gulch near Darby	6.28	Oct. 1957–Sept. 1959	d
Rock Creek:			
Como Lake near Darby	54.6	Oct. 1939–	c
Rock Creek near Darby	55.4	Apr. 1946–Sept. 1953; Aug. 1957–Sept. 1959.	a
Lost Horse Creek near Darby	66.3	Oct. 1957–Sept. 1959	d
Camas Creek near Hamilton	6.01	Oct. 1957–Sept. 1959	d
Sleeping Child Creek near Hamilton	64.7	Oct. 1957–Sept. 1959	d
Little Sleeping Child Creek near Hamilton	11.2	Oct. 1957–Sept. 1959	d
Bitterroot River near Grantsdale	1,414	May 1902–Dec. 1907	a
Skalkaho Creek near Hamilton	87.8	Dec. 1948–Sept. 1953; Aug. 1957– .	a
Skalkaho Creek at Brennan's Ranch, near Hamilton.	96.2	May 1920–Sept. 1924	a
Roaring Lion Creek near Hamilton	23.9	Oct. 1957–Sept. 1959	d
Sawtooth Creek near Hamilton	22.6	Oct. 1957–Sept. 1959	d
Gird Creek near Hamilton	28.8	Oct. 1957–Sept. 1959	d
Blodgett Creek near Corvallis	26.4	Dec. 1947–	a
Blodgett Creek near Hamilton	29.2	May 1938–June 1943	a
Willow Creek:			
Upper Horn ditch near Corvallis		June 1958–Sept. 1959	b
Willow Creek near Corvallis	22.4	May 1920–Apr. 1924; Sept. 1957– .	a
Willow Creek at Afinson Ranch, near Corvallis	23.2	May 1938–June 1943	a
Mill Creek near Hamilton	17.6	Oct. 1957–Sept. 1959	d
Fred Burr Creek near Victor	18.4	Dec. 1946–Oct. 1951	a
Bear Creek near Victor	26.8	May 1938–Dec. 1954; Sept. 1957–Sept. 1959.	a
Sweathouse Creek near Victor	10.2	Oct. 1957–Sept. 1959	d
Gash Creek near Victor	3.37	Oct. 1957–Sept. 1959	d
Big Creek near Victor	32.9	Oct. 1957–Sept. 1959	d
Kootenai Creek near Stevensville	28.9	Dec. 1948–Sept. 1953; Sept. 1957–	a
Burnt Fork Creek:			
Sunset Canal near Stevensville		Apr. 1958–Sept. 1959	b
Burnt Fork Creek near Stevensville	74.0	May 1920–Sept. 1924; Apr. 1958– .	a
Bass Creek near Florence	13.1	Oct. 1957–Sept. 1959	d
Sweeney Creek near Florence	16.4	Oct. 1957–Sept. 1959	d
Bitterroot River near Florence	2,354	Sept. 1957–	a
Eightmile Creek near Florence	20.6	Sept. 1957–	a
Lolo Creek near Lolo	231	May 1911–Nov. 1914	a
Lolo Creek above Sleeman Creek, near Lolo	250	Nov. 1950–	a
Bitterroot River near Missoula	2,812	July 1898–Dec. 1904	a
Big Flat Canal near Missoula		Apr. 1958–Sept. 1959	b
Clark Fork below Missoula	9,003	Oct. 1929–	a

[1] a, Daily discharge; b, Discharge measurements; c, Month-end contents in acre-feet; d, Discharge measurements and monthly estimates.

TABLE 4.—*Runoff, in acre-feet, of Bitterroot River near Darby, Mont.*

[Drainage area, 1,049 sq mi]

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1937							18,220	120,900	82,140	23,110	8,980	7,660	
1938	8,800	9,390	11,380	10,210	9,290	13,800	55,820	158,300	160,900	55,970	16,890	10,980	522,200
1939	15,840	15,110	13,800	12,640	9,320	27,530	94,350	193,500	87,560	37,270	10,840	10,110	527,900
1940	12,220	9,530	10,890	9,090	11,080	16,720	51,850	136,700	58,460	12,930	8,660	12,430	350,600
1941	24,580	12,940	11,990	9,690	6,930	10,070	22,830	87,690	84,940	31,610	14,100	37,750	355,100
1942	34,030	32,530	27,340	14,420	13,190	17,080	65,120	154,300	187,800	60,220	17,350	13,440	636,800
1943	37,560	23,980	14,770	15,870	15,590	28,480	150,500	177,000	260,900	114,900	30,280	18,630	888,500
1944	26,740	28,900	11,770	9,680	7,380	8,540	20,010	98,290	120,500	43,700	19,440	12,010	407,000
1945	22,420	24,280	9,090	12,890	10,990	11,480	23,800	124,700	167,300	53,400	14,990	18,000	493,300
1946	26,960	17,460	14,270	16,210	12,420	21,560	71,910	167,100	118,000	46,670	17,470	29,860	559,900
1947	62,690	46,910	47,060	25,870	19,550	38,990	90,520	368,600	173,100	63,580	21,930	18,990	977,800
1948	30,180	29,630	29,900	16,560	15,610	15,230	56,390	315,400	271,600	76,950	27,290	17,440	902,200
1949	22,540	22,420	14,780	13,600	11,380	18,110	101,400	271,100	156,800	39,230	18,110	18,650	708,100
1950	34,850	21,730	16,670	14,330	15,490	19,050	41,410	148,300	290,500	103,600	27,120	19,060	752,100
1951	35,520	30,670	21,290	16,880	22,070	18,620	85,830	266,200	186,900	78,670	26,350	18,760	807,800
1952	36,900	16,220	13,560	13,110	14,280	28,090	91,160	255,700	170,100	50,470	18,400	22,340	730,300
1953	27,390	14,290	11,270	14,700	14,260	16,860	40,730	110,500	278,600	92,010	22,060	12,750	655,400
1954	12,310	14,860	22,430	20,200	19.160	23,580	60,600	185,800	151,400	82,640	23,620	18,850	635,400
1955	16,550	14,650	12,780	12,820	11,340	12,910	23,790	134,200	236,500	105,600	24,100	16,070	621,300
1956	20,020	20,010	23,160	18,670	14,340	25,760	131,500	322,300	195,000	53,150	23,070	15,960	861,900
1957	22,280	15,830	18,000	22,730	22,330	21,200	30,390	239,600	171,500	41,580	17,950	13,650	637,000
1958	21,270	16,750	10,800	15,680	16,490	17,250	34,440	274,100	137,500	45,270	23,850	15,400	628,800
1959	17,370	24,920	27,940	20,550	16,250	19,540	67,790	162,200	249,600	65,060	23,610	24,970	719,800
Average													653,600

TABLE 5.—*Runoff, in acre-feet, from the west-side area*

[Drainage area, 510 sq mi]

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1938	19,880	19,250	26,770	20,870	21,680	21,820	79,790	301,600	308,300	63,860	13,620	4,430	901,900
1939	18,680	21,290	39,160	20,720	12,920	27,130	126,000	304,700	127,000	48,840	10,550	4,420	761,400
1940	10,350	12,590	20,100	12,200	12,110	26,770	83,240	305,400	158,400	29,350	19,290	10,170	700,000
1941	19,470	18,880	16,480	12,260	9,270	15,390	54,470	201,700	121,500	56,150	24,710	49,550	599,800
1942	62,230	51,850	53,350	15,070	9,290	9,940	110,600	188,100	215,400	96,030	31,060	7,350	850,300
1943	4,830	32,130	33,600	22,160	16,450	18,850	147,000	216,000	344,700	213,100	50,830	16,750	1,116,000
1944	11,510	9,900	7,050	5,420	3,510	5,330	33,680	200,200	198,000	60,330	23,130	8,580	566,600
1945	6,100	11,640	8,050	12,260	7,960	7,730	28,230	278,200	265,900	106,400	28,960	12,220	773,600
1946	21,600	30,920	14,480	14,900	9,840	20,390	119,100	244,900	189,000	81,390	35,040	26,000	807,600
1947	70,490	44,270	50,650	22,340	17,860	32,720	109,100	427,000	252,400	93,610	39,870	25,380	1,186,000
1948	73,780	35,080	31,960	41,520	22,000	14,510	72,240	376,300	352,500	70,460	52,200	17,360	1,160,000
1949	22,980	14,360	11,950	9,800	5,160	12,790	125,200	419,100	207,200	72,070	39,170	16,450	956,200
1950	18,920	36,550	27,120	17,170	13,460	17,900	50,500	214,800	390,000	228,200	77,340	27,070	1,119,000
1951	78,730	61,830	41,970	31,350	30,220	20,530	100,400	296,400	245,500	172,000	49,190	28,290	1,156,000
1952	37,710	20,860	14,880	10,400	7,750	6,660	114,400	289,800	225,200	89,910	45,090	11,880	874,500
1953	3,780	3,290	3,700	14,090	14,660	12,180	58,410	164,100	269,600	165,600	50,440	14,990	774,800
1954	5,290	7,730	9,190	8,510	15,120	7,810	73,830	351,700	275,200	191,300	58,410	22,890	1,027,000
1955	23,690	16,450	12,540	10,230	6,560	6,020	21,500	212,200	374,002	152,400	57,810	19,110	912,700
1956	14,480	30,780	48,450	28,860	12,100	19,760	136,300	373,200	276,200	97,910	51,240	14,880	1,104,000
1957	11,070	15,090	19,660	10,280	7,290	17,370	45,050	364,900	249,900	75,500	46,480	10,450	873,000
1958	14,970	9,550	8,660	8,120	9,850	14,410	47,280	398,300	214,600	69,890	36,200	21,680	853,500
1959	23,220	46,350	39,600	18,960	12,400	14,520	77,640	205,800	424,500	126,300	45,600	39,360	1,074,000
Average													915,800

TABLE 6.—*Runoff, in acre-feet, from the east-side area*

[Drainage area, 490 sq mi]

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1938	6,070	5,280	5,880	5,260	4,900	5,710	16,070	59,030	66,050	12,670	6,210	5,310	198,400
1939	7,010	6,130	5,570	5,640	5,330	7,560	20,410	50,420	29,870	13,900	6,890	5,910	164,600
1940	6,580	4,870	5,260	4,800	4,660	6,050	13,800	32,470	20,530	8,120	6,520	6,010	119,700
1941	7,320	5,010	4,740	4,420	3,820	4,780	7,260	14,630	25,410	12,050	6,950	6,490	102,900
1942	7,320	5,770	7,260	4,850	4,950	6,110	26,900	51,280	69,020	27,610	12,110	6,070	229,200
1943	7,130	6,310	6,330	6,030	5,540	6,830	44,690	59,400	92,830	48,510	13,650	8,030	305,300
1944	8,490	6,600	6,000	5,570	4,570	4,270	8,450	28,530	48,670	25,580	10,940	8,090	165,800
1945	7,440	5,270	4,450	5,490	5,100	4,330	6,430	25,580	35,940	18,080	7,750	5,690	131,600
1946	6,390	4,460	4,260	5,060	4,290	6,090	18,270	35,660	31,780	14,820	6,950	7,200	145,200
1947	12,540	10,230	7,870	6,020	6,940	8,300	25,230	88,540	56,650	21,950	8,980	6,660	259,900
1948	10,270	7,080	7,380	7,990	5,370	5,230	22,910	107,600	97,590	29,080	12,790	7,970	321,300
1949	8,180	6,010	5,990	5,690	5,240	5,580	18,390	75,010	56,170	17,340	8,120	6,550	218,300
1950	6,950	5,410	5,070	4,650	4,200	4,270	8,750	32,470	79,740	42,980	11,810	7,680	214,000
1951	9,410	8,930	8,490	7,500	7,160	6,890	22,550	78,090	66,050	37,510	12,670	8,690	273,900
1952	10,210	7,620	6,460	5,740	5,600	5,390	20,110	67,640	46,060	16,910	8,360	6,660	206,800
1953	6,330	5,150	5,340	6,060	5,430	5,330	9,160	19,920	65,450	27,360	9,840	6,660	172,000
1954	6,390	5,150	5,730	4,680	4,980	4,960	10,230	50,420	48,970	32,830	10,820	6,550	191,700
1955	8,120	5,410	5,360	4,910	4,420	5,090	7,560	31,600	65,450	49,250	12,910	8,030	208,100
1956	7,190	6,370	7,190	6,460	5,810	7,620	30,640	76,860	65,450	22,380	10,940	7,260	254,200
1957	7,320	6,250	6,520	4,980	4,950	5,300	8,090	67,020	53,320	16,600	8,920	6,310	195,600
1958	7,380	6,190	6,150	5,150	4,420	4,700	9,340	70,710	49,630	19,550	10,640	6,960	200,800
1959	6,330	6,070	5,830	4,940	4,140	5,710	11,480	27,180	71,400	20,350	9,720	8,030	181,200
Average													202,700

TABLE 7.—*Total inflow, in acre-feet, to the valley-floor area*

[Drainage area, 2,049 sq mi]

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1938	34,750	33,920	44,030	36,340	35,870	41,330	151,700	519,400	535,200	132,500	36,720	20,720	1,622,000
1939	41,530	42,530	58,530	39,000	27,570	62,220	240,800	548,600	244,400	100,000	28,280	20,440	1,454,000
1940	29,150	26,990	36,250	26,090	27,850	49,540	148,900	474,600	237,400	50,400	34,470	28,610	1,170,000
1941	51,370	36,830	33,210	26,370	20,020	30,240	84,560	304,000	231,800	99,810	45,760	93,790	1,058,000
1942	103,600	90,150	87,950	34,340	27,430	33,130	202,600	393,700	472,200	183,900	60,520	26,860	1,716,000
1943	49,520	62,420	54,700	44,060	37,580	54,160	342,200	452,400	698,400	376,500	94,760	43,410	2,310,000
1944	46,740	45,400	24,820	20,670	15,460	18,140	62,140	327,000	367,200	129,600	53,510	28,680	1,139,000
1945	35,960	41,190	21,590	30,640	24,050	23,540	58,460	428,500	469,100	177,900	51,700	35,910	1,399,000
1946	54,950	52,840	33,010	36,170	26,550	48,040	209,300	447,700	338,800	142,900	59,460	63,060	1,513,000
1947	145,700	101,400	105,600	54,230	44,350	80,010	224,800	884,100	482,200	179,100	70,780	51,030	2,423,000
1948	114,200	71,790	69,240	66,070	42,980	34,970	151,500	799,300	721,700	176,500	92,280	42,770	2,383,000
1949	53,700	42,790	32,720	29,090	21,780	36,480	245,000	765,200	420,200	128,600	65,400	41,650	1,883,000
1950	60,720	63,690	48,860	36,150	33,150	41,220	100,700	395,600	760,200	374,800	116,300	53,810	2,085,000
1951	123,700	101,400	71,750	55,730	59,450	46,040	208,800	640,700	498,400	288,200	88,210	55,740	2,238,000
1952	84,820	44,700	34,900	29,250	27,630	40,140	225,700	613,100	441,400	157,300	71,850	40,880	1,812,000
1953	37,500	22,730	20,310	34,850	34,350	34,370	108,300	294,500	613,600	285,000	82,340	34,400	1,602,000
1954	23,990	27,740	37,350	33,390	39,260	36,350	144,700	587,900	475,600	306,800	92,850	48,290	1,854,000
1955	48,360	36,510	30,680	27,960	22,320	24,020	52,850	378,000	676,200	307,200	94,820	43,210	1,742,000
1956	41,690	57,160	78,800	53,990	32,250	53,140	298,400	772,400	536,600	172,400	85,250	38,100	2,220,000
1957	40,670	37,170	44,180	37,990	34,570	43,870	83,530	671,500	474,700	133,700	73,350	30,410	1,706,000
1958	43,820	32,490	25,610	28,950	30,760	36,360	91,060	743,100	401,700	134,700	70,690	44,040	1,683,000
1959	46,920	77,340	73,370	44,450	32,790	39,770	156,900	395,200	745,500	211,700	78,930	72,360	1,975,000
Average	59,690	52,240	48,520	37,540	31,730	41,230	162,900	538,000	492,800	193,200	70,370	43,550	1,772,000

TABLE 8.—*Runoff, in acre-feet, of Bitterroot River near Florence, Mont.*

[Drainage area, 2,354 sq mi]

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
1938	28,280	28,800	38,370	32,470	22,990	43,780	128,900	379,400	491,100	118,300	31,730	31,720	1,376,000
1939	49,500	47,900	53,860	46,550	37,320	53,430	144,800	454,100	225,000	63,950	26,320	32,070	1,235,000
1940	39,230	33,620	39,780	30,620	36,470	43,040	109,200	280,300	169,800	37,080	24,100	28,680	871,900
1941	60,570	41,410	36,090	24,840	24,830	26,010	51,050	162,600	197,400	56,810	30,500	74,620	786,700
1942	85,340	79,500	88,300	49,500	38,880	46,610	136,000	304,900	429,100	110,900	34,130	41,120	1,444,000
1943	61,240	64,740	62,720	54,720	48,930	91,430	330,300	392,200	601,000	285,700	47,680	52,660	2,103,000
1944	59,400	62,360	38,860	31,360	28,590	26,930	43,200	198,500	325,300	71,200	32,770	32,070	950,500
1945	42,670	43,850	31,170	35,600	28,990	26,560	43,740	265,200	355,000	96,170	27,610	34,510	1,031,000
1946	55,340	53,970	42,920	42,180	31,430	45,070	142,500	342,100	293,700	111,700	41,200	70,040	1,272,000
1947	119,300	106,000	119,000	65,420	59,810	79,560	160,700	688,700	462,000	131,100	55,030	63,850	2,110,000
1948	105,000	83,130	84,180	62,350	57,980	58,910	116,400	630,200	760,500	151,900	63,760	47,960	2,222,000
1949	64,250	53,610	42,360	24,530	41,540	61,920	181,900	614,300	404,300	94,510	41,570	52,840	1,678,000
1950	70,460	63,010	63,090	51,160	58,590	68,070	107,900	289,500	683,100	263,500	71,820	55,400	1,846,000
1951	102,400	105,400	86,880	61,730	79,640	66,040	199,400	521,300	429,100	193,600	55,520	62,120	1,963,000
1952	90,330	63,610	49,500	49,190	51,310	58,110	180,400	518,000	385,900	108,100	42,000	45,160	1,642,000
1953	52,330	41,470	34,560	46,360	41,760	38,550	74,500	203,400	533,000	184,600	42,670	39,810	1,333,000
1954	40,700	45,280	55,400	47,960	51,590	56,380	119,100	433,400	414,000	222,500	51,340	57,960	1,596,000
1955	65,300	52,480	43,530	36,710	31,270	34,250	64,740	292,600	566,500	246,800	39,540	41,710	1,515,000
1956	56,940	65,930	94,690	68,190	47,680	70,590	250,700	336,400	536,800	128,800	48,940	48,500	2,054,000
1957	60,930	53,550	54,480	41,010	51,320	63,020	77,710	543,100	448,800	87,740	30,560	35,880	1,548,000
1958	55,790	47,340	39,840	37,720	41,630	43,860	79,420	607,900	353,200	90,880	40,820	38,910	1,477,000
1959	56,040	89,880	98,620	65,630	48,320	66,760	143,000	313,900	656,800	163,100	40,540	82,900	1,825,000
Average	64,620	60,340	59,030	45,750	43,680	53,130	131,100	412,300	441,600	137,200	42,300	48,670	1,540,000

TABLE 9.—*Inflow to and outflow from the study area, in acre-feet*

Year	Bitterroot River near Darby	East-side inflow	West-side inflow	Inflow total	Outflow at Florence	Difference
1938	522,200	198,400	901,900	1,622,500	1,376,000	246,500
1939	527,900	164,600	761,400	1,453,900	1,235,000	218,900
1940	350,600	119,700	700,000	1,170,300	871,900	298,400
1941	355,100	102,900	599,800	1,057,800	786,700	271,100
1942	636,800	229,200	850,300	1,716,300	1,440,000	276,300
1943	888,500	305,300	1,116,000	2,309,800	2,103,000	206,800
1944	407,000	175,800	566,600	1,139,400	950,500	188,900
1945	493,300	131,600	773,600	1,398,500	1,031,000	367,500
1946	559,900	145,200	807,600	1,512,700	1,272,000	240,700
1947	977,800	259,900	1,186,000	2,423,700	2,110,000	313,700
1948	902,200	321,300	1,160,000	2,383,500	2,222,000	161,500
1949	708,100	218,300	956,200	1,882,600	1,678,000	204,600
1950	752,100	214,000	1,119,000	2,085,100	1,846,000	239,100
1951	807,800	273,900	1,156,000	2,237,700	1,963,000	274,700
1952	730,300	206,800	874,500	1,811,600	1,642,000	169,600
1953	655,400	172,000	774,800	1,602,200	1,333,000	269,200
1954	635,400	191,700	1,027,000	1,854,100	1,596,000	258,100
1955	621,300	208,100	912,700	1,742,100	1,515,000	227,100
1956	861,900	254,200	1,104,000	2,220,000	2,054,000	166,100
1957	637,000	195,600	873,000	1,705,600	1,548,000	157,600
1958	628,800	200,800	853,500	1,683,100	1,477,000	206,100
1959	719,800	181,200	1,074,000	1,975,000	1,825,000	150,000
Average	653,600	202,700	915,800	1,772,200	1,540,000	232,400

Knowledge of the magnitude and frequency of floods is particularly useful in designing spillways, stream crossings, and flood-protection works. The recurrence interval of a flood in the annual flood series is the average interval of time within which a given flood will be equaled or exceeded once as an annual maximum. A regional analysis of discharge records is believed to yield more reliable probability information than analysis of records at individual sites. Regional flood-frequency curves for four streams are shown in figure 26.

GROUND WATER

Most of the ground water in the Bitterroot Valley is in the pore spaces of the Tertiary and Quaternary sediments that partly fill the valley; some is in the pre-Tertiary sedimentary, metamorphic, and igneous rocks marginal to and underlying the valley. Water from precipitation, irrigation, and losing tributary streams percolates to the ground-water reservoir and then moves laterally until it is discharged to the earth's surface through springs, wells, and gaining streams, or to the atmosphere by evapotranspiration.

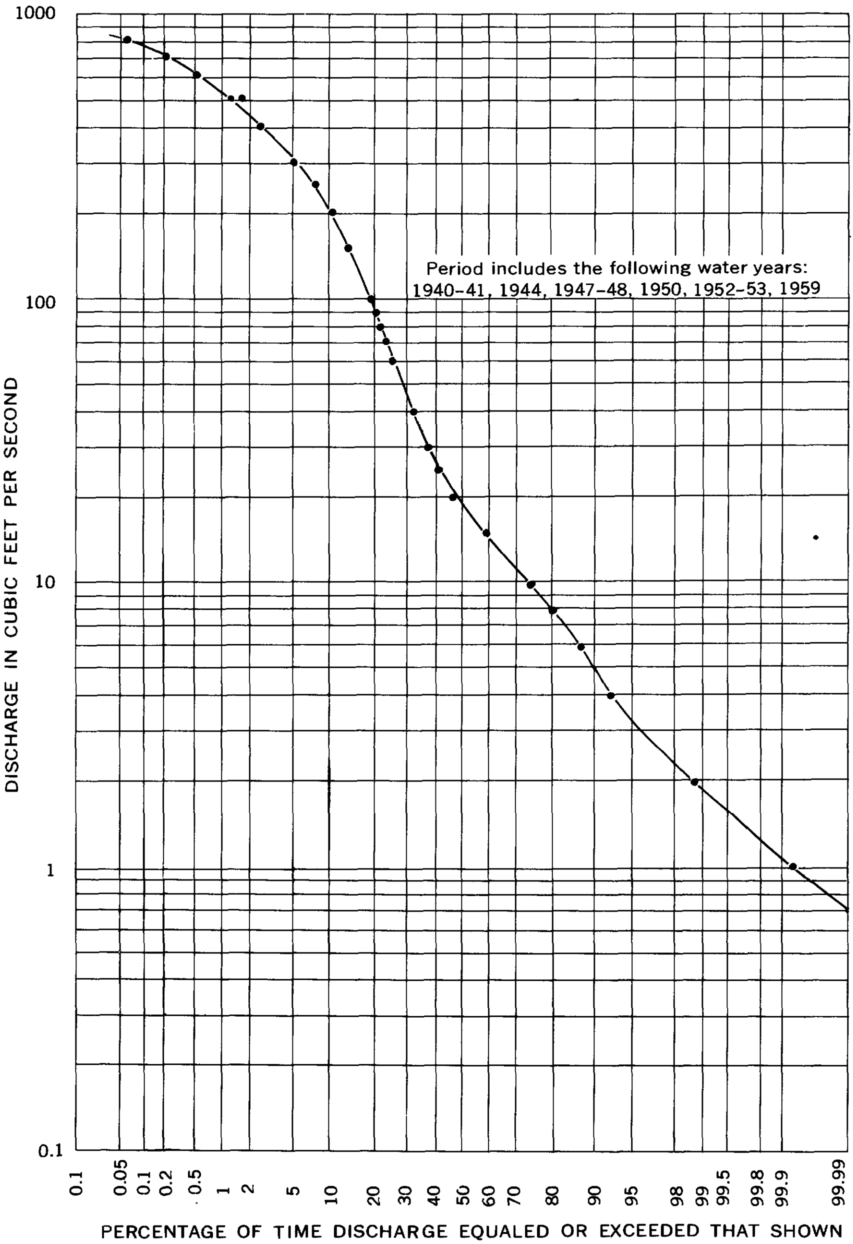


FIGURE 24.—Flow-duration curve of daily flows of Bear Creek near Victor.

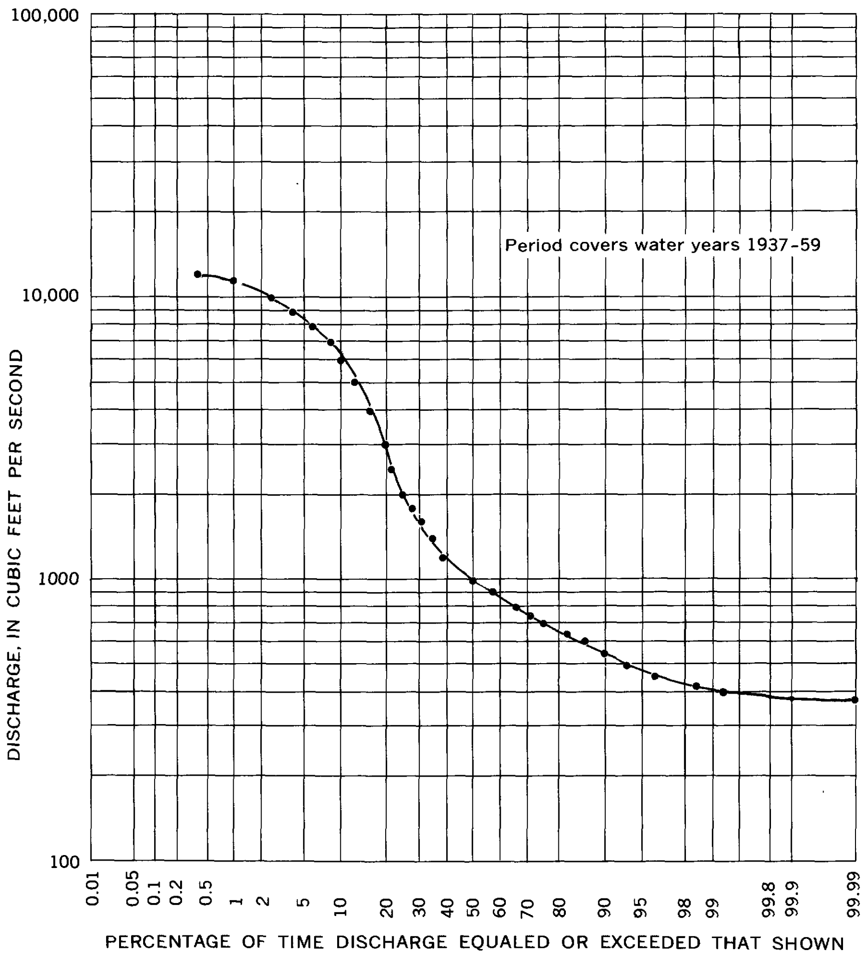
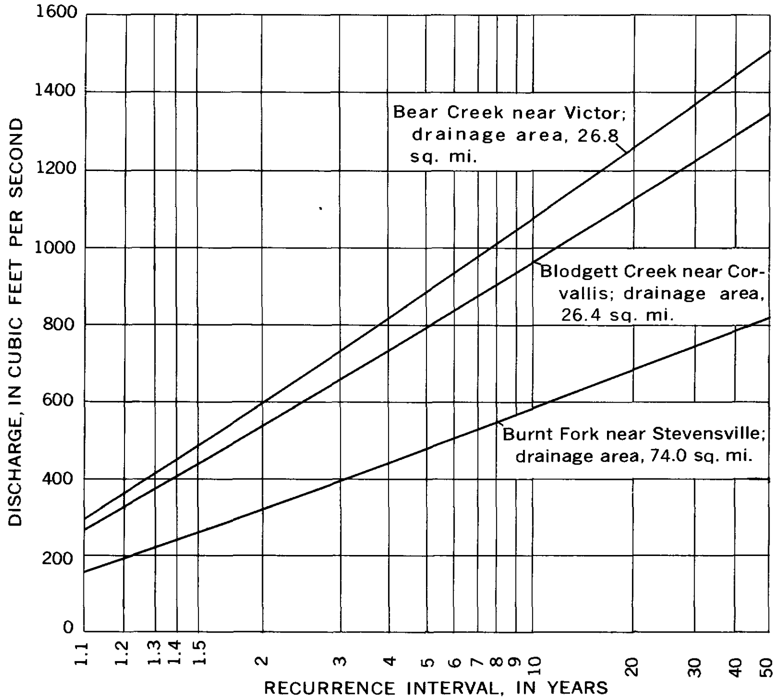


Figure 25.—Flow-duration curve of monthly flows of Bitterroot River near Florence.

HYDROLOGIC PROPERTIES

Two hydrologic properties of an aquifer indicate the aquifer's ability to transmit and store water. The coefficient of transmissibility measures the capacity of an aquifer to transmit water. It is expressed as the rate of flow of water, in gallons per day, at the prevailing water temperature through a vertical strip of the aquifer 1 foot wide extending the full saturated thickness of the aquifer under a hydraulic gradient of 100 percent. The coefficient of storage is a measure of the capacity of an aquifer to store and release water. It is the volume of water released from or taken into storage per unit surface area of



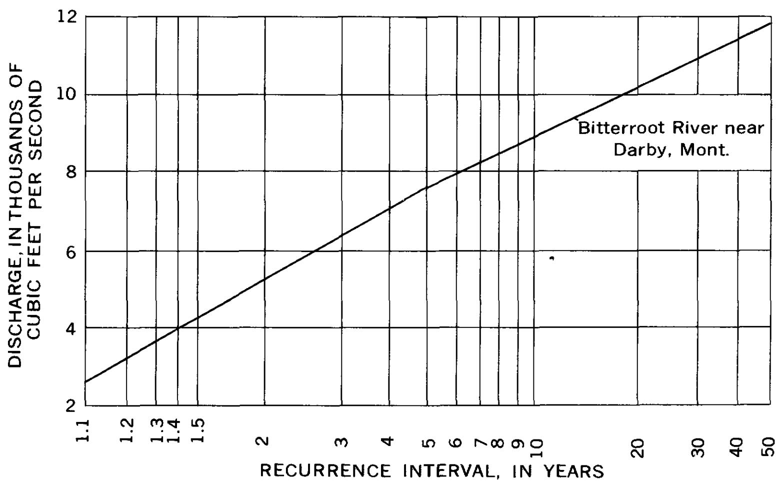


FIGURE 26.—Frequency of annual floods for some typical Bitterroot River tributaries and for Bitterroot River.

the aquifer per unit change in the component of head normal to that surface. These coefficients can be used with other data to estimate (1) the yield and drawdown for proposed wells, (2) the amount of ground water flowing through an aquifer, and (3) the rate at which ground water is moving.

The coefficient of transmissibility was determined at 18 sites from 26 aquifer tests (table 10). The tests were too short to determine accurately the coefficient of storage. The wells pumped during the aquifer tests were shallow domestic and stock wells, observation wells were installed nearby. This situation is not ideal for testing the aquifer because the aquifer thickness may not be known, and generally the pumped well only partially penetrates the aquifer. However, data obtained from the tests are worthwhile as long as the data are not projected beyond the limitations imposed by the tests.

TABLE 10.—*Aquifer-test data*

[Geologic source: A, alluvium; T, Tertiary sediments]

Well number	Geologic source	Depth of well (ft)	Average pumping rate (gpm)	Draw-in pumped well (ft)	Length of test (min)	Coefficient of trans-missibility (gpd per ft)	Remarks
B6-20-3bd	A	35.3	24	3.6	230	------------	
B6-20-6dd	A	9.2	300	1.3	300	280,000	Observation wells 42 and 95 ft from pumped well.
B6-20-8aa	A	20.5	62	.3	200	------------	Observation well 50 ft from pumped well.
B6-21-11aa	A	20.0	87	6.4	200	25,000	
B6-21-26db	A, T	365.0	20	9.4	91	3,800	
B7-20-4aa	A	7.7	30	1.6	320	------------	
B7-20-16ab	A	9.9	220	1.1	420	------------	
B7-20-16ac	A	12.1	135	.9	390	------------	
B7-20-21ab	A	11.6	58	.8	250	150,000	Observation wells 25 and 50 ft from pumped well.
B7-20-28bc1	A	9.5	70	.6	400	130,000	Observation well 54 ft from pumped well.
B7-20-32dd	A	12.7	67	.3	300	240,000	Observation wells 37 and 164 ft from pumped well.
B8-20-14cb	A, T	29.3	30	3.5	300	18,000	
B8-20-28dc1	A	7.1	53	1.4	100	230,000	Observation well 64 ft from pumped well.
B9-19-5ad	A	29.0	60	3.0	287	20,000	
B9-19-5ca	A	21.3	50	4.1	280	------------	
B9-19-6ca	A	14.7	52	1.7	200	27,000	
B9-19-31aa2	T	58.5	20	11.4	200	2,400	Flowing well: static head, 5.4 ft above land surface; drawdown, 6.0 ft below land surface; total drawdown, 11.4 ft.
B9-20-12bb	A	19.7	40	2.2	280	20,000	
B9-20-26ba3	A, T	20.3	60	6.7	455	18,000	Observation wells 82 and 140 ft from pumped well.
B9-20-26ba4	T	46.7	4	11.3	80	3,300	
B9-20-28db	A	8.2	14	1.1	210	------------	
B9-20-34ab4	A	39.1	62	1.5	100	------------	
B10-19-7bd	T	160.0	153	29.4	100	11,000	
B10-19-7dc2	A	64.3	220	25.0	180	40,000	Observation well at 73 ft from pumped well.
B10-20-15dc	A	16.7	82.5	5.9	220	25,000	
B10-20-26ab	A	8.5	22.5	2.7	97	15,000	

SPECIFIC CAPACITY OF WELLS

The specific capacity of a well, or yield per unit of drawdown, is commonly expressed as the number of gallons per minute that a well will yield per foot of drawdown. Drawdown is not only dependent on the water-yielding properties of the aquifer but also on construction and development of the well. Actual drawdown will be greater than the theoretical drawdown even in the best designed and constructed wells and may be several times as great in poorly designed and constructed wells. The discharge and water-level drawdown in the wells used for the aquifer tests are given in table 10.

Specific capacities of wells tapping the alluvium east of the Bitterroot River range from 8 to 230 gpm per foot of drawdown and average about 85 gpm per foot of drawdown. Specific capacities of wells tapping glacial drift west of the Bitterroot River range from 7 to 55 gpm per foot of drawdown and average about 20 gpm per foot of drawdown. Specific capacities of three wells tapping Tertiary sediments are 0.4, 5, and 7 gpm per foot of drawdown. Specific capacities of four wells, which produce both from a thin mantle of alluvium and from Tertiary sediments, are 2, 7, 8, and 9 gpm per foot of drawdown. The wide range in specific capacities is due largely to the differences in thickness and composition of the aquifer but partly to differences in construction and development of the wells.

The theoretical drawdown after 12 hours of pumping 500 gpm for different values of transmissibility and for an assumed storage coefficient of 0.15 is shown in figure 27. This graph can be used to predict drawdown in a perfectly designed and constructed 24-inch-diameter well. It shows that drawdown increases as transmissibility decreases. Though not shown on the graph, the drawdown increases as the storage coefficient decreases, according to the relation $s=k \log \frac{1}{S}$ where s is drawdown, k is a constant, and S is the coefficient of storage.

WATER TABLE

The surface defined by the water level in nonpumped tightly cased wells open to an unconfined aquifer is called the water table. The water table generally lies at higher altitudes under terraces and hills than under valleys; consequently, it is an irregular surface that reflects, in a general way, the topography.

The altitudes of the water level in about 100 wells were used to make a water-table contour map (pl. 1), which shows the configuration of the water surface about March 1, 1968. Ground water moves downslope almost at right angles to the contours.

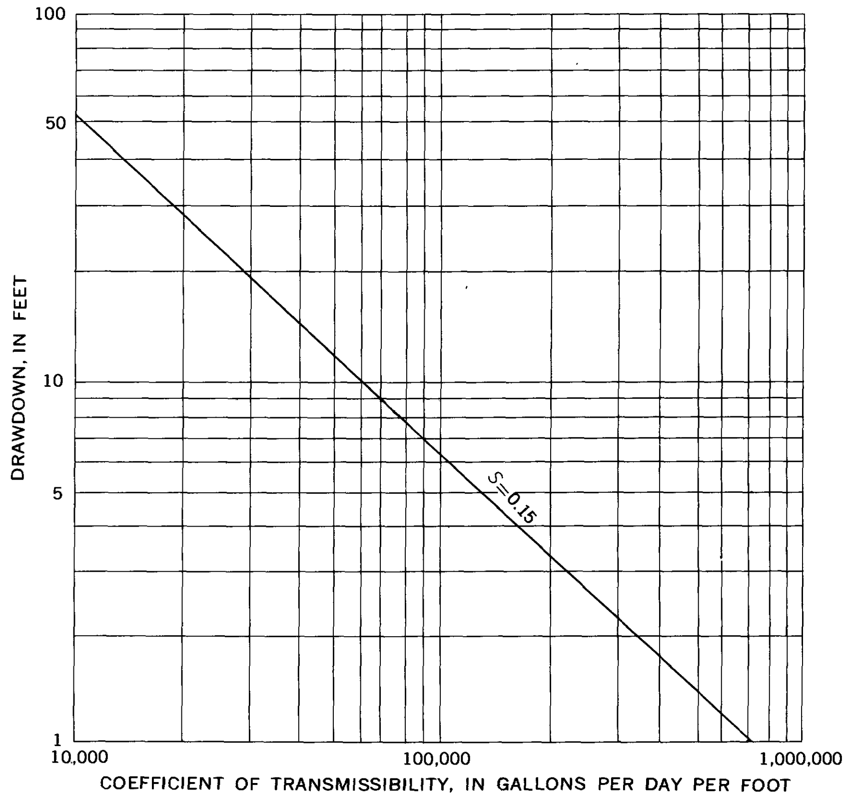


FIGURE 27.—Theoretical drawdown in a well 24 inches in diameter, after pumping for 12 hours at 500 gallons per minute, for various values of transmissibility and a storage coefficient of 0.15.

Ground water moves generally toward the Bitterroot River, but the slope and direction of movement vary locally in detail because differences in topography and transmissibility cause changes in the shape and slope of the water table. Others things being equal, a decrease in transmissibility causes a steepening of the water table and closer spacing of the contours; conversely, an increase in transmissibility tends to flatten the water table. The slope of the water table is greatest (about 150 ft per mile) along the western periphery of the area where the slope of the ground surface is the greatest and the transmissibility is relatively low. The slope is least (about 12 ft per mile) along the valley floor where the slope of the ground surface is low and the transmissibility is relatively high. West of the river, ground water moves eastward toward the river. Beneath the flood plain east of the river, ground water moves almost parallel to the river, as it does beneath the low terrace between Hamilton and Stevensville. It moves northwestward toward the river beneath the low terrace along Skalkaho Creek and Burnt Fork, and westward toward the river beneath the low terrace along Threemile and Eightmile Creeks.

The rate of flow of ground water is slow in comparison with that of surface water and was estimated to be 400 feet per year through Tertiary sand, 700 feet per year through alluvium beneath the flood plain, and 1,000 feet per year through the alluvium west of the river.

The water table fluctuates as water is added or withdrawn from the underground reservoir. Ground water continually discharges by seepage into streams, by evaporation and transpiration (generally along the streams), and by pumping from wells. Discharge gradually lowers the water table except when equaled or exceeded by replenishment to the underground reservoir from snowmelt, precipitation, and seepage from irrigation.

Monthly measurements to determine water-level fluctuations were begun in about 40 wells in the fall of 1955. About 65 wells were measured monthly in 1956 and about 95 in 1957. Automatic water-level recorders were operated in five wells during most of the study. Measurements were continued in 95 wells until October 1959, when the program was reduced to monthly measurements in 23 representative wells.

Water-level fluctuations may be placed into three general groups—short term, seasonal, and long term. In general, each group shows different hydrologic features. Short-term water-level fluctuations may indicate hydrologic characteristics of the aquifer; seasonal fluctuations may be an index of changes in the amount of water in storage; long-term fluctuations may indicate the relative amounts of recharge and discharge from year to year. Short-term fluctuations include (1) daily changes in water level due to pumping or to local recharge, (2) effects of variation in evapotranspiration, (3) changes in barometric pressure, temperature, and wind, (4) instantaneous fluctuations caused by earthquakes and by movement of heavy loads such as railroad trains. Three types of short-term fluctuations are shown in figure 28.

Seasonal fluctuations indicate variations in the amount of water taken into and released from storage. In general, the water level gradually declines through the winter and early spring, then rises rapidly in May and June in response to recharge from precipitation and irrigation. It remains fairly high through the irrigation season, then declines rapidly after irrigation ends. Under the existing water regimen in the valley, the general pattern of fluctuation is not likely to change from year to year, but the magnitude of seasonal changes may vary. Local variations from the general pattern of fluctuations are com-

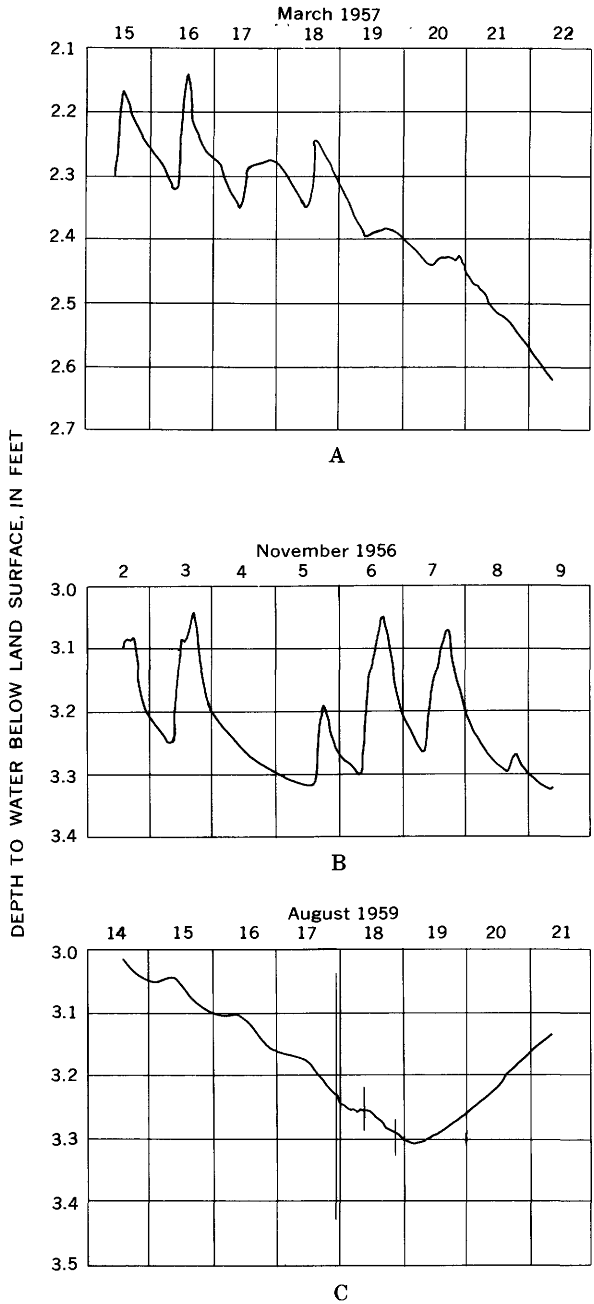


FIGURE 28.—Daily water-level fluctuations in well B9–20–26ba. A, diurnal fluctuations caused by temperature changes; B, fluctuations caused by recharge from industrial waste water; and C, fluctuations caused by earthquake.

mon because of differences in depth to water, source of recharge, and point of discharge. The water levels in deep aquifers may peak later than those in shallow wells. The annual peak water level in well B8–19–7cb, 116 feet deep, lagged behind that in well B8–20–15ba, 19 feet deep, by 3 to 4 months. The magnitude of fluctuation can vary greatly in nearby wells. The water level in well B9–20–34ab1 fluctuated more than 25 feet during 1958, while the water level in well B9–20–26ba1, about half a mile away, fluctuated less than 3 feet. Well B9–20–34ab1 is believed to be in a channel cut into Tertiary sediments and subsequently filled with materials of higher permeability than materials from which well B9–20–26ba1 obtains water. Recharge during the irrigation season fills the reservoir near both wells. Drainage from the more permeable material is much faster; therefore, the water level declines farther at well B9–20–34ab1 between periods of recharge.

Fluctuations of the water level in 74 wells in the valley were used to estimate the monthly change in ground-water storage. The valley was divided into 74 polygons; each included an observation well. The boundaries of the polygons were determined by the Thiessen method (Thiessen, 1911), and the area of each polygon was planimetered. The monthly change in water level in each well, multiplied by the area of the polygon in which the well was located, was considered to be the volume of material saturated or drained within the polygon during the month. The sum of the volumes for all polygons was considered to be the total volume of material saturated or drained. The monthly changes in the volume of saturated material, the cumulative monthly departures from the volume of saturated material at the end of March 1957, and the monthly changes in the volume of ground water in storage are given in table 11. A graph of the monthly cumulative departure from the volume of saturated material at the end of March 1957 in the Bitterroot Valley is shown in figure 29. Changes in volume of ground water in storage were computed by multiplying changes in volume of saturated material by the average specific yield of the material (0.07). This value for specific yield is the average ratio of net gain in volume of surface flow from the area to net loss in volume of saturated material within the area when (1) there was little recharge because the ground was frozen and most of the precipitation was stored as snow, (2) the river stage did not rise appreciably, and (3) very little ground water was lost to evapotranspiration (fig. 30). During such a period, the net gain in surface flow from the valley-floor area was due almost wholly to discharge of ground water. The specific yield of 0.07 is considered to be a minimum because there was probably some evaporation during the period used in making computations.

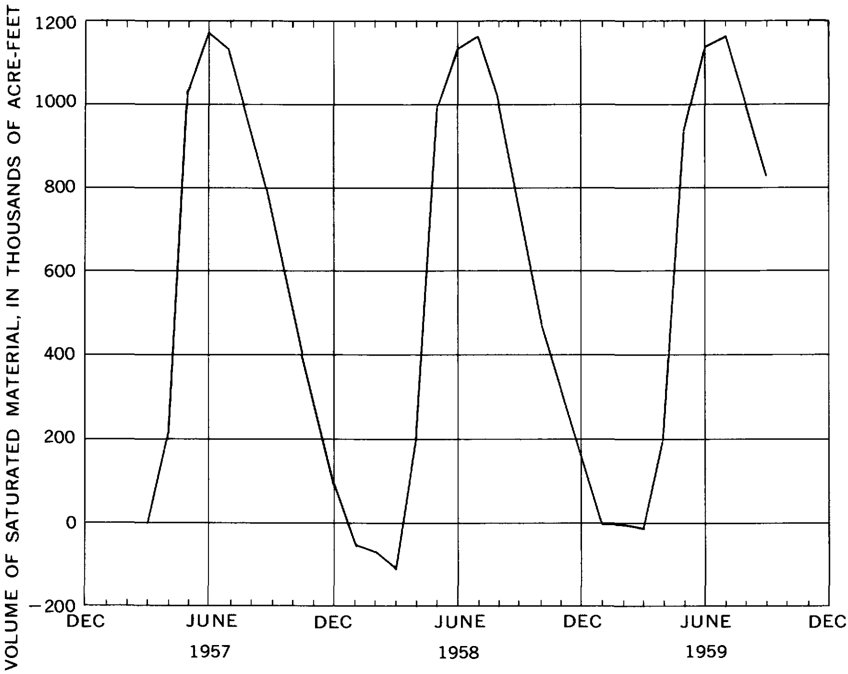


FIGURE 29.—Cumulative departure from the volume of saturated material, March 1957.

Data on long-term fluctuations of the water levels for most of the Bitterroot Valley are limited to 1956–59. Hydrographs for observation wells show no significant or widespread deviations in trend. Yearly recharge to the underground reservoir is approximately equal to yearly discharge, so the water table at the end of the year is at about the same level as at the beginning. Seasonal fluctuations during the period of record ranged from 3 to 30 feet. Although precipitation in June 1958 was one of the highest on record, water levels in many wells were slightly lower in June 1958 than in June 1957 or 1959. The unusually wet June curtailed early irrigation, and probably the recharge to the ground-water reservoir supplied by precipitation was less than normally supplied by irrigation.

RECHARGE

Recharge to the Bitterroot Valley is primarily by infiltration from streams and from irrigation and secondarily by infiltration of precipitation and snowmelt. In most of the valley, the Bitterroot River is normally a gaining stream, but for a short time during the spring

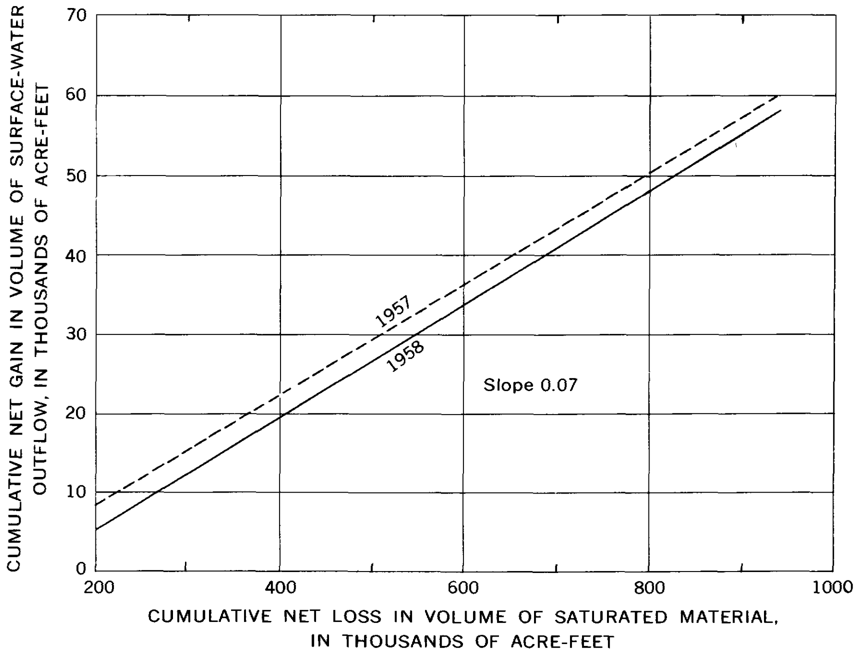


FIGURE 30.—Net gain in volume of surface-water outflow versus net loss in volume of saturated material for October and November 1958. Dashed line (1957) given for comparison.

runoff, the stage is high enough to recharge the ground-water reservoir. Most of the tributary streams are perennial in their upper reaches, but during the summer, water is diverted for irrigation or sinks into the unconsolidated materials, leaving the streams dry in their lower reaches. Some of the streams, especially on the east side of the valley, have been diverted and their original course cultivated so that there is no longer a recognizable channel.

According to the Montana State Engineer (1958, p. 30), 104,570 acres are irrigated in Ravalli County; about 100,000 acres of the total are in the study area. The U.S. Soil Conservation Service (1947, p. 12–13) reported the average maximum diversion requirement to be 1 statutory inch per acre, or 1 cfs (cubic foot per second) per 40 acres, which is generally the ditch capacity. The average maximum diversion requirement for the irrigated land in the study area is 2,500 cfs, or about 150,000 acre-feet per month. In 1958, the maximum requirement was available only in May and June. In 1959, the maximum requirement was available in April, May, June, and July. During the irrigation season (May to September), it is common to divert all the water the ditches will carry when water is available or to divert all that is

TABLE 11.—*Monthly change in volume of saturated material, cumulative monthly change in volume of saturated material, and monthly change in volume of ground water in storage in the Bitterroot Valley, in thousands of acre-feet*

Water year	Monthly change in volume of saturated material	Cumulative monthly change in volume of saturated material	Monthly change in volume of ground water in storage
1957			
April	+220	+220	+15.4
May	+811	+1,031	+56.8
June	+144	+1,175	+10.1
July	−39	+1,136	−2.8
August	−197	+939	−13.8
September	−175	+764	−12.2
1958			
October	−253	+511	−17.7
November	−227	+284	−15.9
December	−187	+97	−13.1
January	−152	−55	−10.6
February	−15	−70	−1.1
March	−38	−108	−2.7
April	+314	+206	+22.0
May	+776	+982	+54.3
June	+157	+1,139	+11.0
July	+31	+1,170	+2.2
August	−164	+1,006	−11.4
September	−258	+748	−18.1
1959			
October	−257	+491	−18.0
November	−178	+313	−12.5
December	−180	+133	−12.6
January	−140	−7	−9.8
February	+1	−6	+0.1
March	−7	−13	−0.5
April	+222	+209	+15.6
May	+725	+934	+50.8
June	+201	+1,135	+14.0
July	+27	+1,162	+1.9
August	−146	+1,016	−10.2
September	−179	+837	−12.6

available when flow is less than ditch capacity. About 570,000 acre-feet of water was diverted in 1958, and about 625,000 acre-feet in 1959. Based on the U.S. Soil Conservation Service's estimate (oral commun. 1959) that less than 30 percent of the water diverted for irrigation in the valley is lost to evapotranspiration, there was more than 400,000 acre-feet of water available for recharge to the ground-water reservoir in 1958 and 440,000 in 1959. However, the reservoir beneath the irrigated area was filled to capacity by the first of June, and recharge during June and July equaled discharge. After July, recharge was less than discharge.

The amount of recharge from precipitation is governed (1) by the amount, distribution, and intensity of rainfall, (2) by topography, transmissibility, and moisture holding capacity of the surficial deposits, and (3) by infiltration capacity of the soil, consumptive use, and the capacity of the ground-water reservoir to store additional water. The average annual precipitation on the valley floor is 12 or 13 inches. More than a fourth of the total normally occurs, in May and June, which are also the months of high recharge from irrigation, so the relative amount of recharge from precipitation cannot be determined from the hydrographs of observation wells. Rainfall on the area was about 161,000 acre-feet between April 1 and September 30, 1958, and about 132,000 acre-feet during the same period in 1959, but very little of it recharged the ground-water reservoir.

Although the relative amounts of recharge from precipitation or irrigation could not be determined, the combined effect was estimated from water-level records. From April 1 to July 31, 1958, the volume of saturated material increased by 1,300,000 acre-feet, and for the same period in 1959 there was an increase of 1,200,000 acre-feet. Multiplying those volumes by an average specific yield of 0.07 (p. 61) shows an increase in ground-water storage of about 90,000 acre-feet in 1958 and 82,000 acre-feet in 1959.

DISCHARGE

Ground water is discharged from the Bitterroot Valley by pumping from wells, by effluent seepage into streams, springs, drains, and seeps, and by evapotranspiration.

Discharge from wells is estimated on the basis of population and on the number of irrigation wells. It is estimated that the per capita use of water from wells by 13,000 people is 100 gallons per day. Therefore, annual ground-water discharge from domestic and municipal wells is almost 1,500 acre-feet. Less than 1,000 acres of land are irrigated from wells. The average application during the irrigation season is about 2 feet. Therefore, less than 2,000 acre-feet of water per year is pumped from irrigation wells. The total 3,500 acre-feet per year represents approximate gross pumpage from the ground-water reservoir. Net discharge would be less because of return seepage from septic tanks, sewer systems, and irrigation.

Ground-water discharge into streams was estimated from figure 29. The average monthly discharge rate is considered to be the average slope of the graph during the fall and early winter, when evapotranspiration is at a minimum. In water years 1958 and 1959, about 150,000 and 160,000 acre-feet of ground water, respectively, was discharged.

Water discharged into the atmosphere by evaporation, transpiration, and sublimation is no longer available for use. The combined action of these processes is called consumptive use and is approximately the difference between inflow and outflow, plus or minus change in storage. Consumptive use in the Bitterroot Valley during the 1958 water year was about 450,000 acre-feet of water (23 percent of the total water entering the area). During the 1959 water year, the consumptive use was about 400,000 acre-feet (18 percent of the total water entering the area).

HYDROLOGIC BUDGET, WATER YEARS 1958 AND 1959

EVALUATION

A hydrologic budget equates accretions to the water supply of an area to depletions. A hydrologic-budget equation basically states that inflow minus outflow equals change in storage. In a general form, which accounts for all water in an area, the budget may be written:

Surface inflow + subsurface inflow + precipitation + decrease in ground-water storage + decrease in surface-water storage + decrease in snow storage + decrease in soil moisture
= surface outflow + subsurface outflow + evapotranspiration + increase in ground-water storage + increase in surface storage + increase in snow storage + increase in soil moisture.

The general equation of the hydrologic budget was modified for the Bitterroot Valley to:

Surface inflow + precipitation + ground-water discharge
= surface outflow + ground-water recharge ± (unmeasured depletions or accretions).

During the 1958 and 1959 water years, surface-water inflow was measured at gaging stations around the margins of the valley; surface-water outflow was measured at the valley's outlet near Florence; precipitation was measured at stations throughout the area; and the change in storage of ground water was computed from measurements of the water level in wells. It is assumed that decrease in ground-water storage equals net ground-water discharge and increase in ground-water storage equals net ground-water recharge. Subsurface inflow and outflow are about equal and are estimated to be less than 2,500 acre-feet per year. Change in surface-water storage is negligible because there are no large storage reservoirs within the area and the average area of water surface of the Bitterroot River is less than 1,000 acres.

The unmeasured depletions and accretions are evapotranspiration, changes in soil moisture, and changes in snow storage. Unmeasured depletions consist largely of increase in snow storage and sublimation in the winter, increase in soil moisture in the spring and fall, and evapotranspiration in the summer. Unmeasured accretions are decrease in snow storage in the winter and spring and decrease in soil moisture during the growing season. Unmeasured accretions equaled or exceeded unmeasured depletions only in March 1958 and March 1959, owing to snowmelt during these 2 months.

A monthly water budget of the area is given in table 12 and shown in figure 31. The accuracy of the figures is limited by the accuracy of determinations of precipitation, change in ground-water storage, and streamflow.The quantities in column 10, table 12, were determined from the measured quantities and therefore include any inaccuracies in the measured quantities.

ANALYSIS

From October 1957 through March 1958, surface-water outflow exceeded inflow. The gain in outflow was derived from ground-water discharge, which exceeded recharge throughout the period, and from precipitation. Some of the precipitation returned to the atmosphere by evaporation and (or) sublimation and some added to the streamflow.

From April through July 1958, surface-water outflow was less than inflow. In April, the ground-water reservoir received some recharge from precipitation and snowmelt. Owing to high streamflow from snowmelt, May was the month of greatest accretion to the total water supply of the area for the 1958 water year and also the month of greatest surface-water outflow for the year. Ground-water recharge, mostly from infiltration of irrigation water but in part from infiltration of rain and snowmelt, was also greatest in May. Much water was consumed by evapotranspiration. There was some net ground-water recharge in June and July 1958, in spite of high evapotranspiration.

During August and September 1958, inflow still exceeded outflow indicating that evapotranspiration was greater than ground-water discharge and precipitation.

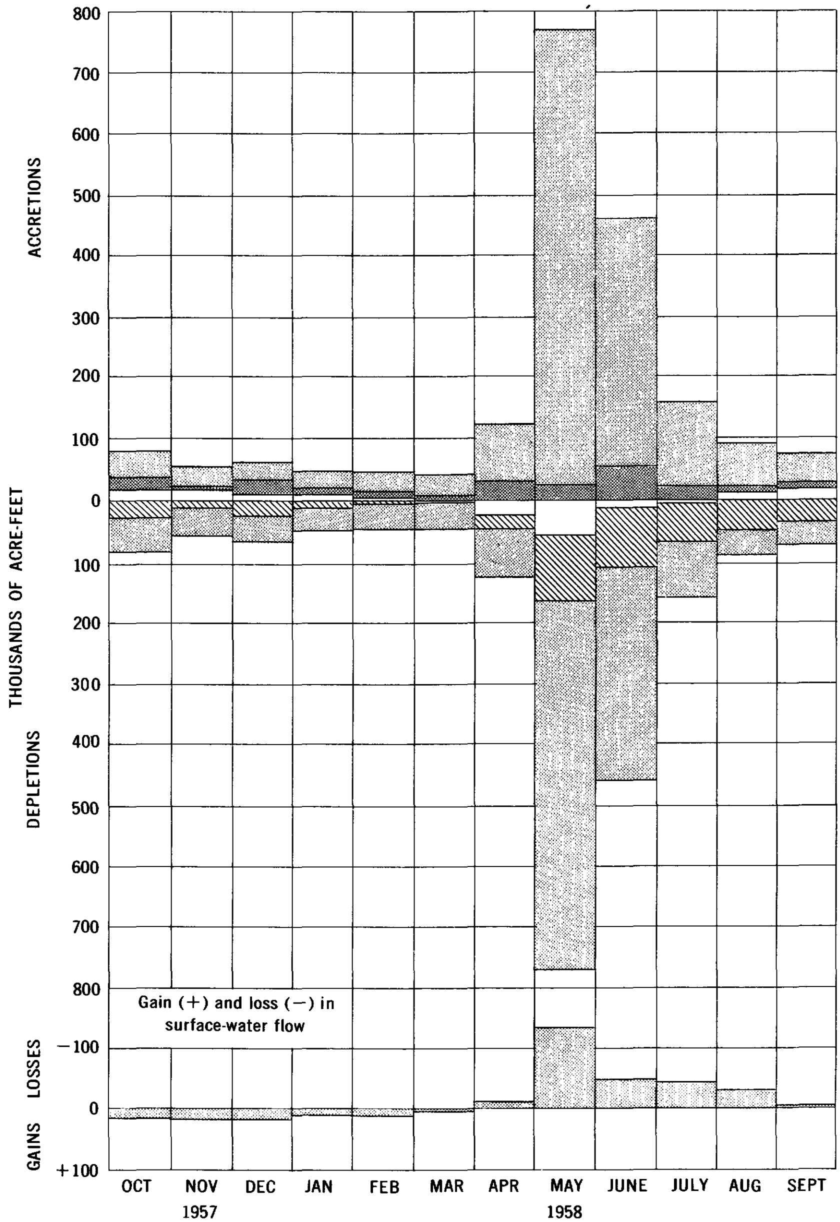
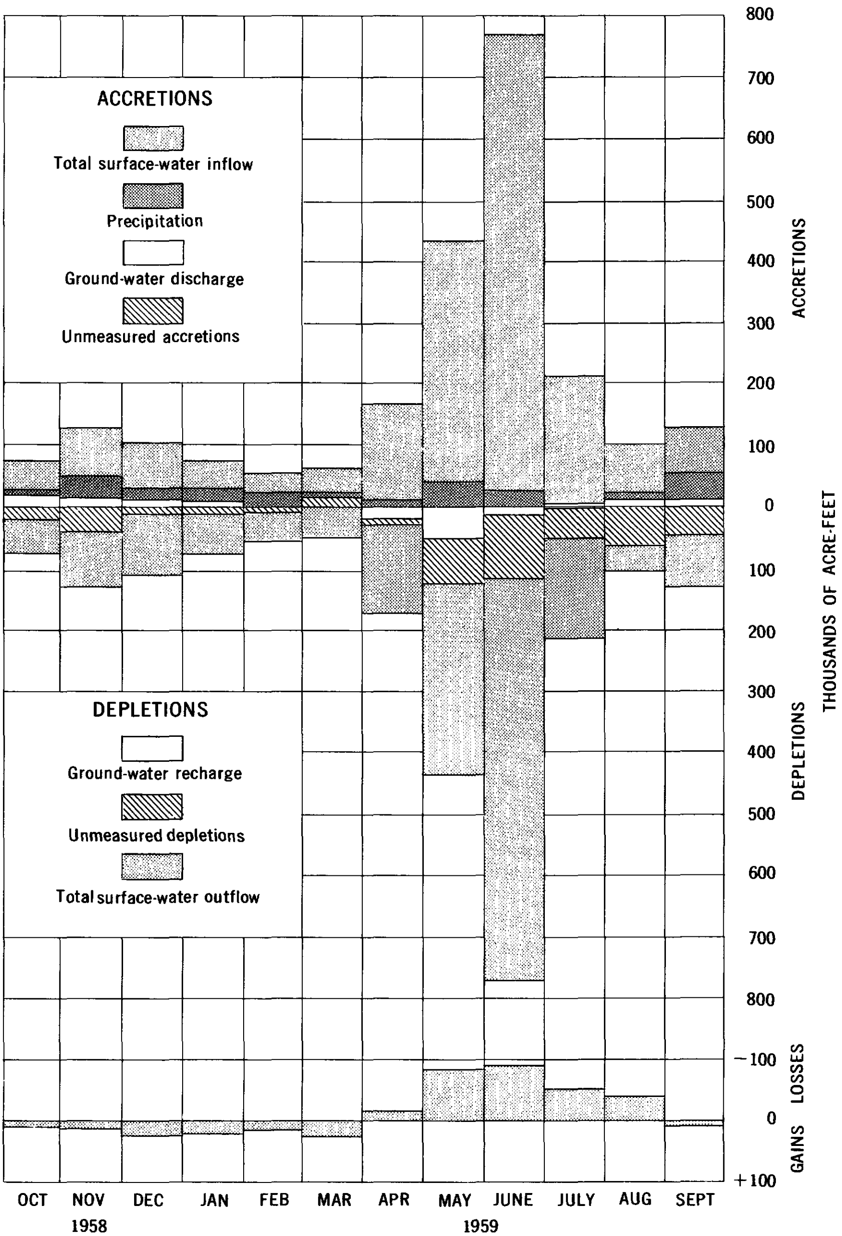


FIGURE 31.—Monthly inventory of the water resources



of the Bitterroot Valley, southwestern Montana.

TABLE 12.—*Monthly and annual changes in the water supply of the Bitterroot Valley, water years 1958 and 1959, in thousands of acre-feet*

Month	Surface-water inflow to Bitterroot Valley				Measured outflow from the Bitterroot Valley (Bitterroot River near Florence)	Net gain (+) or loss (−) in surface flow [2]	Precipitation	Net ground-water discharge	Net ground-water recharge	Unmeasured depletions or accretions (−)[3]	Total of accretions, which is equal to total of depletions [4]
	Bitterroot River near Darby	East-side tributaries	West-side tributaries	Total [1]							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1958 water year											
Oct.	21.27	7.38	14.97	43.62	55.79	+12.17	22.2	17.7		27.7	83.5
Nov.	16.75	6.19	9.55	32.49	47.34	+14.85	6.2	15.9		7.2	54.6
Dec.	10.80	6.15	8.66	25.61	39.84	+14.23	24.7	13.1		23.6	63.4
Jan.	15.68	5.15	8.12	28.95	37.72	+8.77	8.7	10.6		10.5	48.2
Feb.	16.49	4.42	9.85	30.76	41.63	+10.87	13.7	1.1		3.9	45.6
Mar.	17.25	4.70	14.41	36.36	43.86	+7.50	4.8	2.7		0	43.9
Apr.	34.44	9.34	47.28	91.06	79.42	−11.64	31.1		22.0	20.8	122.2
May	274.1	70.71	398.3	743.1	607.9	−135.2	27.2		54.3	108.1	770.3
June	137.5	49.63	214.6	401.7	353.2	−48.5	57.5		11.0	95.0	459.2
July	45.27	19.55	69.89	134.7	90.88	−43.8	24.1		2.2	65.7	158.8
Aug.	23.85	10.64	36.20	70.69	40.82	−29.87	9.0	11.4		50.3	91.1
Sept.	15.40	6.96	21.68	44.04	38.91	−5.13	11.7	18.1		34.9	73.8
Total	628.8	200.8	853.5	1683	1477	−205.8	240.9	90.6	89.5	447.7	2015
1959 water year											
Oct.	17.37	6.33	23.22	46.82	56.04	+9.12	9.9	18.0		18.8	74.8
Nov.	24.92	6.07	46.35	77.34	89.88	+12.54	37.3	12.5		37.3	127.2
Dec.	27.94	5.83	39.60	73.37	98.62	+25.25	18.8	12.6		6.2	104.8
Jan.	20.55	4.94	18.96	44.45	65.63	+21.18	21.5	9.8		10.1	75.7
Feb.	16.25	4.14	12.40	32.79	48.32	+15.53	22.4		0.1	6.8	55.2
Mar.	19.54	5.71	14.52	39.77	66.76	+26.99	9.1	.5		−17.4	48.4
Apr.	67.79	11.48	77.64	156.9	143.0	−13.9	11.3		15.6	9.6	168.2
May	162.2	27.18	205.8	395.2	313.9	−81.3	41.3		50.8	71.8	436.5
June	249.6	71.40	424.5	745.5	656.8	−88.7	25.5		14.0	100.2	771.0
July	65.06	20.35	126.3	211.7	163.1	−48.6	2.1		1.9	48.8	213.8
Aug.	23.61	9.72	45.60	78.93	40.54	−38.39	11.1	10.2		59.7	100.2
Sept.	24.97	8.03	39.36	72.36	82.90	+10.54	41.2	12.6		43.3	126.2
Total	719.8	181.2	1074	1975	1825	−149.7	251.5	76.3	82.4	395.2	2302

[1] Column 1 plus column 2 plus column 3.
[2] Column 5 minus column 4.
[3] Column 7 plus column 8 minus column 6 minus column 9.
[4] Column 4 plus column 7 plus column 8 equals column 5 plus column 9 plus column 10.

Beginning in October 1958 and continuing through March 1959, surface-water outflow was more than surface-water inflow. Ground-water discharge exceeded recharge each month except February 1959. In March 1959, snowmelt within the area exceeded net increase in soil moisture and evapotranspiration.

From April through July 1959, inflow exceeded outflow; there was net ground-water recharge; much water was evapotranspired.

In August 1959, inflow was still greater than outflow; most of the difference was due to evaporation and transpiration. In September 1959, surface-water outflow was more than surface-water inflow. Evapotranspiration about equaled precipitation. There was slightly more water stored in the ground-water reservoir at the end of the 2-year period than there was at the beginning of the period.

CHEMICAL QUALITY OF WATER

By H. A. Swenson

MINERAL CONTENT OF NATURAL WATERS

We know by taste and from common knowledge that rain water is fresh and sea water is salty. Chemical analyses confirm this fact. Laboratory tests show that rain and snow contain some dissolved solids, perhaps as much as 0.001 percent, or 10 mg/l (milligrams per liter), whereas sea water averages about 3.5 percent, or 35,000 mg/l, and some natural brines contain several hundred thousand milligrams per liter. Waters in most of our springs, wells, rivers, and creeks have intermediate concentrations. Tolerances to salt content and to specific constituents in water for drinking, cultivation of crops, industry, and other uses are now generally known. Table 13 lists the common constituents and their concentrations in 36 samples of surface and ground water in the Bitterroot Valley. Measurements of certain physical characteristics such as water temperature and color also are tabulated.

TABLE 13.—*Chemical analyses of*

[Chemical constituents

Well or surface source	Depth of well (ft)	Diameter of well (in)	Date of collection	Temperature (°C)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
GROUND											
Tertiary											
B7-20-22da	79.4	6	10-24-55	-------	44	0.01	47	13	32	9.9	292
B8-20-5cc	95	4	9-13-57	12	32	.03	20	4.4	6.1	.9	94
B9-19-10bb	29.8	42	10-20-55	10	57	.01	58	16	158	20	441
B9-20-10bc	170	6	9-19-57	11	41	4.0	19	6.7	28	2.2	155
Alluvium beneath the											
B6-20-4bc1	43.0	6	10-24-55	11	36	0.00	52	13	24	4.4	257
-30bc [1]	70	--------	7- -34	-------	13	.16	37	12	14		170
B6-21-12db	17	3	8-22-57	14	13	4.1	6.6	2.1	5.2	.9	49
-25aa [1]	70	--------	4- -54	-------	-------	.00	45	14	2.0		189
-25ad [1]	70	--------	11- -53	-------	-------	.00	40	9	7.0		171
-25ad	70	--------	12- 6-55	10	20	.00	38	10	8.6	2.4	181
B7-20-16ab	9.9	50	9-19-57	15	20	.18	45	8.0	12	3.8	195
B7-21-11bc	40.1	6	9-18-57	9	25	.33	8.9	2.8	10		62
-36dd1	30	2	8-27-57	14	13	.19	8.1	1.9	3.0	2.1	44
B8-20-18dd1	12	36	9-17-57	11	16	.16	13	4.6	13		74
B8-21-26dd	25	4	8-27-57	11	19	.19	39	8.5	11	1.4	174
B9-20-34ac	54.1	4	10-18-55	13	17	.00	31	6.2	8.2	3.0	135
B10-19-30cd	Spring	--------	10-15-55	12	23	.00	25	5.0	14	1.8	112
Undifferentiated											
B9-20-16dc	54	6	9-20-57	9	28	0.01	14	6.0	5.7	1.4	82
B10-19-7cd2	60	5	10-31-55	-------	13	2.1	24	8.9	4.4	1.9	120
B10-20-14ba1	43.8	--------	8-26-57	12	11	.02	4.6	1.3	2.2	1.0	25
SURFACE											
Bitterroot River											
Near Darby			10-13-55	9	11	0.00	11	1.4	3.2	1.0	44
Near Darby			7- 6-56	15	11	.00	7.5	.3	1.4	1.2	30
At Florence			10-12-55	11	15	.00	20	3.7	6.6	2.0	89
Streams from											
Sleeping Child Creek near Hamilton			10-13-55	5	16	0.03	7.9	1.4	5.2	1.2	38
Skalkaho Creek near Hamilton			10-11-55	6	12	.00	27	7.4	2.0	1.9	117
Willow Creek near Corvallis			10-14-55	5	20	.00	32	3.4	1.8	1.5	113
Burnt Fork Creek near Stevensville			10-11-55	6	10	.00	22	4.4	2.3	1.5	88
Three mile Creek near Florence			10-12-55	7	17	.03	24	3.4	3.8	2.1	92
Eight mile Creek near Florence			10-12-55	11	15	.00	20	3.7	6.6	2.0	89

See footnote at end of table.

water from the Bitterroot Valley

in milligrams per liter]

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Residue on evaporation at 180°C	Dissolved solids: Sum	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium-adsorption ratio	Specific conductance (micromhos at 25°C)	pH	Color
WATER sediments													
0	9.0	1.5	0.7	1.5	0.05	292	303	171	0	1.1	465	8.0	5
0	2.7	1.0	.2	.5	.00	121	114	68	0	.3	155	7.6	5
0	39	43	.8	131	.08	748	740	210	0	4.7	1,090	7.8	15
0	5.8	3.5	.5	.0	.11	195	183	75	0	1.4	257	7.7	25
flood plain and terraces													
0	12	5.0	0.1	3.9	0.02	278	277	183	0	0.8	447	7.7	0
0	24	3.0	--	--	--	200	--	142	3	--	--	--	--
0	1.6	.8	.2	.0	.05	58	54	25	0	.5	80.9	6.8	5
18	5.0	8.0	.1	1.8	--	200	--	168	0	--	--	--	--
0	3.0	5.0	.2	19	--	200	--	136	0	--	--	--	--
0	5.1	2.0	.0	3.2	--	176	178	136	0	.3	295	7.5	0
0	6.4	2.8	.3	3.1	.01	202	197	145	0	.4	322	7.7	5
0	1.4	2.0	.3	2.2	.00	89	84	34	0	.7	113	7.0	5
0	2.0	1.0	.1	.4	.04	56	54	28	0	.2	78.5	6.7	5
0	6.3	3.0	.3	7.9	.05	117	101	51	0	.2	166	7.1	25
0	2.9	2.5	.3	7.1	.06	176	178	132	0	.4	294	7.6	5
0	5.9	2.0	.0	1.7	.10	139	142	103	0	.4	238	7.1	5
0	8.1	3.0	.2	7.4	.02	147	143	83	0	.7	223	7.5	0
deposits													
0	2.8	0.8	0.1	1.5	0.02	103	100	60	0	0.3	140	7.2	5
0	5.5	2.0	.0	2.4	.08	118	121	96	0	.2	208	7.5	0
0	3.3	.5	.0	.2	--	42	36	17	0	.2	53.5	6.4	5
WATER (main stem)													
0	2.4	0.5	0.1	0.2	0.01	53	53	33	0	0.2	77.5	7.1	5
0	.0	.0	.1	.1	.01	40	--	20	0	.1	54.5	7.6	--
0	2.1	1.5	.1	.4	.04	100	95	65	0	.4	154	7.4	5
Sapphire Mountains													
0	4.4	0.8	0.4	0.3	0.02	60	57	25	0	0.4	76.1	7.0	10
0	4.7	.2	.0	.0	.05	113	113	98	2	.1	194	8.0	5
0	3.5	.2	.3	.2	.15	121	119	94	1	.1	188	7.4	0
0	4.0	.2	.0	.1	.04	89	88	73	1	.1	148	7.6	5
0	4.4	.8	.3	.2	.02	104	101	74	0	.2	160	7.3	5
0	2.1	1.5	.1	.4	.04	100	95	65	0	.4	154	7.4	5

TABLE 13.—*Chemical analyses of water*

Well or surface source	Depth of well (ft)	Diameter of well (in)	Date of collection	Temperature (°C)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
Streams from											
Como Lake on Rock Creek			10-11-55	9	4.9	0.00	2.0	0.2	1.1	0.5	9
Blodgett Creek near Corvallis			9-19-57	7	3.4	.04	1.4	.1	.8	.3	8
Mill Creek near Corvallis			9-19-57	8	7.7	.04	2.2	.1	1.2	.3	11
Bear Creek near Victor			9-19-57	7	7.2	.07	2.2	.2	1.5	.3	12
Big Creek near Victor			9-17-57	12	4.1	.02	2.2	.1	1.3	.3	9
Kootenai Creek near Stevensville			9-12-57	11	6.7	.00	2.6	.2	1.5	.6	10
Bass Creek near Stevensville			9-17-57	10	5.9	.02	2.4	.2	1.1	.6	10

[1] Analysis by Montana State Board of Health.

Residents of the valley generally are favored with water of good chemical quality. Some domestic supplies contain iron and nitrate in objectionable amounts, but this problem is not common. The success of irrigation and the steady economic development of the valley is due in part to good quality water. The surface waters are softer, as a rule, and contain smaller amounts of dissolved solids than the ground water, as shown in the following table:

Source	Number of samples	Range in concentration (mg/l)	
		Dissolved solids	Hardness
Wells and springs	40	42–748	17–210
Streams	16	13–121	4–98

CHEMICAL CHARACTER AND ENVIRONMENT

The chemical character of a natural water reflects the environment through which the water has passed. Geologic factors, as well as the influence of man, play important roles in the composition and concentration of mineral constituents in waters. Water supplies from one side of Bitterroot Valley show distinctive differences in quality from those on the other side, as shown by the relative hardness of water (fig. 32). Streams heading in the Sapphire Mountains (east side of *from the Bitterroot Valley*—Continued

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Residue on evaporation at 180°C	Dissolved solids: Sum	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium-adsorption ratio	Specific conductance (micromhos at 25°C)	pH	Color
Bitterroot Range													
0	0.7	0.2	0.0	0.3	0.01	16	14	6	0	0.2	22.3	6.4	5
0	1.1	.2	.2	.0	.01	13	11	4	0	.2	15.1	6.5	5
0	1.0	.2	.2	.0	.00	20	18	6	0	.2	20.1	6.6	5
0	1.4	.2	.3	.2	.04	21	19	6	0	.3	23.0	6.7	5
0	2.9	.2	.1	.1	.00	17	16	6	0	.2	21.3	6.7	5
0	4.4	.2	.1	.0	.04	22	21	7	0	.2	28.2	6.8	5
0	2.8	.2	.1	.2	.02	20	18	7	0	.2	23.3	6.9	5

valley) are more mineralized than those heading in the Bitterroot Mountains (west side). Ground water, which is recharged by creek and irrigation water, reflects similar differences.

Streams draining the Bitterroot Mountains flow through an area of igneous and metamorphic rocks, which are resistant to rapid solution by water. As a result, these waters have small concentrations of dissolved solids. A sample of water from Como Lake, collected on October 11, 1955, contained only 16 mg/l of dissolved solids. In the spring, melting of the heavy snowpack in the mountains above Como Lake releases water of even lower mineral content to the reservoir. Chemical analyses of water from seven creeks draining the Bitterroot Mountains are reported in table 13.

The Sapphire Mountains east of the Bitterroot River are composed of sedimentary and igneous rocks. These rocks contain higher proportions of readily soluble minerals than rocks in the Bitterroot Mountains. Water from Skalkaho Creek near Hamilton, on October 11, 1955, had 113 mg/l of dissolved solids and was of the calcium magnesium bicarbonate type. This creek heads in an area of granitic gneiss and sedimentary rocks. Daly Creek, a tributary entering above the sampling site, flows through outcrops of argillaceous limestone and probably contributes most of the dissolved solids to Skalkaho Creek. Analyses of waters from six streams that drain the Sapphire Mountains are listed in table 13.

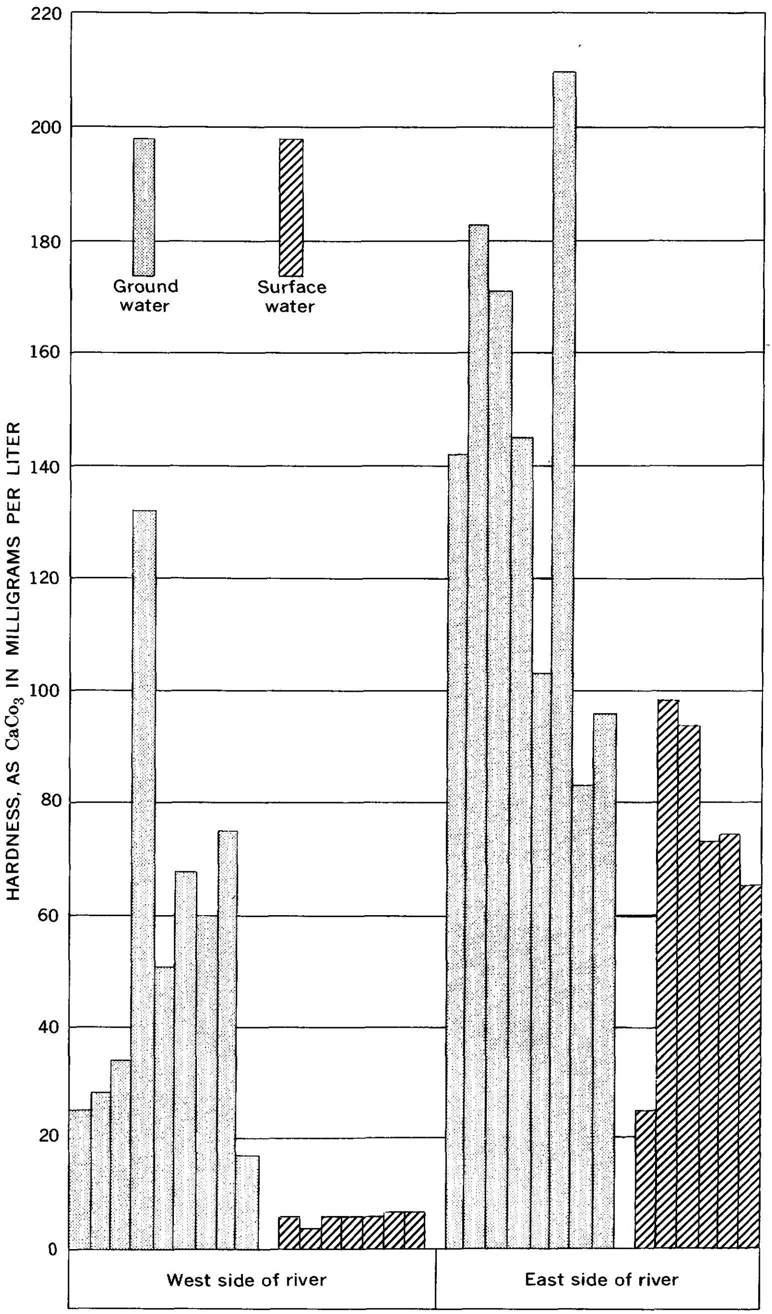


FIGURE 32.—Hardness of waters from Darby to Florence. Samples are arranged in downstream order for each side of the river.

Bitterroot River water in October 1955 contained 53 mg/l dissolved solids near Darby and 95 mg/l dissolved solids at Florence, near the north end of the valley. This increase in concentration, which is not significant in relation to the usefulness of the water, is the net effect of inflow from 20 tributaries from the west and five from the east, ground-water discharge, and irrigation return flow.

Water from alluvium beneath the flood plain and terraces is of variable but generally acceptable quality for most uses (table 13). The chemical character of the ground water is influenced by source of recharge, permeability, chemical character of the aquifer, soil cover, and rate of ground-water movement.

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INDEX

[Italic page numbers indicate major references]