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GEOLOGY AND GROUND-WATER RESOURCES OF THE HELENA VALLEY, MONTANA

By

Howard W. Lorenz and Frank A. Swenson

With a Section on the

CHEMICAL QUALITY OF THE WATER

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Herbert A. Swenson

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ABSTRACT

A study of the geology and the ground-water conditions of the Helena Valley, in the west-central part of Montana, was made during the summer of 1948. The purpose of the study was to gather data on the occurrence of ground water and its relation to present and proposed irrigation in the area. With such data one may better predict the effects of the application of irrigation water to additional lands in the area.

The Helena Valley is a small intermontane basin. It is surrounded by rocks ranging in age from pre-Cambrian to Cretaceous and its floor is underlain by Tertiary "lake beds," which are mantled by younger alluvial fans in much of the valley. Folded and faulted Paleozoic limestone, shale, and quartzite beds, more than 5,000 feet in total thickness, are exposed in the mountains south of Helena. These sedimentary rocks have been metamorphosed by intrusion of the adjacent Boulder batholith. Folded pre-Cambrian sedimentary rocks form the other mountains that surround the area.

The principal water-bearing formations are the thick alluvial fans and the underlying "lake beds." The water in the alluvial fans generally is under water-table conditions whereas the water in the "lake beds" in the lower part of the valley is confined under artesian pressure and produces large flows of good-quality water in places. Wells drilled into the deposits of coarse boulders, cobbles, and indurated tuffs of "lake beds" along the southern margin of the valley yield only meager supplies of water. The Cretaceous, Paleozoic, and pre-Cambrian rocks yield only small quantities of water to wells and springs.

Approximately 8,500 acres of formerly productive farm land in the lower part of the Helena Valley is waterlogged at the present time as a result of the increased ground-water recharge caused by irrigation of the higher lands in the valley. If more lands in the higher part of the valley are irrigated, the extent of the waterlogged area will increase unless provision is made either to prevent additional ground-water recharge or to recover and dispose of the excess ground water.

Ground waters in the valley contain moderate amounts of dissolved solids, the predominant ions being calcium, bicarbonate, and sulfate, Little difference is discernible in the composition of waters in the Quaternary and Tertiary deposits; the dilute nature of these waters indicates that the valley fill is derived from formations containing only small amounts of soluble minerals.

The quality of the ground water appears to be little affected by recharge of the ground-water reservoir from return irrigation flows. Waterlogged areas may in time show an increase in mineralization as a result of evaporation.

Both ground and surface waters are classified as "excellent to good" on the basis of Wilcox's criteria for irrigation waters. Boron, percent sodium, and dissolved solids are relatively low. Waters used for drinking or domestic purposes are generally considered satisfactory except, in some instances, for hardness.

INTRODUCTION

Purpose and Scope of Investigation

The purpose of this investigation was to gather data on the occurrence, conditions, and potentialities of the ground water in the Helena Valley. Special consideration was given to the source of the ground water, to its direction of movement, to the fluctuations of water levels in wells, to the depth to the water table below the land surface, to the available supply, and to the present and potential extent of waterlogging and means for alleviating it. This study was a part of the program of the Interior Department for development of the Missouri River basin, and it is directly related to the proposed Canyon Ferry project which calls for diversion of water from the Missouri River into the Helena Valley to irrigate about 10,000 acres of land not now irrigated and to furnish additional water to about 5,000 acres of land already irrigated.

This report is based principally on field work done by Howard W. Lorenz between July and early November 1948. However, water-level measurements made during April, May, and June, 1948, by the Bureau of Reclamation are incorporated in this report. The geology of the area was mapped on aerial photographs, and the field data were later transferred to a base map by use of a sketchmaster. An inventory was made of all wells in the area; water levels in observation wells were measured periodically; and a water-table contour map was constructed from instrumentally determined altitudes of water levels in wells.

The field investigation was under the general supervision of A. N. Sayre, chief of the Ground Water Branch of the Federal Geological Survey, and G. H. Taylor, regional engineer in charge of ground-water investigations in the Missouri River basin. F. A. Swenson district geologist was in immediate charge of the field studies and collaborated in the preparation of this report.

The quality-of-water study was under the general direction of S. K. Love, chief of the Quality of Water Branch, and under the immediate supervision of P. C. Benedict, regional engineer in charge of quality-of-water investigations, Missouri River basin. Analyses of samples completed for this report were made by M. B. Florin, R. H. Langford, and R. P. Orth.

Location and Extent of Area

The Helena Valley lies in the southeastern part of Lewis and Clark County in west-central Montana. (See fig. 1.) The area studied is 9 miles wide and 15 miles long and is completely surrounded by hills and mountains except for a narrow canyon that connects Helena Valley on the northeast with the valley of the Missouri River. It is bordered on the west by the main range of the Rocky Mountains and on the east by the Spokane Hills. Helena, the capital city of Montana, lies in the southwest corner of the valley, and East Helena, the second largest city in the valley, is 5 miles east of Helena.

Previous Investigations

The geology of the Helena mining district is described in detail in reports by Knopf and by Pardee and Schrader. These reports, and other publications consulted by the authors, are listed at the end of this report.

Acknowledgments

The writers are indebted to many persons for assistance in the field study and in the preparation of this report. A. H. Tuttle, district engineer, Surface Water Branch, United States Geological Survey, rendered many services to the writers during the field season. F. V. Munro and other Bureau of Reclamation personnel made available the valuable data they had gathered in beginning a drainage study in the Helena Valley. F. E. Buck, state engineer, supplied information concerning irrigation, and H. B. Foote, director, Division of Sanitary Engineering, Montana State Board of Health, furnished well logs. Walter Riddock, local well driller, and the Porter Brothers Mining Co. furnished detailed information about wells and test holes they had drilled. Many farmers furnished data concerning their wells and gave permission for periodic measurement of the water level in them.

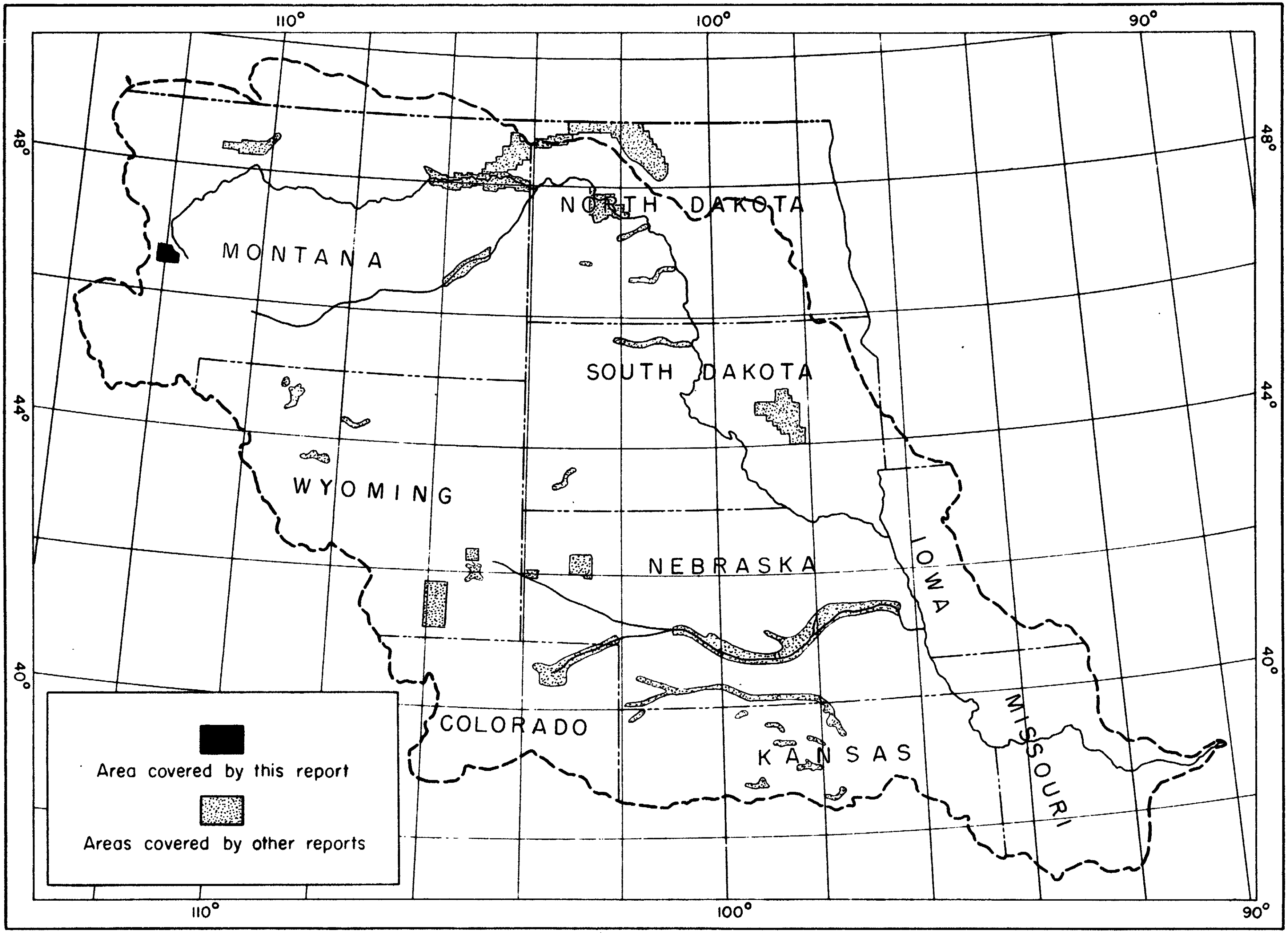


Figure 1.—Map of the Missouri River Basin showing areas in which ground-water studies have been made under Missouri Basin program.

History of the Area

Arrowheads and tomahawks carved from stones of local origin indicate that the Helena Valley was at one time inhabited or visited by Indian tribes.

Members of the Lewis and Clark Expedition were undoubtedly the first white men to see the valley. On July 19, 1805, Lewis and his party passed through the narrow gorge cut by the Missouri River through the folded structure of the Big Belt Mountains 15 miles northeast of Helena. Clark (Thwaites, 1904, vol. 2, pt. 2, pp. 248-251) described the rocks of this region in his journal and he named the narrow canyon the descriptive and now well-known "Gates of the Mountains." In the same journal Captain Clark described the journey he and his scouting party made through a beautiful valley of great extent and across which a beautiful creek flowed. That valley is believed to be the valley described in this report. Clark mentions having pulled 17 prickly pear thorns from his bruised feet that evening and it may have been from that circumstance that Prickly Pear Creek in Helena Valley received its name.

In 1864 a group of miners under the leadership of John Cowan (Campbell, 1915, p. 123) and known as the Georgians were prospecting in this area. Their search for gold had proved fruitless, but before returning to the east they decided to take one last chance in a small gulch that previously had been bypassed. It was here on July 14 that gold was discovered, and immediately the small valley became known as Last Chance Gulch. Word of the strike spread rapidly, and soon mining cabins were clustered along the slopes of the gulch. Tailings from the sluice boxes, which washed down the gulch, formed the roadbed of the wagon trail that later became Main Street of Helena. The same year the name of the small settlement was changed from Last Chance to Helena, in honor of Helena, Minn., the home of a prominent miner.

With continued discoveries of gold, silver, and lead bodies in the mountains to the south, Helena in 1875 became the capital and most important town in the territory. By 1888 it was well known as a great mining center and, being credited with some fifty millionaires (Montana State Guide Book, 1939, p. 161) was said to be one of the richest cities per capita in the United States. The Northern Pacific Railway was completed to Helena in 1883, and the first train crossed the Continental Divide west of Helena on August 7 of that year. The Helena & Jefferson Railroad, now part of the Great Falls-Butte branch of the Great Northern Railway, was completed during the latter part of the same year. Ten years later, however, a drop in silver prices brought an end to the thriving prosperity.

Development of this region by the building of Hauser, Holter, and Canyon Ferry Dams on the Missouri River between 1900 and 1910 brought another period of temporary prosperity, and work now being done on the Canyon Ferry dam site has again brought prosperity to this area.

Well Numbering System

In this report, wells are numbered according to their location within the General Land Office system of land subdivision. The component parts of a well number are the township number, the range number, the section number, and the two lower-case letters which indicate, respectively, the quarter section and the quarter-quarter section in which the well is located. The lower-case letters are assigned in counter-clockwise order beginning with a in the northeast quarter or quarter-quarter section. Serial numbers are appended to the location number if two or more wells located within the same quarter-quarter section are to be distinguished from each other.

This system of numbering wells according to their location is illustrated in the figure below.

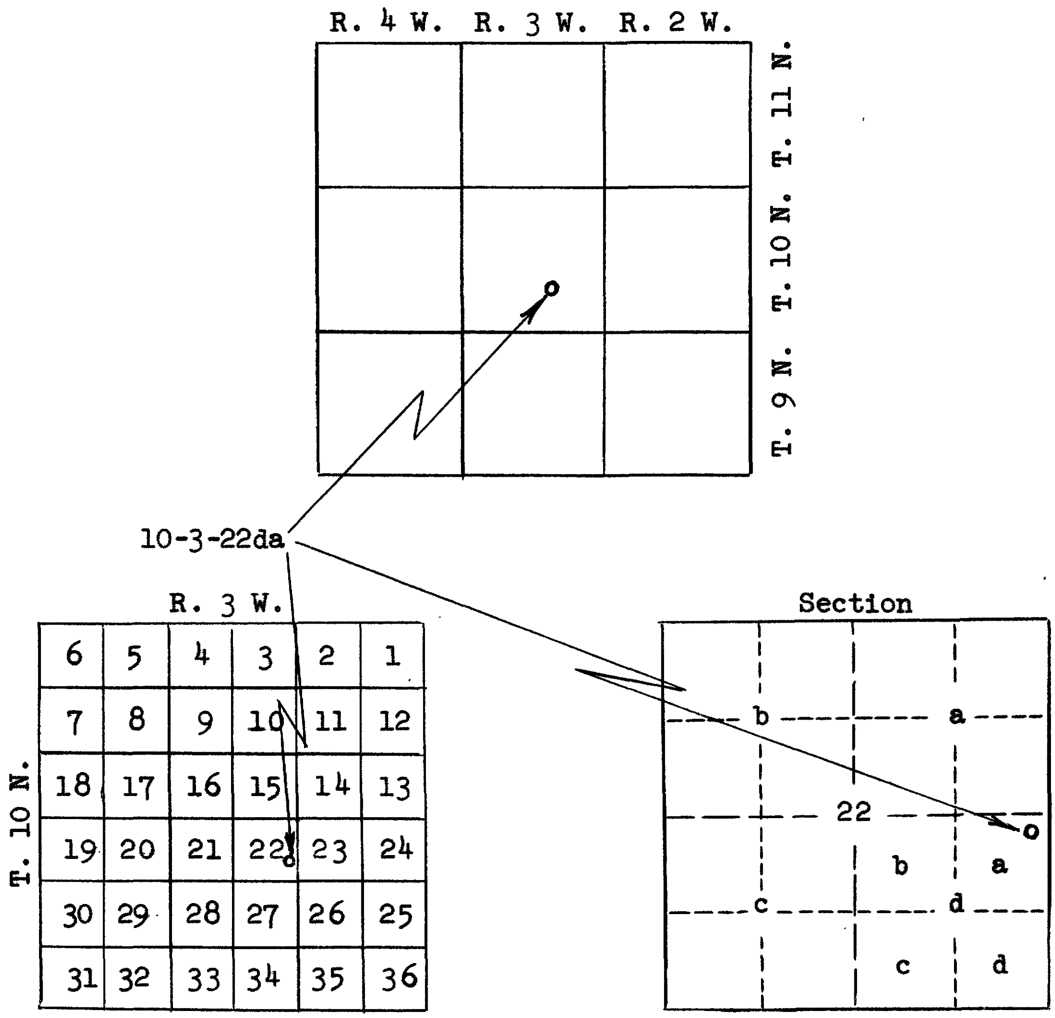


Figure 2.--Sketch showing well-numbering system used in this report.

Physiography

The Helena Valley is in the north-central part of the northern Rocky Mountain physiographic province (Fenneman, 1931, p. 214). It is a typical intermontane basin (see fig. 3, A), roughly oval in shape and trending northwest-southeast. The lowest part of the valley is occupied by Lake Helena, which is backwater from Hauser Dam on the Missouri River.

On the southeast side of the valley are low rolling hills composed of fine-grained, poorly consolidated sediments. These low hills rise toward the east and grade into the more rugged Spokane Hills, which are composed of resistant Paleozoic and pre-Cambrian rocks. The main valley of the Missouri River lies east of these hills. The Spokane Hills are separated from the rugged mountains to the south by the low divide between the Helena and Townsend Valleys. Piedmont alluvial fans slope gradually from the mountains that border the valley on the south and west. These mountains are composed of folded and faulted Paleozoic and pre-Cambrian limestone, shale, and quartzite, and differential erosion of the tilted beds gives a marked linear grain to the topography. (See fig. 3, B.) The city of Helena is built on the lower flanks of Mount Helena and Mount Ascension, which rise conspicuously to altitudes of about 5,400 feet. These peaks are foothills to the main range of the Rocky Mountains, which form the continental divide some 12 to 15 miles west of Helena. The mountains have been aptly described by Barrell (1907, p. 1) as:

> "a deeply dissected plateau country" that "does not present here the usual concept of the backbone of a continent," but "is a somewhat broad, grassy, soil-clad axis less than 7,000 feet in elevation."

In the western part of the valley, the Scratchgravel Hills occupy an area of approximately 12 square miles. From the valley of Sevenmile Creek, 2 miles north of Helena, they extend northward a distance of 4 miles. A low ridge connects them with the foothills of the mountains to the west. The highest summit has an altitude of 5,250 feet, several high ridges extending to the north and two low projections to the south.

A gap between these ridges and the folded mountains to the north connects the Helena Valley with Little Prickly Pear Valley to the northwest. To the north the Helena Valley is bordered by mountains formed by folded beds of pre-Cambrian shale.

Drainage

The mountainous slopes that lie west, southwest, and south of Helena Valley are drained by streams which in their lower courses cross the valley floor and empty into Lake Helena. The principal streams are Prickly Pear Creek which heads in the Elkhorn Mountains to the south, Tenmile Creek which drains the area to the southwest, and Sevenmile and Silver Creeks

Figure 3.--A, Northeast view of the Helena Valley showing the contrasting topography of the Belt Mountains in the background. Note the large (dark) waterlogged area where the two streams join in the central part of the valley. B, View showing the contrasting topography of the valley and the folded and faulted beds south of Helena. The noticeable linear form of the upturned edges shows offsets along faults nearly perpendicular to the strike of the beds. Photographs by H. W. Lorenz.

Table 1.--Average monthly discharge, in second-feet, of Tenmile Creek, 2 miles west of Helena, Mont. ($SE\frac{1}{4}$ sec. 22, T. 10 N., R. 4 W.) from October 1935 to October 1945

[Compiled from data in U. S. Geol. Survey Water-Supply Papers 806, 826, 856, 876, 896, 926, 956, 976, 1006, 1036]

Note: A second-foot is 1 cubic foot per second, or about 449 gallons per minute

Month	Water year									
	1935-36	1936-37	1937-38	1938-39	1939-40	1940-41	1941-42	1942-43	1943-44	1944-45
October	0.62	1.23	0.85	5.58	1.47	1.19	13.3	1.20	3.26	4.46
November	3.31	1.83	.99	9.40	1.83	1.33	9.78	3.15	4.91	4.17
December	3.60	1.90	1.50	6.89	2.23	1.80	9.84	4.42	4.39	4.85
January	3.21	1.51	1.66	7.14	2.43	2.10	4.96	4.65	3.40	6.59
February	2.28	+2.0	1.78	3.27	2.88	2.35	4.67	4.82	3.11	6.17
March	3.18	3.00	4.97	17.1	5.25	2.08	6.99	16.6	6.65	7.96
April	16.4	6.45	18.5	41.4	19.5	8.54	59.0	90.6	11.1	12.8
May	27.4	47.9	160	55.5	42.5	33.6	105	133	59.7	98.3
June	19.6	23.5	119	31.9	26.3	31.5	86.5	155	148	142
July	.53	1.00	56.1	9.60	2.18	12.5	10.7	22.1	46.1	9.55
August	.49	.44	4.87	.76	.38	1.31	.97	2.13	6.33	1.21
September	.84	.53	1.91	.88	.94	3.63	.77	.92	1.85	2.91
Maximum	83	71	572	104	75	110	222	249	251	294
Minimum	.3	.3	.5	.4	.2	.5	.4	.3	1.0	.8
Mean	6.78	7.65	31.2	15.8	8.97	8.51	26.1	36.5	24.9	25.1
Runoff in acre-feet	4,931	5,540	22,560	11,470	6,510	6,160	18,900	26,390	18,040	18,170

which drain the mountainous slopes to the west of Helena Valley. Spokane Creek drains the hilly area at the southeastern end of the valley and flows directly into the Missouri River.

Prickly Pear Creek splits into several distributaries on entering the valley near East Helena. The principal distributary flows northwestward to its confluence with Tenmile Creek about a mile southwest of Lake Helena, but the water in the other distributaries is used principally for irrigation in the area between East Helena and Lake Helena. Sevenmile Creek joins Tenmile Creek about 3 miles northwest of Helena, but Silver Creek, which is joined by a stream draining the northwestern end of the valley, flows directly into Lake Helena.

The Geological Survey maintains a gaging station on Tenmile Creek near Broadwater. The discharge figures for this station for the 10-year period 1936 to 1945 are given in table 1. Discharge measurements, made October 25, 1944 at two points, are the only stream-flow records available for Prickly Pear Creek. (See table 2.)

Table 2.--Discharge measurements at two points on Prickly Pear Creek, October 25, 1944

Location	Discharge (sec.-ft.)
$SE\frac{1}{4}SE\frac{1}{4}$ sec. 36, T. 10 N., R. 3 W., 1 mile upstream from East Helena, Montana..................................	41.7
$NE\frac{1}{4}NE\frac{1}{4}$ sec. 36, T. 10 N., R. 3 W., 500 feet downstream from highway bridge in East Helena, Montana..........	a 33.9
Do..	36.2

a Difference in flow due to change in diversions upstream.

Climate

The climate of the Helena Valley is characterized by low precipitation and a wide temperature range. The low relative humidity tempers the discomfort that might otherwise be caused by the temperature extremes. In the winter occasional warm northwest winds, known as chinooks, usually prevent the accumulation of a persistent snow cover. The summer days are sunny and warm and the nights are cool. All in all the climate is pleasant and invigorating.

The average annual precipitation recorded by the U. S. Weather Bureau station at the Helena airport for a 65-year period, 1884-1948, is 12.61 inches. (See fig. 4.) About 33 percent of the annual precipitation occurs during the months of May and June. June is the wettest month, receiving on the average, 18 percent of the annual precipitation. February is the driest month receiving, on the average, only 5 percent of the annual precipitation.

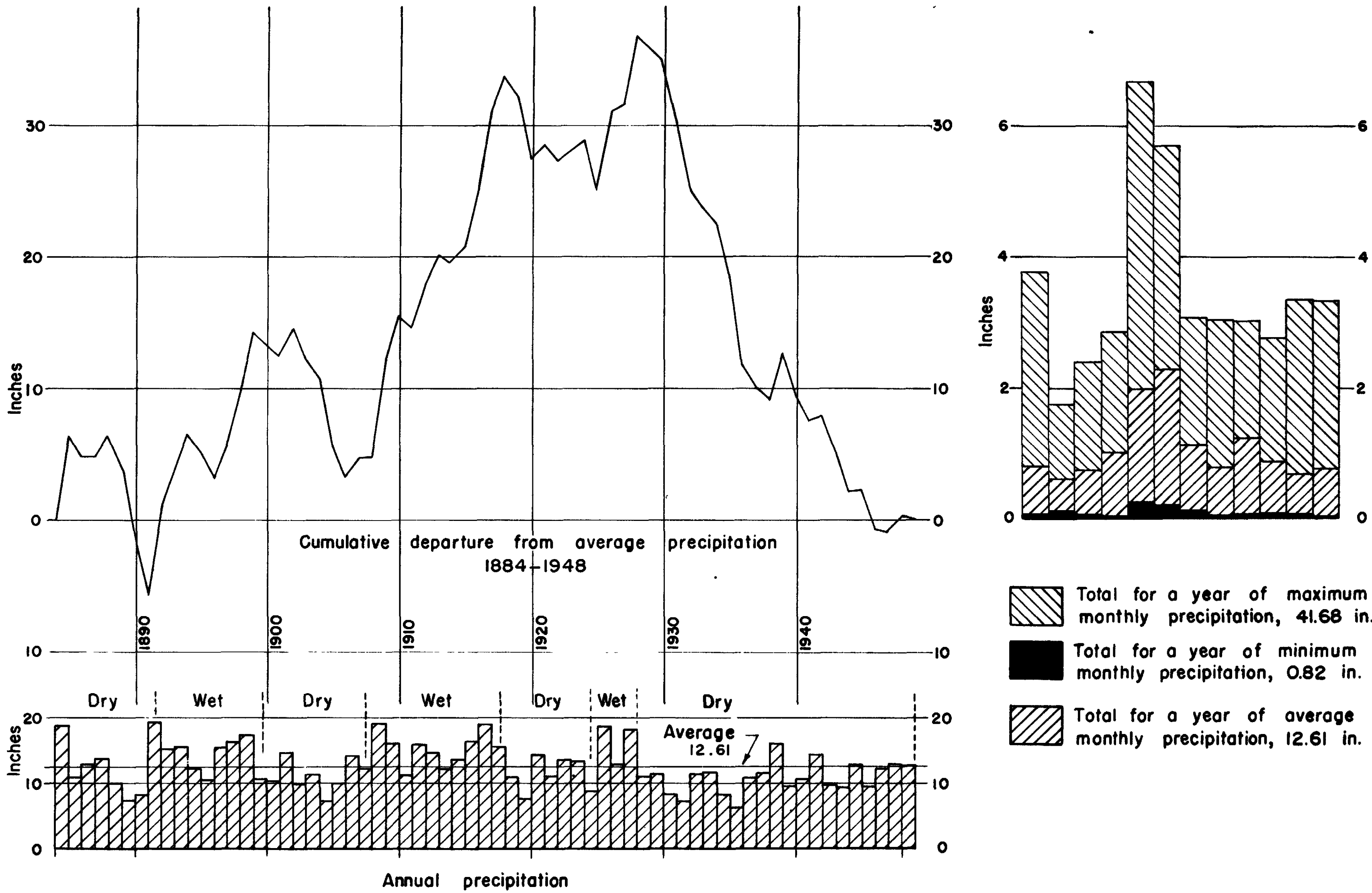


Figure 4.– Precipitation records at Helena, Montana, 1884-1948
(From records of the U.S. Weather Bureau)

Local, dashing showers characterize much of the spring and summer rainfall. Occasionally these showers are accompanied by hail that is very damaging to farm crops, especially when whipped by high winds.

Since 1884 the annual precipitation has ranged from 6.28 to 19.63 inches. The rainfall often is very spotty in occurrence; several exceedingly dry months are sometimes followed by months of excessive rainfall--a fact not indicated in annual rainfall totals. If all the wettest months in this 65-year period were to occur in any one year, a total of 41.68 inches would be received. In like fashion, if the driest months in this period were to occur in any single year, the total annual precipitation would be only 0.82 inch.

Pardee (1925, p. 12) studied precipitation data recorded at Helena and noted a marked cyclic recurrence of dry and wet periods from 1881 to 1922. The cycles were approximately 9 years long. However, records of more recent years do not show such a cycle. Since 1927 the annual rainfall has frequently been below the pre-1927 average and the average yearly precipitation has declined from 13.77 to 12.61 inches. The graph showing the cumulative departures from average precipitation indicates that the period between 1890 and 1917 was characterized by excess precipitation and that the period from 1917 to 1948 has been characterized by generally deficient precipitation. (See fig. 4.)

The mean annual temperature at Helena is 43.8° F. The lowest recorded midwinter temperature was -42° on January 31, 1893, and the highest recorded midsummer temperature was 103° F. on August 21, 1940. January is the coldest month with an average temperature of 20.5° F. and July is the warmest with an average of 67.8° F. The normal frost-free period is from May 3 to October 1, an average growing season of 151 days. Small grains are usually seeded during the last part of April or early in May and are rarely injured by late spring frosts, but occasional early fall frosts damage irrigated crops in the lower parts of the valley.

Brisk westerly and northwesterly winds occasionally sweep across this area, especially during late winter and early spring. During dry periods the winds accelerate the evaporation of needed soil moisture and damage newly seeded fields by whipping and drifting the loose soil. The warm chinook winds during the winter are very beneficial to both the farmer and the rancher, melting burdensome snow and keeping open watering holes and springs from which stock may drink. Because of the irregularity of the winds, windmills and electric windchargers are lacking in the Helena Valley.

Agriculture and Vegetation

The Helena Valley, because of its low mean annual precipitation and temperate growing season, is best suited for the raising of small grain crops and of livestock. Winter wheat is the principal small grain crop and is grown extensively on the higher, rolling land at the eastern end of the valley. Small acreages of barley and oats are sown each year in the valley. The subnormal rainfall of the last 21 years has prompted farmers to summer-fallow and use other dry-land farming methods where supplemental water supplies are unavailable. Approximately half the land under cultivation in this area is farmed by dry-land methods.

Lowlands in the central part of the valley, which have a high groundwater level, are used for hay production and pasture land. Other lowland areas, if irrigated, produce high yields when planted with potatoes, forage crops, and certain small grains. The farmers of the valley have a good market for their poultry, eggs, and dairy products at Helena and East Helena; often the demand exceeds the supply of some farm products and their import from neighboring regions is necessary. Many farmers of the valley have range land in the mountains for summer grazing. During the winter the herds are brought down and wintered in the valley. Large herds of cattle and sheep are raised in this area.

Yellow pine and Douglas fir cover a large part of the mountain slopes in the southern and western parts of the area; there is an especially heavy growth of these trees on the highly weathered surface of the Boulder batholith near Unionville. The lower mountain slopes and the rough mountains north of the valley support a sparse growth of pine, cedar, juniper, some tall grasses, and various shrubs. Cottonwood and willow trees and serviceberry shrubs grow along the streams of the valley and on favorable canyon slopes. Quaking aspen is confined to the seeped (waterlogged) and poorly drained areas.

Tall grasses, such as the bunch wheat grass and the fescues, predominate on the higher table lands and lower mountain slopes. The short grass, such as grama grass and its associated species, grow better on the lower valley ground. Sedges, wire grass, and slough grass make up a large part of the vegetation on the wet bottom lands, and greasewood, salt bush, and salt sage thrive in the more poorly drained and saline soils. A few larkspur and locoweed, plants poisonous to livestock, grow in the lower valley areas.

History of Irrigation

During the early agricultural development of the Helena Valley, farmers began diverting water from the perennial streams to irrigate their crops. At the present time, approximately 10,000 acres are irrigated from waters of Prickly Pear Creek and several thousand acres more from Tenmile and Sevenmile Creeks (Gieseker, 1947, p. 27). In 1912 the Montana Reservoir and Irrigation Co. was organized, contracting to supply the farmers with irrigation water for a 30-year period. Two pumping plants were built along Lake Helena, the source of the water for the project. The North Pumping Station is designed to pump water to three canals at successively higher altitudes, with an average lift of 112 feet. During recent years, only the two lower lifts and canals have been in operation. This station supplies water for the area north and west of Lake Helena. The South Pumping Station has a single 162-foot lift supplying water to the area south and east of Lake Helena. The water is raised from the lake to the higher levels by a series of large electrically driven centrifugal pumps. The efficiency rate between water pumped and that delivered to the farmers is moderately high; at times only 20 to 25 percent of the water pumped is lost through canal seepage. Information received from the State Engineer's Office at Helena indicates that an even smaller loss of water through canal seepage occurs in the southern unit where the canals are in fine clay materials. Approximately 10,000 acres of farm land are irrigated by the two units. Since the recent fulfillment and termination of the long-term contract by the Montana Reservoir and Irrigation Co. the project has been operated by the Montana State Water Conservation Board. According to present plans, the Bureau of Reclamation will supply irrigation water to approximately 10,000 acres of now unusable land in the Helena Valley and will furnish supplementary water to about 5,000 acres more by pumping from the reservoir to be created by the proposed Canyon Ferry Dam on the Missouri River 15 miles east of Helena.

Mining

The chief minerals mined in the Helena district are gold, silver and lead and a small amount of copper. The discovery of placer gold in Last Chance Gulch began a rich mining industry in this region. Soon afterward lode gold was found and mined in the mountains to the south, mainly from the rich Whitlatch-Union gold vein. The Last Chance placer deposit yielded about $16,000,000 worth of gold, most of it before 1868 (Knopf, 1913, p. 15). The total value of ores mined in the area south of Helena before 1928 amounted to nearly $130,000,000 (Pardee and Schrader, 1933, p. 185). The estimated value of gold and silver produced from mines in the Scratchgravel Hills was $1,000,000. These mines closed shortly after World War I, but placer mining has been continued intermittently in the auriferous deposits of Prickly Pear and Silver Creeks and in Holmes Gulch.

In 1935 placer mining in this area was revived on a large scale with mining equipment of modern design. During the latter part of that year, Porter Brothers Mining Co. began dredging the gravels at the lower end of Last Chance Gulch. From August 1943 to July 1945 the dredge was idle because of the war, but has been in constant operation since. Fine gold produced from 1935 to 1945 is valued at $2,500,000 (Lyden, 1948, pp. 56-57). Eldorado and French Bars along the Missouri have also been dredged for gold in recent years. These gravels have also yielded many sapphires, which were used chiefly for precision instruments during World War II. Small deposits of copper ore occur in the area north of the Spokane Hills.

Many smelters were erected during the early mining period, but only the smelter and reduction plants at East Helena are now in operation. Smelting and refining are still one of the largest industries of the Helena Valley. The American Smelting and Refining Company is principally a lead smelter and the Anaconda Company is a zinc recovery plant. Ores of both local and regional origins are processed.

Transportation

The Helena Valley is served by branch lines of both the Northern Pacific and Great Northern Railways.

U. S. Highway 10N crosses this area, leading south to Three Forks and west to Missoula. U. S. Highway 91 leads north to Great Falls and south to Butte. Both roads are hard-surfaced and are used by a large number of tourists in the summer.

GEOLOGY

Stratigraphy

The oldest rocks of the region consist of limestone and shale beds of the Belt series of pre-Cambrian age. Of the eight formations recognized by Walcott (1899, p. 204) only the upper five are present in the Helena Valley. In ascending order, they are the Greyson shale, Spokane shale, Empire shale, Helena limestone, and Marsh shale, in places measuring 3,300 feet in thickness, of which 2,400 feet is Helena limestone. These five formations were mapped as a unit for this report. (See pl. 1.)

Paleozoic rocks constitute the main mass of folded sedimentary rocks south of Helena and consist chiefly of limestone, with some interbedded shale and quartzite. The Flathead quartzite of Middle Cambrian age, the oldest Paleozoic formation, rests unconformably upon the Marsh shale in most places. It is a vitreous coarse-grained light- to reddish-brown quartzite characteristically forming low ridges in the southern part of this region. The Wolsey shale, Meagher limestone, Park shale, Pilgrim limestone and Dry Creek shale, all of Cambrian age, lie above the Flathead quartzite and crop out in this area. The total Cambrian section is nearly 2,000 feet thick.

No recognizable rocks of Ordovician or Silurian age are present in this region. The Jefferson limestone of Upper Devonian age, which lies disconformably upon the Dry Creek shale, is about 240 feet thick at Helena, and is composed chiefly of dark granular limestone mottled with light-colored patches. The Three Forks shale, also of Upper Devonian age, overlies the Jefferson limestone. It is 270 feet thick and consists of alternate beds of black shale and limestone. Overlying the Three Forks shale is the Madison limestone of Mississippian age. The lower part of the formation is locally characterized by a bluish thin-bedded limestone containing small black crystals of tourmaline, and the upper part of the formation has been metamorphosed into marble in some parts of the area. The Madison limestone has a total thickness of 2,600 feet. The Quadrant quartzite forms the upper part of the Paleozoic section. It is predominantly a light-colored quartzite in the Helena area with a small amount of interbedded limestone, and its average thickness is 300 feet.

The rocks between the Quadrant quartzite and the intrusive granitic mass in the southern part of the area are considered Cretaceous in age by Knopf (1913, p. 93) because of their stratigraphic position, although possibly rocks of Jurassic age may be included. They are chiefly metamorphosed shale and sandstone.

A large part of the floor of the Helena Valley is underlain by Tertiary "lake-bed" deposits. These deposits are composed mainly of light-colored clay with interbedded sand and gravel, the texture and character of these beds varying in different parts of the valley. Along the gentle valley slope between Helena and East Helena they consist chiefly of fine-grained volcanic ash which has weathered to indurated tuff. An exposure of these beds can be seen in a deep road cut half a mile west of East Helena along U. S. Highway 10.

About a mile west of Hauser Lake in the SE$\frac{1}{4}$ sec. 28, T. 11 N., R. 2 W., a thick section of these deposits is exposed in a ravine. (See fig. 5, A.) The lower part of the section consists chiefly of olive-gray clay in which are embedded light-colored fragments of quartz and feldspar. The clay becomes light gray upon exposure to weathering. It appears to contain a considerable amount of bentonite, which expands when wet and causes the weathered surface to develop numerous small cracks and fractures. Small crystals of selenite are present on the weathered surface; these probably are the result of chemical interaction between the small amount of lime and the sulfides present in the material. Vertebrate fossils of Oligocene age were collected from these beds, but a detailed study of them has not been made.

Above the bentonitic clay are reddish-brown shale and olive-gray, yellow-streaked clay. The material of these beds appears to be chiefly fine- to medium-grained volcanic ash containing various amounts of iron oxides.

In the upper part of this section is a prominent siliceous, glassy layer 6 to 8 inches in thickness; in places it has been altered to lavender-gray opal which fractures very easily. Above this are many thin layers of lignite interbedded with dark-brown shale and gray clay. The lignite is light brown where weathered but much darker when freshly exposed. The lignite beds have a maximum thickness of 8 inches and are protected in many places by a thin overlying layer of indurated siliceous volcanic ash.

In this exposure the beds dip southeastward as a result of crustal movements during late Tertiary time. Lithologically these beds resemble the "Toston beds" (Pardee, 1925, pp. 22, 23) exposed in the southern part of Townsend Valley, northeast of Toston, and to other Oligocene deposits in the northern part of the valley. However, the coal deposits of the "Toston beds" are thicker and are of subbituminous rank.

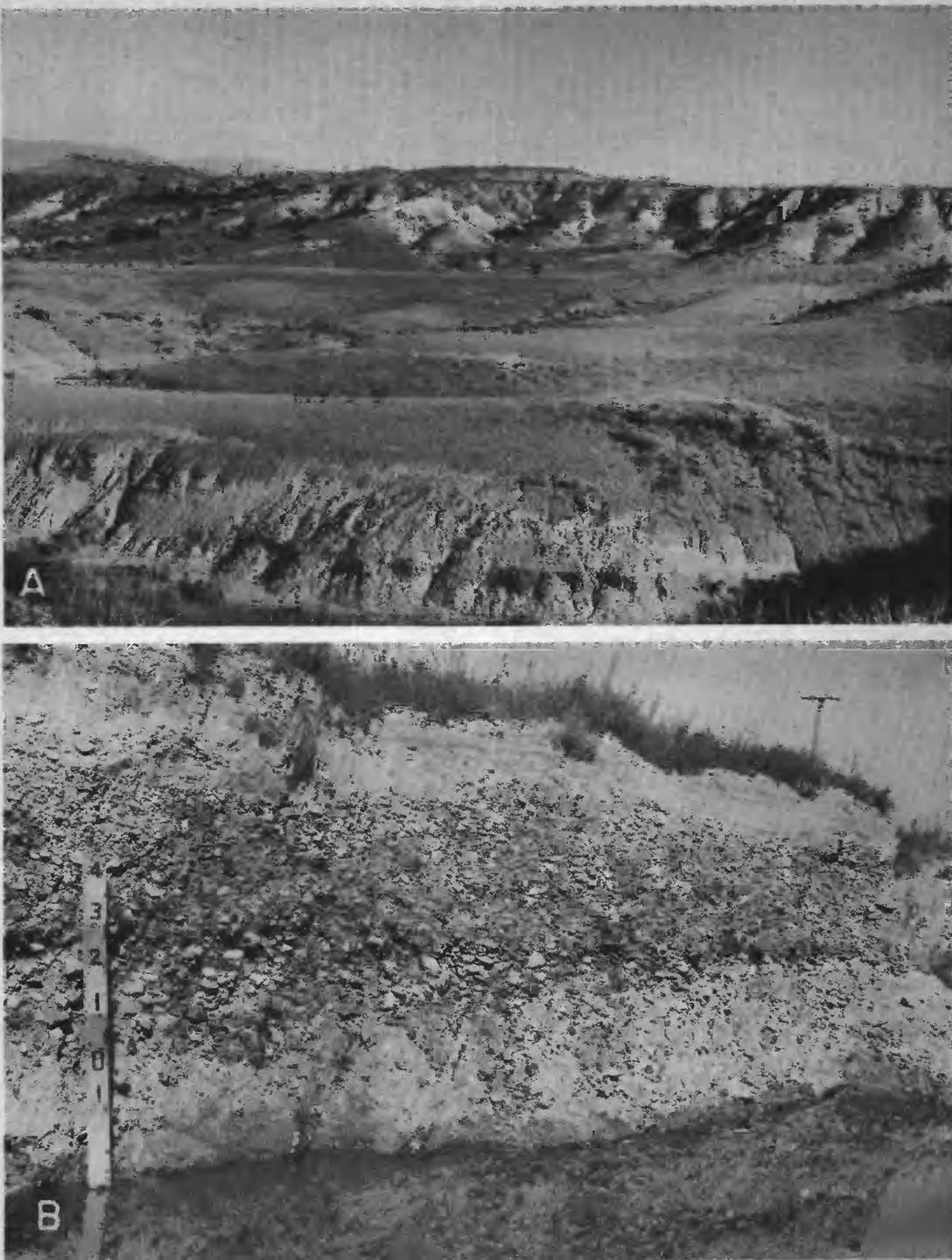


Figure 5.--A, Tertiary "lake beds" of Oligocene age. The "lake beds" are composed largely of bentonitic clay in this exposure. B, Auriferous gravels below Last Chance Gulch. The gravel is composed of rounded fragments of quartzite, quartz monzonite, shale, and limestone interbedded with clay. The water is part of a maintained lake level needed to float the gold dredge and does not represent ground-water conditions. Photographs by H. W. Lorenz.

Knopf (1913, p. 94) regarded the auriferous gravels as Pliocene in age on the basis of mammoth and other vertebrate fossils reportedly found in these deposits near Montana City and Helena. Because the conditions under which these fossils were found are not known, Pardee and Schrader (1933, p. 15) suggested that originally they may have been buried in the Tertiary deposits which locally form the bedrock of the placer deposits. The topographic position of these deposits on the higher parts of the valley floor is similar to that of probable Pleistocene gravel deposits in the Townsend Valley (Pardee, 1925, p. 35). In Last Chance Gulch the deposits are composed mainly of water-worn quartzite and quartz-monzonite boulders and cobbles interbedded with sand and gravel. (See fig. 5, B.) In the deposits at Montana City, cobbles of andesite are more numerous.

Much of the floor of Helena Valley is mantled by alluvium of Pleistocene to Recent age. The alluvium consists of broad, gently sloping alluvial fans formed by Prickly Pear and Tenmile Creeks and other streams and they contain fragments of rocks present in the drainage basin of the stream that formed the deposit. These alluvial deposits are coarse-grained and thicker near the mountains but are finer-textured and thinner in lower parts of the valley. They were deposited over folded and eroded Tertiary "lake beds" and older rocks. There appears to be no stratigraphic break between these deposits and the auriferous gravels described above.

The thickness of the alluvium ranges from a feather edge to 100 feet and local drillers report that there is a considerable range in thickness within short distances. Well 10-4-23ba, at the Montana Club near the edge of the Valley along Tenmile Creek, passed through 100 feet of unconsolidated material before reaching the underlying Tertiary "lake beds," but the driller was unable to determine precisely the contact between the alluvium and the Tertiary beds.

Geologic History

The earliest geologic history of this region is recorded in the thick section of pre-Cambrian rocks known as the Belt series. After these sediments were deposited, the area was subjected to diastrophism and was reduced by erosion to low relief. The Flathead quartzite of Middle Cambrian time, basal formation of the Paleozoic section, was deposited on the truncated beds of the Belt series. Conditions of deposition changed during Cambrian time in such ways that shale mud was deposited alternately with lime. No general stratigraphic breaks between these Cambrian formations are recognized; they are separated chiefly on the basis of lithologic differences.

No record of geologic events in this area during Ordovician and Silurian times is preserved; only a disconformity marks the long gap in geologic history. The Jefferson limestone of Devonian age was deposited after this long period of time, and the Three Forks shale was deposited conformably on the Jefferson limestone. In Mississippian time the thick Madison limestone was deposited. Conditions of deposition appear to have remained fairly uniform for a long period to have permitted the deposition of about 2,600 feet of limestone of more or less uniform lithology. At the end of Mississippian time conditions changed abruptly and sand was deposited in this area to form the Quadrant quartzite of Pennsylvanian age. Apparently these were the first coarse clastic materials deposited in this area since the coarse sands forming the Flathead quartzite were deposited in Cambrian time.

After the deposition of materials now forming the Quadrant quartzite there is a long gap in the recorded geologic history of the immediate region. About 2 miles south of Helena, however, there is a thick section of metamorphosed shale, sandstone, and limestone which has been referred, by previous workers, to the Cretaceous period. The metamorphosed condition of these beds at present prevents a more certain age determination, but these beds may include rocks of several periods. They are bordered by the intrusive late Cretaceous or early Tertiary Boulder batholith that probably was the major cause of the metamorphism.

Shortly before or during the intrusion of the Boulder batholith this region was subjected to major diastrophism. The sedimentary rocks were folded and faulted along northwest trending axes, resulting in the distinct grain to the topography developed later by erosion. The Boulder batholith lies largely south and west of the Helena Valley but several stocks and dikes connected with this large intrusive mass are within the area covered by this report. The mineralization of the region is closely related to this intrusion.

A long period of erosion followed this major diastrophism and again the area was reduced to nearly mature topography.

In Tertiary time crustal movements again caused warping and faulting and the formation of broad intermontane basins in which were deposited great thicknesses of volcanic ash with interbedded sand and gravel. Folding and faulting, which continued through late Tertiary time, warped the basin sediments ("lake beds") and formed the present mountains. Probably, the present cycle of erosion began in Pliocene time.

Igneous Rocks

The coarse-grained quartz monzonite of late Cretaceous or early Tertiary age, which makes up a large part of the high rugged mountains south of Helena, is the northern extension of the Boulder batholith. According to Knopf (1913, p. 97), a part of this granitic mass extends northward under the sedimentary Paleozoic and pre-Cambrian rocks and has been exposed by erosion in several places. Among the prominent granitic exposures are those south of Broadwater and those in the Scratchgravel Hills to the north.

Near Montana City extrusive rocks, probably of Tertiary age, are exposed. These consist of volcanic breccia and some rhyolite flows, and probably are closely related to the volcanic-ash deposits that form the major part of the "lake beds."

Structure

Knopf (1913, p. 97) has described the Helena Valley as follows:

> The Helena district lies on the south side of a great dome-shaped uplift some 25 miles in diameter, whose center lies north of the Scratchgravel Hills. This dome extends from the mountain ridge west of Marysville eastward to York, on the west side of the Belt Mountains. The city of Helena and the mountains south of it lie on the south side of the dome. Although the general structure is that of a simple anticline, the dome is not perfectly regular but shows secondary crumpling. Within the Helena district the dome shape is well shown. Subsequent to the folding which formed this great dome, the granitic rocks broke through and faulted the south flank of this anticline.
>
> Broadly considered, Prickly Pear Valley (here called Helena Valley) is a basin deeply eroded in the dome-shaped uplift noted above, an arch whose summit has been worn away and cut down into the soft shales of the Belt series that form its nucleus, so that the sheets of white limestone and other rocks that once covered it are now only seen on Mount Helena and the hills south of the city, in the Spokane Hills to the east, and the flanks of the Belt mountains north of the district. This broad arch involved the entire sedimentary series of the region from Algonkian to Cretaceous. The simplicity of structure has been, however, modified by the granite intrusion and faulting.

Faults and Earthquakes

The numerous faults in the Helena area appear to be associated with adjustments of the rocks resulting from granitic intrusion. These faults cut across the sedimentary rocks south and east of Helena and are nearly normal to the strike. The shear zones are less resistant to erosion and stream valleys have been cut along several of them.

A conspicuous fault extends along the city's west side and up Oro Fino Gulch to the south (Knopf, 1913, p. 98). The upthrow is on the east with 290 feet of vertical displacement, and 500 feet of offset. A long northeast-southwest fault, with the upthrow on the west side, passes through the east side of Helena. Two other great faults lie southeast of Helena: the Mount Ascension fault, which has an offset of 850 feet, and half a mile to the east a second fault, of nearly the same magnitude. The two faults bound a wedge block or graben that dropped 765 feet, forming a low structural trough that extends from Mount Ascension northward into the valley. (See fig. 3, B.) It is believed that there are many other faults covered by the mantle of Tertiary and Quaternary sediments. Movement along these faults is believed by some to be the cause of the numerous earthquakes in the Helena Valley during recent years.

The Helena Valley is in an active seismic area. Between 1903 and 1935 more than 60 minor earthquakes were recorded. Beginning on October 3, 1935, more than 1,200 earthquakes were recorded in 80 days. The first destructive shock occurred October 12. It lasted 7 seconds and was followed by 60 minor tremors over the next 6 days (Scott, 1936). Then the most violent of the earthquakes occurred: it had an intensity rating of 9 (Rossi-Forel scale) and lasted 30 to 40 seconds. Thirteen days later, October 31, after 505 aftershocks, Helena experienced another severe quake which resulted in additional property damage, loss of life, and suffering. Two persons lost their lives on each day of the two major shocks. Property damage estimated at $3,500,000 was caused at Helena by the October 18 shock, damage being greatest to buildings on alluvial fill. Numerous minor tremors have since been felt in this area, two during the 1948 field season.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

The thick stratigraphic section exposed in the Helena area contains a number of water-bearing beds that yield fairly prolifically, but some of the strata are comparatively dense and yield water only from open fissures or solution channels. Generalized data on the lithology and water-bearing possibilities of the complete stratigraphic section are presented in the columnar section on the following page (table 3).

Pre-Tertiary Rocks

The older sedimentary rocks, pre-Cambrian to Cretaceous in age, in general have been metamorphosed by igneous intrusions. Some shale beds have been changed to argillite and some of the limestone has been recrystallized to fine-grained marble. The rocks are not very porous, but deformation has caused considerable fracturing in some formations, and these fractures contain water. Solution of the fracture walls has somewhat increased the capacity of the ground-water reservoir.

Table 3.--Sedimentary rocks of the Helena Valley and their water-bearing properties

Age		Formation	Thickness (feet)	Lithologic character	Water supply
Quaternary		Alluvium		Sand and gravel deposited in broad coalescing fans along the southern and western slopes of the valley, thinning and grading into finer materials toward the central part of the valley.	Yields adequate supplies for domestic and stock purposes except in areas where very thin and fine-grained; in some places yields are sufficient for irrigation. Water is highly mineralized in places.
Tertiary		Auriferous gravels		Local deposits of locally derived boulders, cobbles, gravel, and sand; composed mainly of andesite, vein quartz, and granite fragments near Montana City; of quartz monzonite and limestone fragments in Last Chance Gulch.	Yield moderate supply of water to a few wells.
Tertiary		"Lake beds"		Mainly fine-grained light-colored clay of volcanic origin interbedded with sand and gravel and some lignite; indurated tuffs present in south part of area between Helena and East Helena. Broad exposures in southeast part of valley; mantled by alluvium elsewhere.	Lower beds in central part of valley contain water under artesian pressure and will yield large supplies to wells. Yields sufficient for domestic and stock use in areas where beds are composed of clay and interbedded sand. Indurated tuffs yield only very small quantities of water to wells.
Cretaceous				Originally sandstone, and shale but later altered by intense metamorphism.	Not water bearing.
Carboniferous	Pennsylvanian	Quadrant quartzite	150-190	Quartzite, sandstone, and some interbedded white limestone; altered by contact metamorphism.	Yields small supplies, but not important as source of water.
Carboniferous	Mississippian	Madison limestone	2,600	The upper part is very massive light-colored limestone that has been altered to white marble in the vicinity of Helena. The middle part consists of light- to dark-gray limestone beds separated by shale partings; much of the limestone is cherty. The lower part is thin-bedded impure blue limestone containing crinoid stems and other fossil fragments. A persistent bed near the base contains needles of black tourmaline.	Not an important source of water in this aree.
Devonian	Upper	Three Forks shale	270-282	Composed essentially of black shale and beds of limestone. A 15-foot bed of black carbonaceous shale at the top of the formation rests on light-colored calcareous shale that grades downward into earthy shale with interbedded quartzite.	Generally either not water bearing or productive of only meager supplies.
Devonian	Upper	Jefferson limestone	243	Dark-colored limestone with some light-colored beds. The dark beds have a granular structure, are commonly mottled by light-colored patches of metamorphosed corals, and produce a fetid odor when struck with a hammer.	Yields water to small springs from joints and solution passages.

Table 3.--Sedimentary rocks of the Helena Valley and their water-bearing properties--Continued

Age		Formation	Thickness (feet)	Lithologic character	Water supply
Cambrian	Upper	Dry Creek shale	175-490	Light-colored thin-bedded limestone with crinkled bands of jasper; in places the rock is composed of limestone pebbles held in a glauconitic matrix. Basal 40 feet consist of brownish-yellow, red, and pink shale and calcareous sandstone.	Yields very little water.
		Pilgrim limestone	317	Massive blue to dark-gray limestone. The upper bed is a light-gray limestone. The lowest bed is a dark crystalline rock mottled with yellow and dark-gray spots.	Yields water for small springs from joints, bedding planes, and solution channels.
	Middle	Park shale	150	Earthy and micaceous dark-gray to green or purple shales, not well indurated.	Not water bearing.
		Meagher limestone	400	Light-gray to blue limestone and shale. Thin-bedded fossiliferous limestone at top grades downward into massive limestone that becomes shaly near the base.	Not water bearing.
		Wolsey shale	420	Micaceous and calcareous gray to green shale with small concretions of limestone.	Not water bearing.
		Flathead quartzite	300	Hard fine-grained massive quartzite to gray and yellow sandstone. In upper part are thin beds of gray, brown, and green micaceous shale. The lowest stratum is pebbly in places, grading into a conglomerate at the base. The pebbles in the basal beds consist chiefly of material derived from the underlying rocks.	Yields water to small springs from numerous cracks and fractures.
Pre-Cambrian	Belt series	Marsh shale	75-300	Red and yellowish-green shale and thin-bedded sandstone.	May yield small supplies locally.
		Helena limestone	2,400	Impure blue to gray noncrystalline limestone occurring in beds 1 to 6 feet thick separated by thin bands of shale. The limestone is blue on fresh fracture but has a characteristic buff velvety-appearing surface on weathering.	Yields small supplies to shallow wells and springs.
		Empire shale	600	Shale and greenish-gray slate with characteristic purple spots.	Yields small supplies to springs.
		Spokane shale	1,500	Massive and thin-bedded siliceous shale, commonly deep-red.	Yields small supplies to numerous springs.
		Greyson shale	3,000	Shale, dark-gray, weathering to rusty brown. Dark-gray shale with interbedded quartzitic layers near middle of formation is underlain by a considerable thickness of fissile light-gray to pale-buff shale.	Not water bearing.

Springs

In the mountains south of Helena and in the Spokane Hills to the east, springs issuing from these older rocks maintain perennial flow in some of the small streams. In many instances the streams furnish both domestic and stock supplies to farmers and ranchers. Both Helena and East Helena obtain municipal supplies from these spring-fed streams.

Numerous springs issue from the Empire shale along a small tributary of Prickly Pear Creek near the eastern edge of sec. 27, T. 10 N., R. 3 W. These springs furnish the water supply for several farmers living nearby who have developed the springs and pump the water to storage tanks for both domestic and stock use.

On the west slopes of the Spokane Hills, numerous small springs issue from the Spokane shale where it is exposed along the gulches cut by tributaries of Spokane Creek. These springs have considerable importance because they are the chief source of domestic and stock water for ranchers in the area. The supply is limited and in no instance is it sufficient for irrigation.

A few small springs are present in the Scratchgravel Hills but are not large enough to maintain perennial streams.

The Helena Hot Springs, 1 mile southwest of Broadwater, a short distance west of U. S. Highway 10, have a flow of about 30 gallons per minute (Stearns, Stearns, and Waring, 1937, p. 152). The water, which has a temperature between 122° and 141° F., flows from several small fissures or openings in the coarse-grained quartz monzonite. During the prosperous mining days, this hot spring water was utilized by a popular health resort, the Broadwater Natatorium. At the present time a small amount of the water is used to heat one of the homes near the spring and plans have been made to rebuild and revive the health resort.

Wells

Few wells have been drilled into the pre-Tertiary rocks. The small yield from most of these formations is unimportant but a few of the limestone formations may yield large quantities of water from fractures and solution passages. A shallow well (10-3-30ca1), drilled in 1944 for the Dairyland Confectionary, is reported to have penetrated 152 feet of Helena limestone and produces 25 gallons per minute of good-quality water from a sandstone lens. Another well (10-3-30ca2), reported to have been drilled in 1941 for the Eddy Bakery, passed through nearly 127 feet of the Marsh shale. It was reported to have yielded 15 gallons per minute when first drilled, but has gone dry in recent years.

During the active mining days ground water was reported at a depth of 120 feet below the surface of the granitic mass of the Scratchgravel Hills

(Pardee and Schrader, 1933, p. 35). Rather large quantities of water were pumped from several mine shafts that penetrated more than 400 feet of this rock. The granite, however, is not considered a good source of water.

Tertiary "Lake Beds"

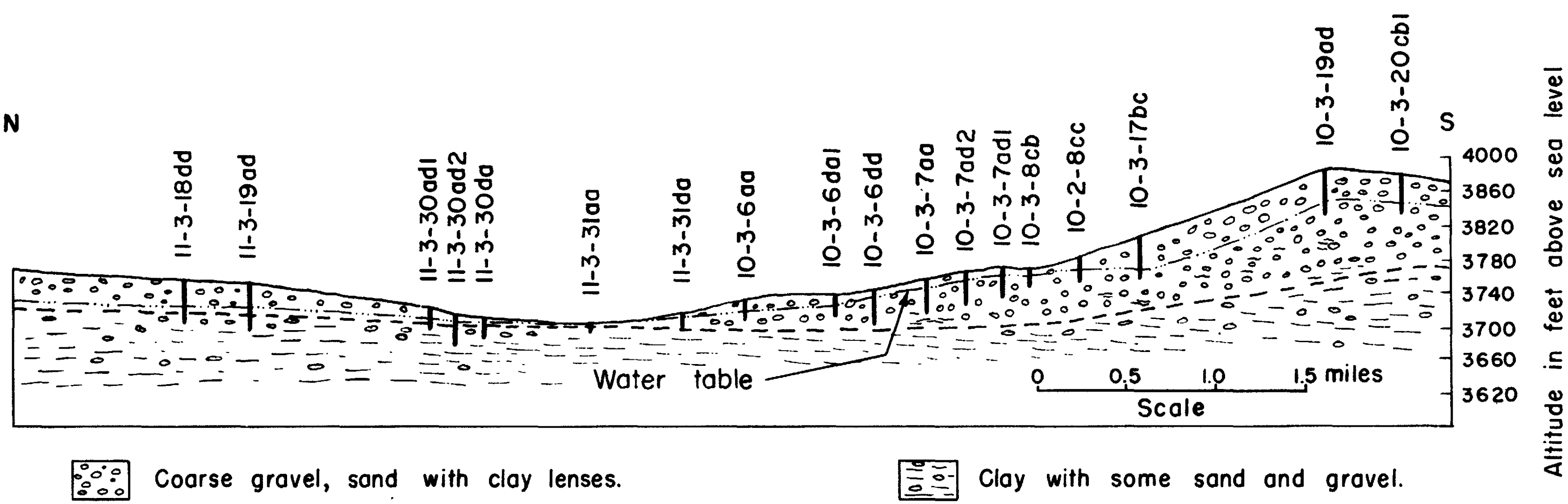
The "lake beds" underlie the entire Helena Valley and form the floor of the southeastern part of the valley. They are important not only as a source of water but because of their relation to the now waterlogged areas in the valley.

Several wells in the lower part of the valley are definitely known to obtain water from the Tertiary "lake beds," but as the ordinary driller's log does not distinguish between the "lake beds" material and the overlying alluvial deposits, which they resemble in this part of the valley, it is not always possible to determine whether a well obtains its water from one or the other or from both. Test holes drilled near the southern edge of Lake Helena indicate that the "lake beds" are fairly close to the surface near the center of the valley. (See fig. 6.)

One of the wells that is most likely drawing water from these "lake beds" is 11-3-21cd2 at the Masonic Home. This well, the deepest known near the center of the valley, obtained a flow of about 125 gallons per minute from sand and gravel interbedded with clay. The driller's log of this well is presented below.

[Driller's log of well 11-3-21cd2, obtained from Masonic Home]

	Depth (feet)
Sand-gravel	0 - 50
Sand-clay	50 - 108
Gravel strata; strong flow	108 - 114
Sand-clay	114 - 182
Gravel; strong flow	182 - 185
Clay	185 - 272
Fine sand; small flow	272 - 273
Very sticky clay; would make water for drilling	273 - 407
?	407 - 408
Sand-clay	408 - 414
Small flow	414 - 416
Clay	416 - 426
Sand; strong flow	426 - 430
Clay; small flow	430 - 450
Clay; small flow	450 - 454
Clay	454 - 460



Coarse gravel, sand with clay lenses.

Clay with some sand and gravel.

Quaternary and Tertiary undifferentiated; inferred boundary indicated by dashed line.

Figure 6. — North-south section across the Helena Valley north of Helena, Montana.

Well 11-3-34cc, at the Montana State Vocational School, was drilled to a depth of 340 feet and obtained a flow of about 25 gallons per minute.

Well 10-4-23ba, at the Montana Club, was drilled to a depth of 510 feet. It was started in alluvial gravel and was reported by the driller to have penetrated about 400 feet of "lake beds." However, only a small yield of water was obtained. The city of Helena has put down a number of test holes into the "lake beds" but has not obtained much water.

Several wells drilled into the "lake beds" in the hill lands in the east part of the valley yield supplies of water adequate for domestic and limited stock needs. The water is under hydrostatic pressure but must be pumped.

Probably some of the irrigation wells, used as stand-by supplies when water is not available in the ditches, draw water from these beds. Some of these wells are in places where the alluvial mantle is believed to be relatively thin and fairly fine textured.

Quaternary Deposits

Many wells in the Helena Valley obtain adequate supplies of water for domestic and stock needs from the Quaternary deposits that mantle the greater part of the floor of the Helena Valley. As noted in the discussion of the water-bearing properties of the "lake beds," the difficulty of recognizing the contact between the Quaternary and Tertiary deposits in well samples prevents the accurate determination of the source of water in many of the wells, but some of the irrigation wells are known to obtain water exclusively from these deposits. On the alluvial fan of Prickly Pear, north of East Helena, large pits are dug in the unconsolidated sand and gravel by power shovels. These pits, as much as 100 feet across and 40 to 50 feet deep, serve as stand-by irrigation wells. During the summer of 1948 none of these pits was being pumped and no determinations of yield could be made. In other areas irrigation wells have been dug by hand and are supported by wooden or masonry cribbing. According to reports most of these wells have capacities of 150 to 300 gallons per minute.

SOURCE OF GROUND-WATER RECHARGE

Tertiary "Lake Beds"

Tertiary "lake beds" are exposed on the flanks of the highlands that border the valley on the south and east. Since their deposition the "lake beds" have been deformed by differential subsidence and, in general, they dip toward the center of the valley. Water, derived from precipitation and streams flowing over the permeable beds, moves down the dip where it becomes confined under less permeable beds. Wells drilled through these less permeable beds encounter the water under artesian pressure in the sand and gravel zones. In some wells in the lower part of the valley the water is under sufficient artesian head to flow at the surface, as do the wells at the Masonic Home (11-3-21cd2) and at the Montana State Vocational School (11-3-34cc). In higher parts of the valley the water rises within the casing above the level at which it was encountered but it will not flow at the surface. Some water may enter the permeable beds where they underlie the unconsolidated materials of Quaternary age; in general the hydrostatic pressure in beds obtaining recharge by this means will be less than that in beds exposed higher on the valley edges.

Quaternary Deposits

A study of water-table fluctuations in wells indicates that the principal recharge to the ground-water reservoir contained in the Quaternary unconsolidated materials is derived from irrigation. In nonirrigated areas the water table normally is highest in the spring months, shortly after the accumulated winter snow has melted, and is lowest in late summer. In the Helena Valley much of the winter's snow has melted by early April. The peak flow of Tenmile and Prickly Pear Creeks normally comes in May and June, the months of maximum precipitation but the water level in most wells is lowest in April and is highest at the peak of the irrigation season in August. (See figs. 7, 8, and 9 and table 5, p. 43. Some recharge is derived directly from precipitation and some from influent seepage of streams crossing the valley. A study of the ground-water contour map (pl. 3) indicates that Tenmile Creek is influent throughout most of its course after leaving the mountains. Prickly Pear Creek, however, is effluent in its course below East Helena. This condition results mainly from the fact that much of the water has been diverted for irrigation of the gravelly alluvial fan lying east of the creek. This land is somewhat higher than the shallow channel occupied by the stream.

FLUCTUATIONS OF WATER LEVELS

Monthly measurements were made of the water level in approximately 130 observation wells in the Helena Valley. (See tabulated measurements in table 5, p. 43, and records of wells in table 6, p. 63.) Hydrographs of the measurements in 19 representative wells are shown in figures 7, 8, and 9. The hydrographs reveal that the water-level fluctuations in different parts of the valley display different characteristics.

The water level in the wells in the lower part of the valley shows the least amount of fluctuation, several wells having only 0.5 foot difference between their high and low stages; these wells penetrate fine alluvial materials.

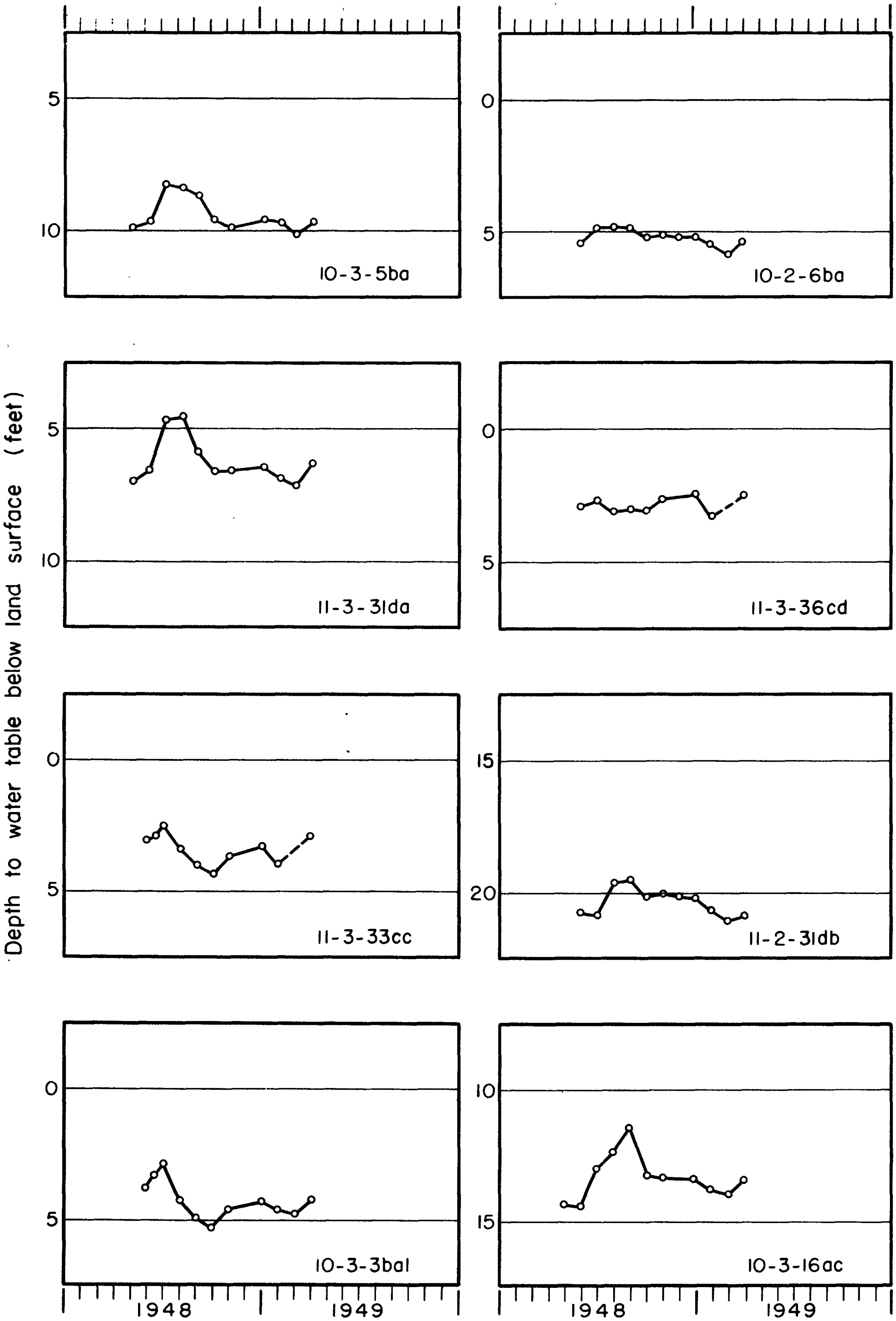


Figure 7.— Hydrographs of shallow observation wells in fine-grained material

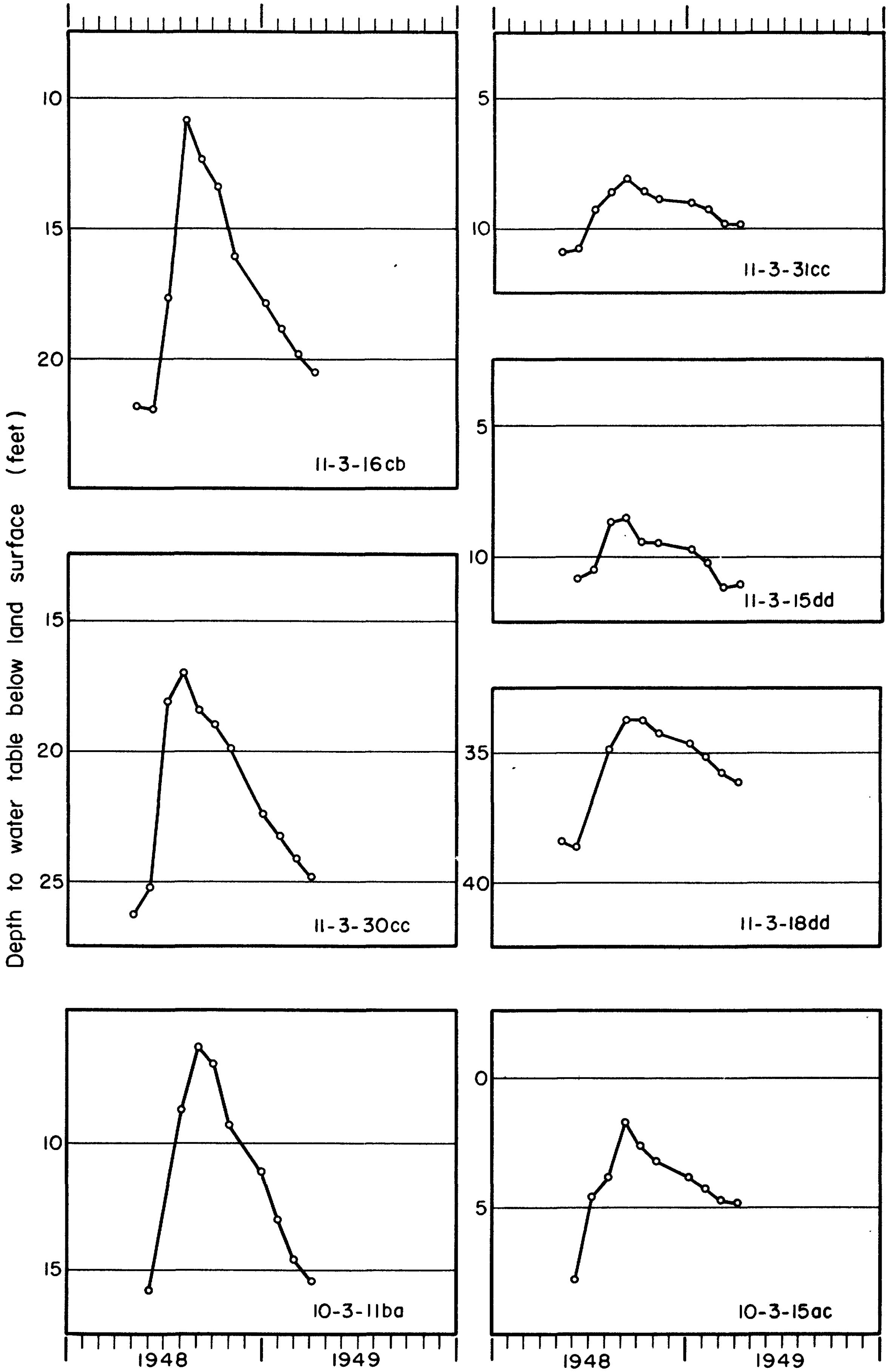


Figure 8.— Hydrographs of shallow observation wells in medium-grained material

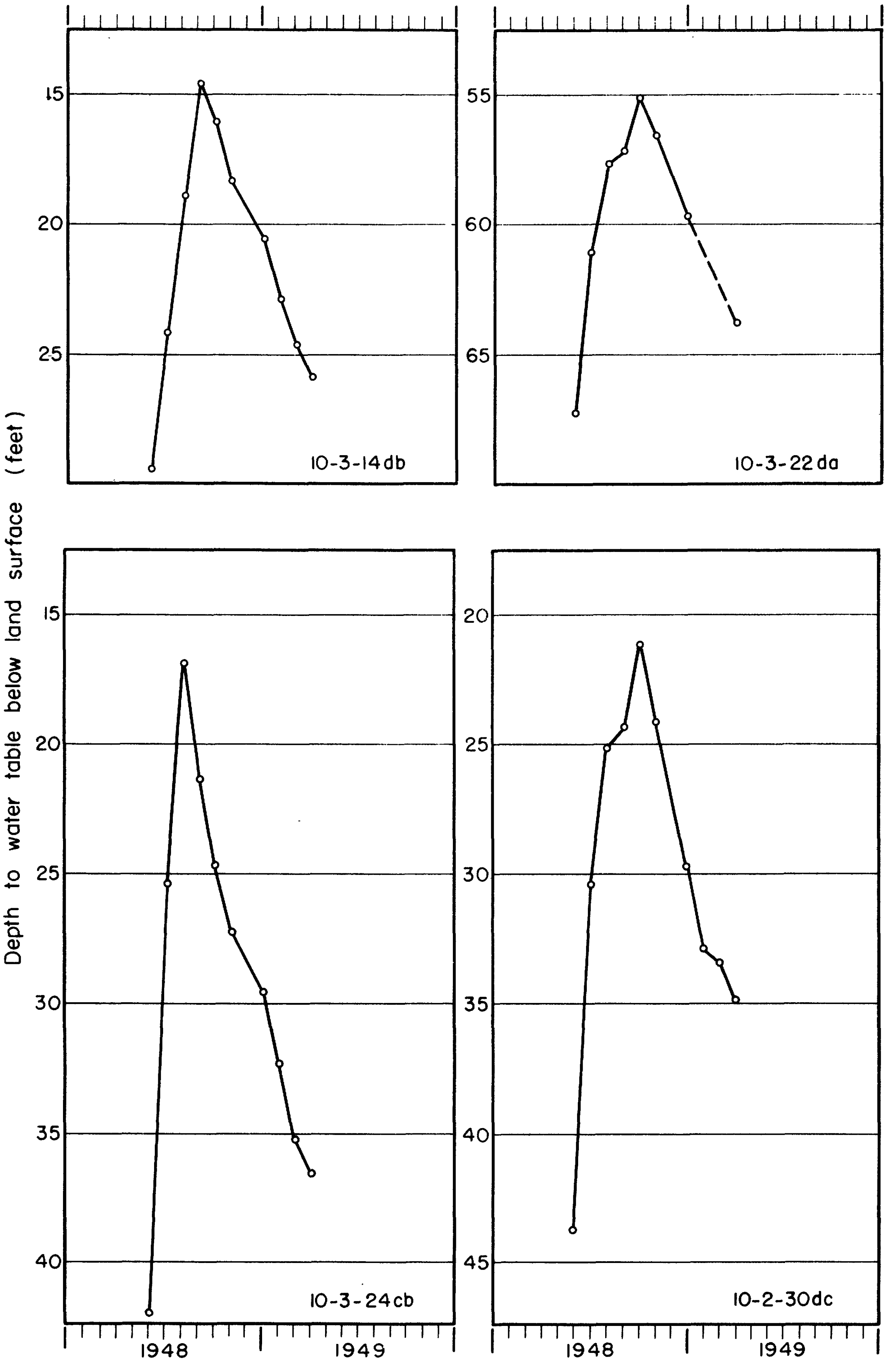


Figure 9.—Hydrographs of shallow observation wells in coarse-grained material

The water level in wells located in the higher, coarser alluvial materials shows the largest amount of fluctuation. A difference of 25.13 feet between high and low water-level readings was recorded in well 10-3-24cb. This well and other wells near Tenmile and Prickly Pear Creek are influenced by seepage from these streams and have their highest water level in June when the streams have their greatest discharge.

In general, the wells in the lower parts of the valley and in the waterlogged lands along Tenmile and Prickly Pear Creeks also have their highest water levels in June. In a narrow belt surrounding the area represented by these wells the water level is higher in July. In the higher parts of the valley the water level in the observation wells reaches its highest stage in August or later in the fall. In most wells the water level is highest during August.

Changes of water level during the June-to-September period in five wells on the south slope of the valley floor are shown in the profile section. (See pl. 2.) The water level in the well at the lower end of the section is highest in June whereas the water level in the well at the upper end is highest in September. The water level in the intermediate wells is highest at some time between June and September.

EFFECTS OF EARTHQUAKES ON GROUND WATER

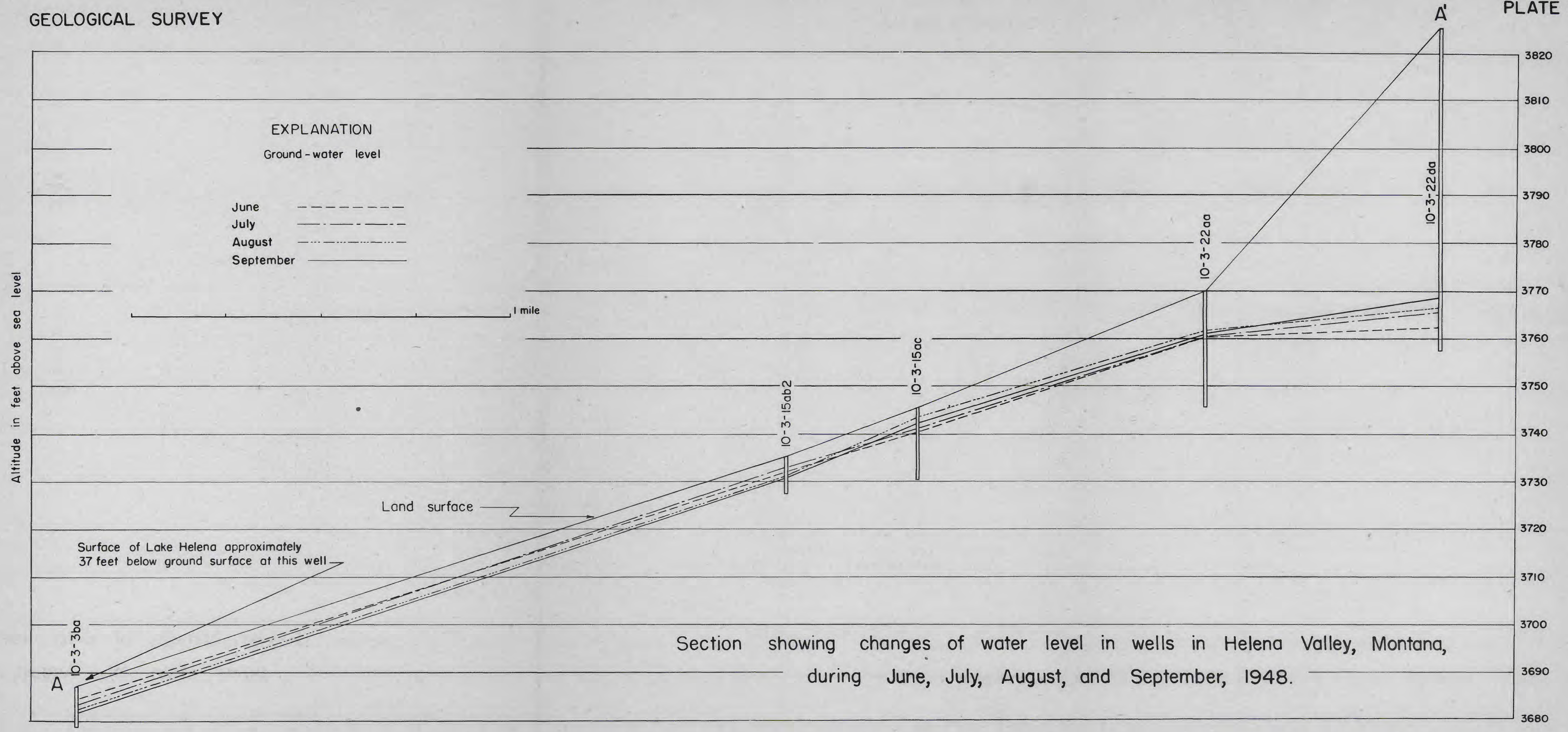
The severe earthquakes of 1935 had noticeable effects on the ground water (Scott, 1936). Many springs and some wells had marked changes in the amount of flow. New springs issued and the flow of others increased; this caused a large increase in the flow of some of the mountain streams. The flow of Prickly Pear Creek increased about one-third within 12 hours after the October 18 shock. Several of the mines in the region reported an increase in ground-water flow.

CHEMICAL QUALITY OF WATER IN THE HELENA VALLEY

By Herbert A. Swenson

Introduction

During September 1948, 17 water samples were collected from wells in the area for chemical analysis. Of this number, 15 were collected from wells in the Quaternary deposits that mantle the greater part of the floor of the valley and 2 were obtained from wells believed to be reaching the underlying



Section showing changes of water level in wells in Helena Valley, Montana, during June, July, August, and September, 1948.

Tertiary "lake beds. Samples of the water in Tenmile and Prickly Pear Creeks and in Lake Helena were analyzed also. The location of sampling points is shown on plate 4.

The study of the quality of the water in the Helena Valley is significant for several reasons. The analyses reveal the present chemical characteristics of the ground waters, and give some indication of the composition of surface waters. The water quality reflects the amounts of soluble materials present in the water-bearing beds. Furthermore, hydrologic interpretation of the chemical data, when correlated with water-table fluctuations in wells, aids in the determination of the principal sources of ground-water recharge. Finally, the use of the water for irrigation or domestic purposes is governed largely by its chemical content.

Mineral Character of the Ground Water

All ground waters sampled in the study are of moderate mineral content: most of them contain less than 300 parts per million of dissolved solids. Well 10-3-3bal, dug 8.2 feet deep and lying in the center of the valley east of Prickly Pear Creek, yields a water that contains 514 parts per million of solids, the maximum concentration found among the samples analyzed. Much of the dissolved material in the waters is calcium bicarbonate and hardness ranges from 90 to 336 parts per million as $CaCO_3$ (calcium carbonate); in more than half of the samples it was less than 200 parts per million. Results of chemical analyses are given in table 4.

Quaternary Deposits

The Quaternary alluvium is an important water-bearing formation and yields waters with an average salinity of 298 parts per million and the following average percentage composition, based on 15 samples analyzed:

Composition in percent of anhydrous residue .

Silica..........	8.9
Iron............	.3
Calcium.........	18.4
Magnesium.......	4.7
Sodium..........	6.7
Potassium.......	.6
Carbonate.......	32.5
Sulfate.........	22.8
Chloride........	3.2
Fluoride........	.2
Nitrate.........	1.7
	100.0

Table 4.--Chemical analyses and related physical measurements of waters in the Helena Valley

[parts per million]

Well number or location	Depth of well (feet)	pH	Specific conductance at 25° C. (micromhos)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Noncarbonate	Percent sodium
Ground Waters																			
10-2-6cc	38.5	8.4	244	19	0.00	28	6.5	14	3.2	86	49	2.4	0.3	0.3	0.00	162	96	25	23
-19cb	45.5	7.0	359	21	.04	44	9.7	17	.4	135	68	2.0	1.5	3.9	.03	254	150	39	20
-30dc1	49	7.1	391	18	.20	52	10	12	3.2	148	67	4.0	.6	1.7	.00	254	171	50	13
10-3-3ba1	8.2	7.9	755	23	.04	100	21	32	2.0	310	146	10	.3	4.1	.08	514	336	82	17
-5ad	56	7.4	366	20	4.4	45	11	12	1.6	176	40	3.0	.4	2.6	.00	232	158	14	14
-6bd	90	7.5	510	22	1.6	69	17	18	.4	265	55	5.0	.8	2.7	.00	332	242	25	14
-15ba2	15.2	7.5	329	27	.00	45	9.3	12	4.4	160	47	.0	.4	2.2	.00	216	151	20	14
-17bc	55.8	8.2	608	23	.10	74	2.5	21	1.6	278	74	21	.2	2.8	.04	386	287	59	14
-20bc1	17	8.0	697	18	.04	65	32	34	.4	217	99	47	1.5	34	.00	448	294	116	20
-22aa2	56.2	8.0	357	23	.04	42	9.7	16	1.2	130	70	3.0	.3	3.9	.06	238	145	38	19
10-4-23ba	510	7.7	356	18	.30	30	9.2	37	1.6	188	34	6.0	.9	.0	.00	232	113	0	41
-24ab	10.4	7.7	618	18	.50	56	31	32	.8	258	78	21	.2	15	.00	388	267	55	21
11-2-19db	50	7.1	261	32	.04	27	5.3	17	.4	130	12	6.0	.5	1.6	.07	184	90	0	29
-30cc	4.2	7.1	259	33	2.0	31	7.3	12	1.6	102	44	4.0	.6	.2	.04	176	108	24	19
11-3-19ad	63	7.4	542	13	.04	57	22	22	1.2	174	102	22	.4	9.2	.01	368	232	89	17
-21cd1	408	7.8	391	18	.60	51	13	12	.8	210	25	5.4	.1	3.1	.07	220	181	9	13
-32db2	8.2	7.2	517	27	.12	67	18	19	1.6	258	55	13	.6	2.4	.00	324	241	29	15
Surface Waters																			
Tenmile Creek	.....	7.8	298	31	.00	37	8.5	16	.4	134	43	2.0	.4	.0	.00	210	127	17	21
Prickly Pear Creek	.....	7.4	333	21	.03	41	9.0	13	1.2	101	80	3.0	.4	.9	.04	226	140	57	17
Lake Helena	.....	7.7	482	26	.02	58	16	23	2.0	208	65	12	.5	2.1	.00	302	210	39	19

The composition of waters in the Quaternary alluvium is also shown graphically in figure 10 where principal constituents are plotted in equivalents per million. Diagrams for waters of maximum and minimum concentrations are shown as well as the analysis of the average of 15 waters in the alluvium. It is seen that calcium and bicarbonate characterize these waters, although some sulfate is present.

The moderate amounts of solids in solution indicate that here the valley fill is derived largely from rock materials containing only moderate amounts of soluble constituents. For example, the water in well 10-3-6bd, sunk 90 feet into the valley alluvium, contains only 332 parts per million of dissolved solids, indicating that the sands and gravels apparently contain relatively little soluble material. Furthermore, because the material is unconsolidated, water moves through the sands and gravels with comparative rapidity, affording little opportunity for solution of the rock materials.

Tertiary "Lake Beds"

Two wells, 10-4-23ba and 11-3-21cd1 (see table 4), are thought to be tapping the Tertiary beds. Analyses of waters from these wells show little difference in mineral character from waters in the Quaternary deposits. As it is difficult in many places to recognize the contact between the Quaternary and Tertiary deposits, discussion of the "lake bed" (?) waters is limited to presentation of the basic data. Graphical expression of the analyses for two waters probably of "lake-bed" origin is shown in figure 10.

Mineral Character of the Surface Water

Single analyses of Prickly Pear and Tenmile Creek waters and Lake Helena water are shown in table 4 and graphically in figure 10. Although spot samples of surface waters are seldom reliable guides to the average composition of the waters, the analyses of the creek waters are probably typical of low-flow conditions, whereas values for the Lake Helena water may be fairly representative. The analysis of the Tenmile Creek water showing 210 parts per million dissolved solids reflects low-water stage, at which time the maximum concentration is generally found. Some minor recharge to the ground-water reservoir is the result of influent seepage from Tenmile Creek.

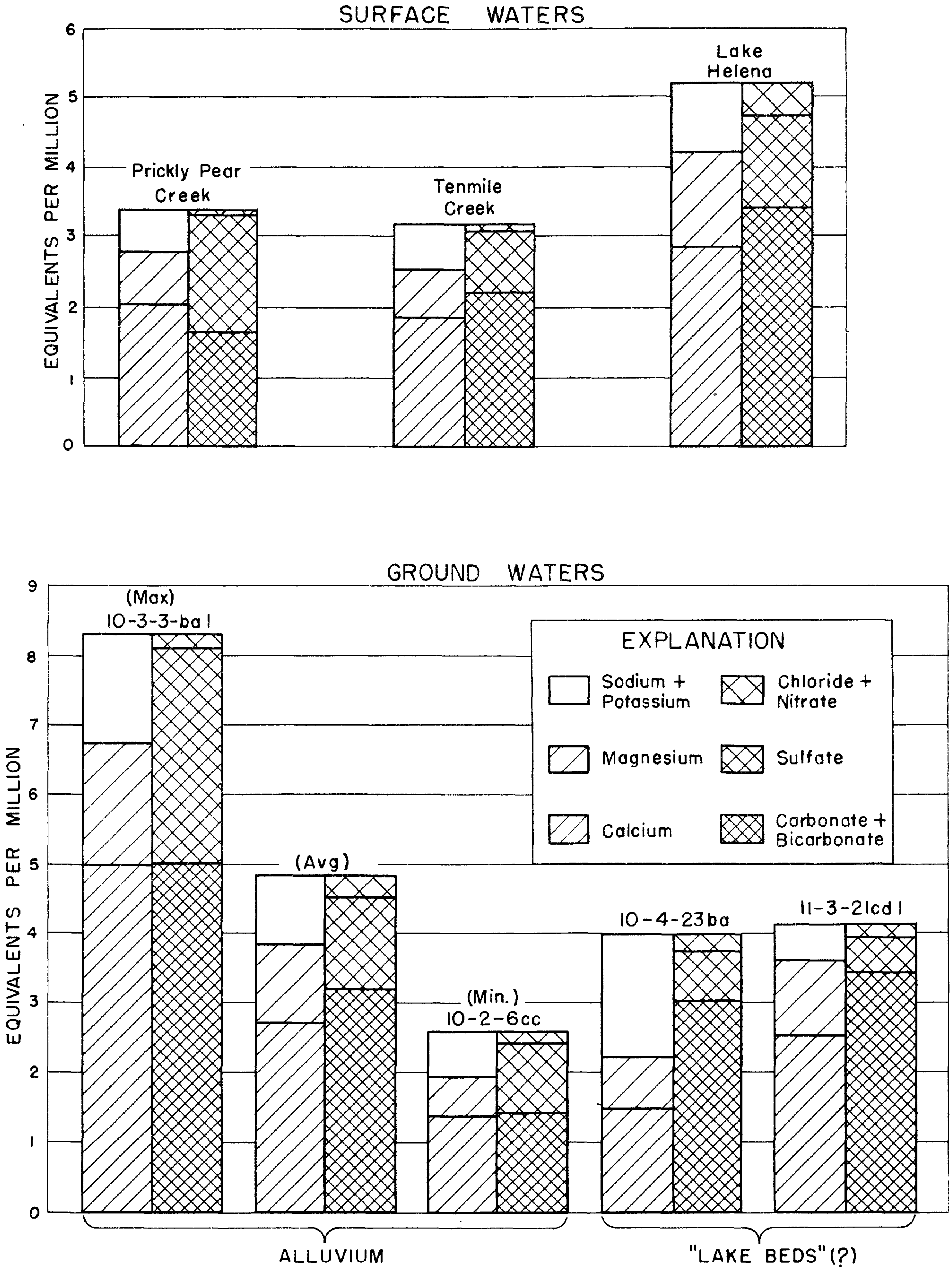


Figure 10.--Graphical representation of the composition of

Relation of Quality of Water to Recharge

Return irrigation flows constitute the principal recharge to the ground-water reservoirs in the Quaternary deposits; however, no evidence is available from quality-of-water data as to increased concentrations resulting from use and reuse of irrigation waters. The distributary of Prickly Pear Creek flowing due north from East Helena to Lake Helena drains a small valley in which four wells yield waters (in south to north order) containing 254, 254, 162, and 176 parts per million of dissolved solids, respectively. Here decrease in salt content is noted downstream. The usual increase in concentration from the reuse of irrigation waters is not apparent from the samples collected for analysis during the time of this study.

Effects of Waterlogging on the Quality of the Ground Water

No information is available on the effects of waterlogging in areas in the lower part of the Helena Valley on the quality of the ground water. The analyses do not indicate any great alteration in the chemical character of ground waters as a result of this condition; well 10-3-3bal, for example, in the waterlogged area, yields a water that contains only 514 parts per million of dissolved solids and has 17 percent sodium. However, continual evaporation of ground water that reaches the surface will eventually result in local "alkali" patches, higher and possibly harmful concentration of salts in the ground waters, and damage to cultivated lands.

Relation of Quality of Water to Use

Of 17 ground waters analyzed, 6 are used for irrigation, 9 are used for domestic or stock purposes, and 2 are unused. On the basis of the classification of Wilcox (1948, pp. 25-27) all ground waters sampled would be classified as "excellent to good" for irrigation purposes. Boron is insignificant and the percent sodium, low. Figure 11 shows the classification of both ground and surface waters sampled in the Helena Valley.

None of the ground waters sampled would be objectionable for domestic use on the basis of mineral content. Most of the waters are somewhat harder than usually considered desirable. The well waters used for drinking would meet Public Health Service standards (U. S. Public Health Service, 1946, pp. 371-384) insofar as chemical constituents are concerned.

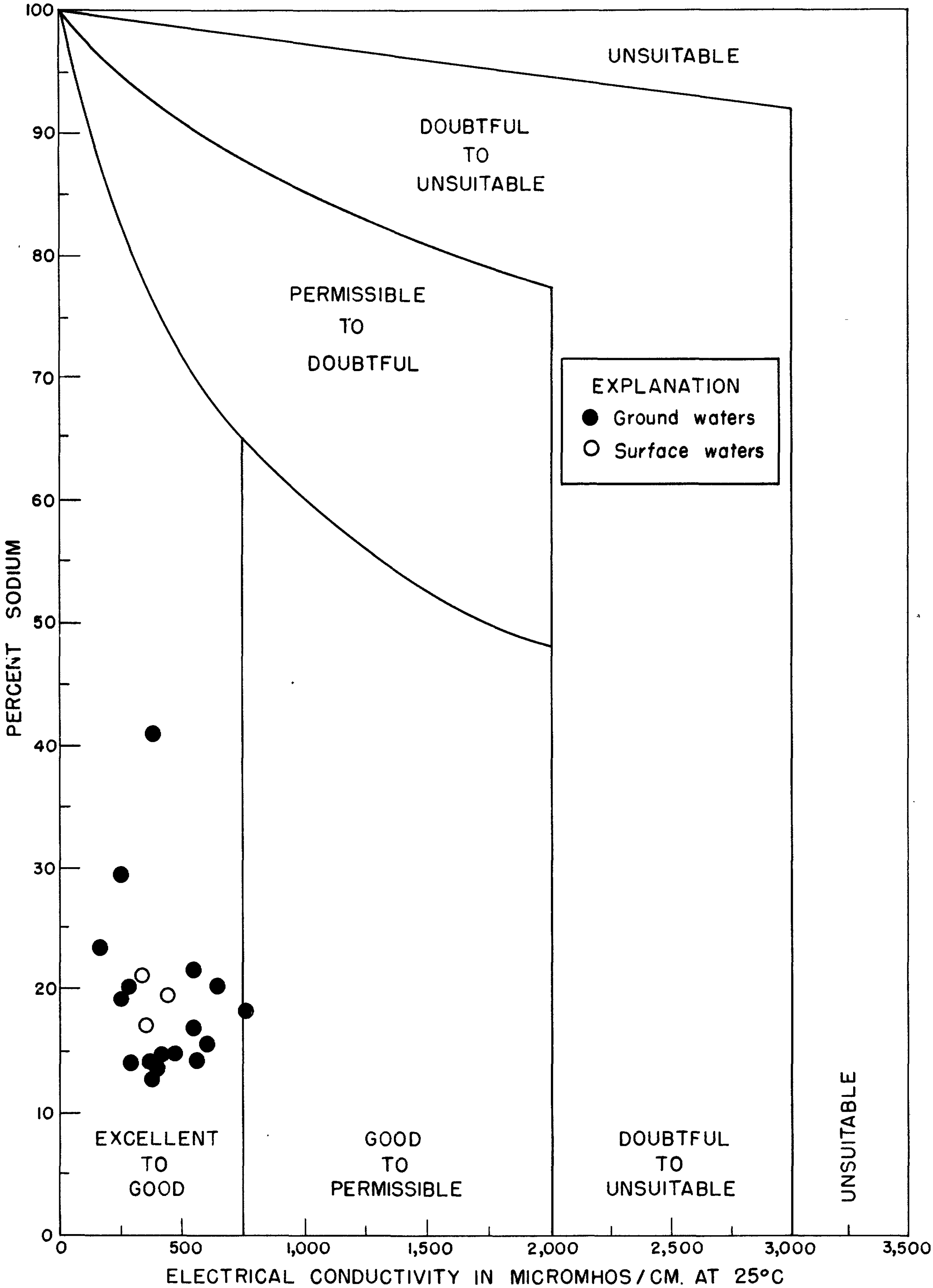


Figure 11.--Classification of Helena Valley waters considered as

Summary of the Quality of Water

The waters in the Helena Valley are characterized by moderate concentrations of dissolved solids composed principally of calcium, bicarbonate, and sulfate. The fact that the ground waters are on the whole rather dilute indicates that the valley fill is derived largely from rock materials containing small amounts of soluble minerals.

The analytical data do not indicate substantial alteration in mineral character of the ground water as a result of recharge of the ground-water reservoir from return irrigation flows. Future effects of waterlogging on the quality of the ground water cannot be predicted, but it seems reasonable to believe that the mineral content of the ground water would increase as a result of evaporation.

Both ground and surface waters sampled can be classified as "excellent to good" for irrigation. Boron, percent sodium, and dissolved solids meet requirements for this classification. Waters for drinking and general domestic use are satisfactory, although some are harder than generally considered desirable.

WATERLOGGING IN THE HELENA VALLEY

Present Conditions

The extent of waterlogged lands in the Helena Valley was mapped from field observations and aerial photographs. (See pl. 3.) More than 8,000 acres of land either are unproductive at the present time or their productivity has been greatly decreased as a result of the high water table. Nearly the entire waterlogged area was formerly productive farm land, but now only parts of the area are suitable even for grazing. A small rise of the water table will probably take out of production even those lands now under marginal cultivation.

The rise of the water table has been caused by ground-water recharge resulting from irrigation on the higher lands in the valley. Seepage from the irrigation canals and laterals and from water spread on the irrigated fields moves downward to the water table and then down the hydraulic gradient toward the lower part of the valley. The alluvial deposits, through which the water is moving, are progressively finer grained, less permeable, and thinner toward the lower part of the valley. Consequently the ground water, in excess of that which the materials in the lower part of the valley are able to transmit, is forced to the surface. The water does not issue at the surface in individual springs but over a fairly continuous area in the lower part of the valley. The relationship of the water table to the land surface is shown in the generalized cross section (fig. 6, p. 26).

Probable Future Conditions

Marked changes in the ground-water regimen of the Helena Valley will take place if additional large areas are irrigated and if supplemental water is applied to much of the already irrigated land. Nearly all the land proposed for new irrigation is on the flanks of the valley above the presently irrigated land. The soil of this new land is relatively thin and underlain by very permeable gravel; if these lands are irrigated, large quantities of irrigation water will percolate downward as ground-water recharge. Supplemental water provided for presently irrigated land will also increase the existing ground-water recharge from irrigation seepage. Considerable additional ground-water recharge will result from seepage losses of irrigation canals excavated in permeable gravel unless the canals are lined adequately.

Over a considerable area the alluvium in the Helena Valley is now saturated and unable to transmit the quantity of ground water now available for recharge. This condition will be aggravated if additional ground water becomes available for recharge. Unless provision can be made to prevent additional ground-water recharge or to recover and dispose of the excess ground water, the area of waterlogged land will increase. Careful and detailed investigations are needed to determine whether this problem can be solved. If an adequate solution is not found, any considerable increase to ground-water recharge will result in the ruin of much of the remaining good agricultural land in the valley.

SUMMARY AND RECOMMENDATIONS

In parts of the valley underlain by alluvium, adequate water supplies for domestic and stock uses generally can be obtained from wells drilled to relatively shallow depths. In areas where the alluvium is thin or of low permeability more adequate supplies can be obtained by drilling into the underlying "lake beds." Adequate water supplies generally can be obtained from the "lake beds" where they are at or near the surface. In some places, however, the "lake beds" have a high clay content or consist of volcanic tuff and yield only a small amount of water.

Ground water is not so readily obtained in the area that surrounds Helena Valley and that is underlain by older rocks. Shallow wells, dug in narrow alluvial deposits along streams, and springs are the principal sources of water for domestic and stock needs in this area. Drilled wells may be feasible in places, but the choice of each drilling site would require individual consideration.

The geologic and ground-water studies made to date indicate that a large ground-water reservoir may exist under the valley, and it is possible that much, if not all, of the land now irrigated with surface-water supplies could be irrigated with ground water pumped from this aquifer.

Use of ground water instead of surface water for irrigation of presently irrigated lands would allow use of the surface water for the irrigation of new lands. If use of ground water for irrigation is proved feasible, electric power for operation of the pumps could be obtained from the Canyon Ferry Dam, when completed. The economics of the use of water already in the valley should be studied exhaustively before decision is made to import additional water. This is especially true because it appears that the use of imported water will aggravate existing waterlogging conditions over a considerable part of the valley. The development of pump irrigation also would aid materially in the solution of the waterlogging problem which now exists in the valley and is likely to be aggravated if additional lands in the valley are irrigated.

If water is brought into the valley, provision must be made to prevent any appreciable rise of the water table under presently irrigated land. Drains that have a maximum depth of about 4 feet serve only to remove excess surface water and may do more damage than good. At the height of the irrigation season water may move slowly across the marshy ground surface, removing salt precipitated from irrigation water previously applied. During the remainder of the year, although the water table remains below the ground surface, the capillary fringe above the water table may extend up to the surface most of the time. As water evaporates from the ground surface, additional water will move upward from the water table by capillary action and the soluble salts in the water will be concentrated in the upper part of the soil mantle. White saline deposits, commonly called alkali, may cover the land near such drainage ditches and only salt-tolerant vegetation will grow. Halfway drainage measures can not be wholly successful. Waterlogged lands can be rendered productive again only by lowering the water table to a depth below the land surface greater than the height of the capillary fringe and maintaining it at that depth for the greater part of each year. In parts of the valley where the soil materials are very fine grained the depth to the water table should be 10 to 12 feet below the land surface. Subsurface (open or tile) drains of this depth may not be economically feasible in the Helena Valley because in addition to the great initial cost of construction the drains may require frequent and expensive maintenance and would take much land out of cultivation. Probably much of this land can be drained adequately by pumping wells, which will lower the water table and prevent the capillary fringe from extending to the land surface.

The relative economics of the use of the water already in the valley should be exhaustively studied before decision is made to import additional water. If the economic studies indicate the desirability of use of ground water as a major source of supply then it is recommended that quantitative ground-water studies be carried out in the Helena Valley. The investigation should include the drilling of test holes and the construction of test wells. Detailed geologic sections based on the test drilling should be prepared and pumping tests should be made of the wells to determine with reasonable accuracy the quantity of water available for supplemental irrigation supplies. The effect of well pumping on the water table should be measured. An adequately planned study made by qualified investigators will also provide basic data needed for the proper design, location, and construction of required drainage works. It is believed that the benefits derived from such a study would greatly exceed the costs of the study.

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Table 5.--Records of water levels in wells in Helena Valley, Mont.

10-2-6ba.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 10, 1948	5.33	Aug. 24, 1948	4.73	Jan. 8, 1949	5.43
20	5.53	Sept.22	5.15	Feb. 9	5.75
June 24	4.73	Oct. 21	5.06	Mar. 9	5.35
July 26	4.71	Dec. 21	5.10		

10-2-6bb.

May 10, 1948	5.34	July 26, 1948	3.78	Sept.22, 1948	4.19
20	4.54	Aug. 24	3.68	Oct. 21	4.12
June 24	3.94				

10-2-6bc.

May 10, 1948	11.11	July 26, 1948	10.27	Sept.22, 1948	9.66
20	11.21	Aug. 25	8.93	Oct. 22	10.09
June 24	10.21				

10-2-6ca.

May 10, 1948	11.60	July 26, 1948	9.85	Sept.22, 1948	10.10
20	11.70	Aug. 24	9.45	Oct. 22	9.59
June 24	9.70				

10-2-6cc.

May 11, 1948	22.67	July 26, 1948	15.81	Sept.22, 1948	14.81
20	17.76	Aug. 25	14.52	Oct. 22	15.34
June 24	17.06				

10-2-17ca.

May 10, 1948	65.50	Aug. 25, 1948	64.15	Jan. 8, 1949	63.88
20	65.90	Sept.22	64.35	Feb. 9	63.96
June 24	66.50	Oct. 22	64.07	Apr. 9	64.00
July 26	65.62	Dec. 4	63.85		

 Table 5.--Records of water levels in wells in Helena Valley, Mont.--Con.

10-2-30dc.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 10, 1948	43.62	Aug. 25, 1948	24.37	Jan. 8, 1949	32.92
20	43.72	Sept.22	21.14	Feb. 9	33.32
June 24	30.42	Oct. 22	24.12	Mar. 9	34.86
July 26	25.12	Dec. 4	29.62		

10-3-2bb.

May 6, 1948	3.50	July 23, 1948	3.98	Sept.22, 1948	4.31
19	3.60	Aug. 24	4.24	Oct. 21	3.29
June 24	3.30				

10-3-2cd.

May 6, 1948	10.70	Aug. 23, 1948	3.59	Jan. 7, 1949	10.13
19	9.90	Sept.22	4.11	Feb. 8	11.55
June 24	7.30	Oct. 21	6.84	Mar. 9	12.18
July 23	5.67	Dec. 3	8.51		

10-3-2db1.

May 6, 1948	5.70	Aug. 24, 1948	3.21	Jan. 7, 1949	7.15
19	5.80	Sept.22	3.85	Feb. 8	8.89
June 24	5.40	Oct. 21	4.90	Mar. 9	8.66
July 23	4.26	Dec. 3	5.73		

10-3-2db2.

May 6, 1948	5.90	July 23, 1948	3.72	Oct. 21, 1948	3.64
19	5.70	Aug. 23	a .00	Dec. 3	4.56
June 24	4.30	Sept.22	2.91		

10-3-3ba1.

May 4, 1948	3.70	Aug. 24, 1948	4.99	Jan. 7, 1949	4.53
18	3.20	Sept.22	5.28	Feb. 9	4.74
June 23	2.80	Oct. 21	4.52	Mar. 9	4.10
July 22	4.19	Dec. 3	4.23		

a Flooded with irrigation water.

10-3-3ba2.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 4, 1948	5.90	Aug. 24, 1948	5.06	Jan. 7, 1949	5.82
18	6.00	Oct. 20	5.65	Feb. 9	5.95
June 23	3.50	Dec. 3	5.37	Mar. 9	4.87
July 22	4.59				

10-3-3bc.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 4, 1948	4.45	Aug. 24, 1948	5.56	Jan. 7, 1949	4.17
18	3.25	Sept. 22	5.65	Feb. 8	2.85
June 23	3.05	Oct. 21	5.10	Mar. 9	4.80
July 22	5.08	Dec. 3	5.40		

10-3-3cc.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 4, 1948	3.20	Aug. 24, 1948	4.30	Jan. 7, 1949	3.61
18	2.80	Sept. 22	4.40	Feb. 8	2.57
June 23	2.20	Oct. 21	3.64	Mar. 9	3.25
July 22	3.36	Dec. 3	3.47		

10-3-4ab.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 4, 1948	2.80	Aug. 24, 1948	4.21	Jan. 9, 1949	(b)
18	2.50	Sept. 22	4.33	Feb. 9	(b)
June 23	2.20	Oct. 21	3.83	Mar. 9	3.06
July 22	3.32	Dec. 3	3.50		

10-3-4ba.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 4, 1948	4.30	Aug. 24, 1948	5.74	Jan. 7, 1949	5.63
18	3.30	Sept. 22	5.74	Feb. 9	(c)
June 23	3.10	Oct. 21	5.35	Mar. 9	5.05
July 22	4.95	Dec. 3	5.18		

10-3-5aa.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 4, 1948	4.60	Aug. 23, 1948	3.34	Jan. 7, 1949	3.57
18	2.60	Sept. 22	4.10	Feb. 9	(b)
June 23	2.20	Oct. 21	3.52	Mar. 9	2.80
July 22	2.64	Dec. 3	3.08		

b Frozen over.
c Well could not be reached.

 Table 5.--Records of water levels in wells in Helena Valley, Mont.--Con.

10-3-5ad.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 4, 1948	6.70	Aug. 23, 1948	12.88	Dec. 3, 1948	6.86
18	6.30	24	7.25	Jan. 7, 1949	7.36
June 22	5.60	Sept.21	8.33	Feb. 9	8.42
July 22	5.93	Oct. 20	7.05	Mar. 9	6.25

10-3-5ba.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 28, 1948	9.90	Aug. 21, 1948	8.59	Jan. 6, 1949	9.68
May 17	9.60	Sept.20	9.51	Feb. 8	10.06
June 22	8.20	Oct. 19	9.71	Mar. 9	9.67
July 21	8.35	Dec. 2	9.55		

10-3-5cb.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 28, 1948	17.00	July 21, 1948	13.50	Oct. 19, 1948	14.68
May 17	16.90	Aug. 21	13.15	Dec. 2	14.61
June 22	14.50	Sept.20	14.32		

10-3-5dd1.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 28, 1948	4.34	Aug. 21, 1948	3.36	Dec. 2, 1948	4.26
May 17	3.84	Sept.20	5.66	Jan. 6, 1949	4.19
June 22	3.14	Oct. 19	4.46	Feb. 7	5.11
July 21	2.64				

10-3-5dd2.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 28, 1948	4.05	Aug. 21, 1948	3.75	Dec. 2, 1948	3.92
May 17	3.65	Sept.20	5.84	Jan. 6, 1949	4.35
June 22	2.95	Oct. 19	4.33	Feb. 7	5.60
July 21	2.53				

10-3-6ac.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 27, 1948	20.75	July 21, 1948	16.13	Sept.20, 1948	16.55
May 17	20.85	Aug. 21	15.63	Oct. 19	17.97
June 22	16.95				

10-3-6bd.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 27, 1948	22.76	Aug. 21, 1948	d 23.44	Jan. 5, 1949	19.73
May 17	20.86	Sept.20	18.29	Feb. 7	20.31
June 22	17.36	Oct. 19	18.67	Mar. 9	20.42
July 27	17.13	Dec. 1	19.31		

10-3-6ca.

Apr. 27, 1948	23.20	July 21, 1948	18.49	Oct. 19, 1948	20.26
May 17	22.40	Aug. 21	18.64	Dec. 1	20.85
June 22	18.60	Sept.20	19.80		

10-3-6da1.

Apr. 28, 1948	17.52	Aug. 21, 1948	13.65	Jan. 6, 1949	15.17
May 17	17.82	Sept.20	14.25	Feb. 8	15.57
June 22	14.82	Oct. 19	14.80	Mar. 9	14.82
July 21	13.85	Dec. 2	14.86		

10-3-6da2.

Apr. 28, 1948	15.11	Aug. 21, 1948	10.67	Dec. 2, 1948	12.16
May 17	15.81	Sept.20	11.99	Jan. 1, 1949	12.46
June 22	12.21	Oct. 19	12.04	Feb. 8	12.71
July 21	11.27				

10-3-6dd.

Apr. 28, 1948	13.70	Aug. 21, 1948	9.14	Dec. 2, 1948	10.47
May 17	13.50	Sept.20	10.12	Jan. 6, 1949	10.73
June 22	11.10	Oct. 19	10.56	Feb. 7	(e)
July 21	9.59				

10-3-7aa1.

Apr. 28, 1948	12.90	July 21, 1948	7.52	Sept.20, 1948	9.19
May 17	12.70	Aug. 21	7.49	Oct. 19	8.75
June 22	10.60				

d Well pumped recently.
e Well covered for the winter.

 Table 5.--Records of water levels in wells in Helena Valley, Mont.--Con.

10-3-7aa2.

Date	Depth of water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 28, 1948	18.57	Aug. 21, 1948	11.59	Jan. 6, 1949	13.29
May 17	18.13	Sept. 20	12.36	Feb. 7	13.24
June 22	14.13	Oct. 19	13.04	Mar. 9	12.27
July 21	12.33	Dec. 2	13.79		

10-3-7ac.

Apr. 27, 1948	14.65	Aug. 21, 1948	7.67	Jan. 5, 1949	8.57
May 17	13.65	Sept. 20	8.60	Feb. 7	8.02
June 22	8.35	Oct. 19	8.71	Mar. 9	7.70
July 21	7.83	Dec. 2	8.40		

10-3-7ad1.

Apr. 27, 1948	9.80	Aug. 21, 1948	4.91	Dec. 2, 1948	5.23
May 17	7.80	Sept. 20	5.64	Jan. 6, 1949	3.45
June 22	4.00	Oct. 19	5.30	Feb. 7	(f)
July 21	4.55				

10-3-7ad2.

Apr. 27, 1948	11.50	Aug. 21, 1948	5.92	Dec. 2, 1948	6.54
May 17	10.40	Sept. 20	6.72	Jan. 6, 1949	5.31
June 22	6.20	Oct. 19	6.68	Feb. 7	(b)
July 21	5.94				

10-3-7cd.

Apr. 27, 1948	9.94	Aug. 21, 1948	4.62	Jan. 5, 1949	5.79
May 17	7.34	Sept. 20	5.43	Feb. 7	5.84
June 22	4.24	Oct. 19	5.49	Mar. 9	5.25
July 21	3.39	Dec. 2	5.64		

10-3-7dc.

Apr. 27, 1948	16.00	Aug. 21, 1948	10.01	Dec. 2, 1948	10.98
May 17	13.80	Sept. 20	10.80	Jan. 5, 1949	11.05
June 22	10.20	Oct. 19	10.93	Feb. 7	11.42
July 21	9.98				

b Frozen over.
f Flooded over.

10-3-8aa.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 30, 1948	3.40	Aug. 21, 1948	2.12	Dec. 2, 1948	2.95
May 17	3.40	Sept.20	2.72	Jan. 1, 1949	2.92
June 22	1.90	Oct. 19	3.15	Feb. 7	.....
July 21	1.99				

10-3-8bc.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 27, 1948	8.78	Aug. 21, 1948	5.00	Dec. 2, 1948	5.23
May 17	7.68	Sept.20	7.26	Jan. 6, 1949	4.81
June 22	4.48	Oct. 19	5.39	Feb. 7	(f)
July 21	4.45				

10-3-8cb.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 27, 1948	10.70	Aug. 21, 1948	5.42	Jan. 1, 1949	5.92
May 17	8.40	Sept.20	7.29	Feb. 7	3.35
June 22	5.00	Oct. 19	6.73	Mar. 9	5.39
July 21	6.07	Dec. 2	6.85		

10-3-8cc.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 27, 1948	21.23	Aug. 21, 1948	12.95	Jan. 6, 1949	16.57
May 17	20.93	Sept.20	15.49	Feb. 7	15.98
June 22	16.53	Oct. 19	16.52	Mar. 9	15.44
July 21	16.25	Dec. 2	16.57		

10-3-8dd.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 27, 1948	6.66	Aug. 21, 1948	4.52	Jan. 6, 1949	5.52
May 17	6.86	Sept.20	4.93	Feb. 7	.....
June 22	4.66	Oct. 19	4.98	Mar. 9	4.16
July 21	5.28	Dec. 2	5.06		

10-3-9da.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 3, 1948	1.10	Aug. 23, 1948	1.35	Dec. 3, 1948	0.85
18	1.10	Sept.21	1.36	Jan. 7, 1949	(b)
June 23	.60	Oct. 20	1.10	Feb. 8	(b)
July 22	1.15				

b Frozen over.
f Flooded over.

 Table 5.--Records of water levels in wells in Helena Valley, Mont.--Con.

10-3-9dd.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 3, 1948	4.10	Aug. 23, 1948	4.60	Jan. 7, 1949	4.35
18	3.10	Sept. 21	4.10	Feb. 8	4.33
June 23	2.80	Oct. 20	4.21	Mar. 9	4.15
July 22	4.17	Dec. 3	4.10		

10-3-10bb.

May 4, 1948	6.12	July 22, 1948	6.54	Oct. 21, 1948	6.25
18	6.52	Aug. 24	6.96	Dec. 3	6.32
June 28	5.82	Sept. 22	7.04	Jan. 7, 1949	7.73

10-3-10cc.

May 3, 1948	4.10	Aug. 23, 1948	4.75	Jan. 7, 1949	4.75
18	3.60	Sept. 21	4.91	Feb. 8	5.00
June 24	2.90	Oct. 20	4.49	Mar. 10	4.70
July 22	4.27	Dec. 3	4.37		

10-3-10dd.

May 3, 1948	12.34	Aug. 23, 1948	3.49	Jan. 7, 1949	8.87
18	10.64	Sept. 21	4.46	Feb. 8	(b)
June 23	7.74	Oct. 20	5.84	Mar. 10	10.34
July 22	3.84	Dec. 3	7.29		

10-3-11ab1.

May 6, 1948	17.52	Aug. 23, 1948	8.72	Jan. 7, 1949	15.05
19	17.07	Sept. 22	9.30	Feb. 8	16.57
June 24	14.82	Oct. 21	11.40	Mar. 10	17.47
July 23	11.69	Dec. 3	12.89		

10-3-11ab2.

May 6, 1948	18.48	Aug. 24, 1948	10.24	Jan. 7, 1949	15.64
19	17.68	Sept. 22	10.66	Feb. 8	17.35
June 24	16.58	Oct. 21	12.08	Mar. 10	17.90
July 23	13.73	Dec. 3	13.55		

b Frozen over.

10-3-11ba.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 5, 1948	15.80	Aug. 24, 1948	6.39	Jan. 7, 1949	13.00
19	15.00	Sept.21	6.96	Feb. 8	14.55
June 24	12.00	Oct. 20	9.40	Mar. 10	15.43
July 23	8.71	Dec. 5	11.16		

10-3-11cc.

May 3, 1948	15.90	Aug. 23, 1948	3.57	Jan. 7, 1949	11.84
18	14.50	Sept.21	4.57	Feb. 8	13.27
June 23	8.50	Oct. 20	8.05	Mar. 10	14.05
July 22	4.67	Dec. 3	9.97		

10-3-14cb.

May 3, 1948	23.98	Aug. 23, 1948	9.81	Jan. 7, 1949	(g)
18	23.98	Sept.21	11.45	Feb. 8	(g)
June 24	16.88	Oct. 20	12.37	Mar. 10	18.77
July 22	9.26	Dec. 3	15.06		

10-3-14db.

May 3, 1948	29.40	Aug. 23, 1948	14.60	Jan. 7, 1949	22.85
18	28.30	Sept.21	16.19	Feb. 8	24.62
June 24	24.20	Oct. 20	18.25	Mar. 10	25.85
July 22	18.88	Dec. 3	20.51		

10-3-15ab1.

May 3, 1948	7.40	Aug. 23, 1948	3.70	Jan. 7, 1949	6.15
18	7.00	Sept.21	3.95	Feb. 8	6.35
June 23	3.20	Oct. 20	4.30	Mar. 10	6.80
July 22	3.01	Dec. 3	5.33		

10-3-15ab2.

May 3, 1948	7.50	July 22, 1948	1.92	Oct. 20, 1948	3.66
18	6.40	Aug. 23	3.00	Dec. 3	4.54
June 23	2.90	Sept.21	3.05		

g Road closed.

 Table 5.--Records of water levels in wells in Helena Valley, Mont.--Con.

10-3-15ac.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 3, 1948	7.80	Aug. 23, 1948	1.65	Jan. 7, 1949	4.27
18	6.70	Sept.21	2.66	Feb. 8	4.75
June 24	4.60	Oct. 20	3.21	Mar. 10	4.89
July 22	3.91	Dec. 3	3.86		

10-3-15ba.

May 3, 1948	2.80	Aug. 23, 1948	3.05	Jan. 7, 1949	4.85
18	3.80	Sept.21	3.41	Feb. 8	5.22
June 23	2.40	Oct. 20	2.99	Mar. 10	4.72
July 22	2.64	Dec. 3	4.03		

10-3-15bd.

Apr. 30, 1948	4.40	Aug. 23, 1948	4.45	Jan. 7, 1949	4.70
May 18	3.80	Sept.21	4.85	Feb. 8	4.70
June 23	3.60	Oct. 20	4.64	Mar. 10	4.66
July 22	4.53	Dec. 3	4.61		

10-3-16ac.

Apr. 30, 1948	14.30	Aug. 23, 1948	11.39	Jan. 7, 1949	13.69
May 18	14.30	Sept.21	13.11	Feb. 8	13.80
June 23	12.90	Oct. 20	13.12	Mar. 9	13.33
July 22	12.29	Dec. 2	13.35		

10-3-16bc.

Apr. 30, 1948	27.26	Aug. 21, 1948	22.34	Jan. 7, 1949	24.81
May 18	27.26	Sept.21	22.47	Feb. 8	25.46
June 23	24.36	Oct. 20	23.00	Mar. 10	25.36
July 21	22.65	Dec. 2	24.26		

10-3-16da.

Apr. 30, 1948	3.90	Aug. 23, 1948	3.20	Jan. 7, 1949	3.96
May 18	3.90	Sept.21	3.25	Feb. 8	4.00
June 23	2.40	Oct. 20	3.55	Mar. 10	3.42
July 22	3.10	Dec. 3	3.80		

10-3-17bc.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 27, 1948	42.30	Aug. 21, 1948	37.87	Jan. 1, 1949	34.30
May 17	42.40	Sept.20	36.72	Feb. 7	33.55
June 22	40.50	Oct. 19	35.64	Mar. 9	32.97
July 21	h 44.09	Dec. 2	34.63		

10-3-18ac.

Apr. 27, 1948	37.57	Aug. 21, 1948	34.02	Jan. 5, 1949	34.62
May 17	37.37	Sept.20	34.77	Feb. 7	34.59
June 22	33.37	Oct. 19	33.84	Mar. 9	33.94
July 21	34.34	Dec. 2	34.07		

10-3-18ad.

Apr. 27, 1948	40.30	Aug. 21, 1948	34.58	Jan. 6, 1949	31.92
May 17	40.10	Sept.20	33.78	Feb. 7	30.75
June 22	38.00	Oct. 19	33.55	Mar. 9	30.44
July 21	36.36	Dec. 2	32.56		

10-3-22aa1.

May 3, 1948	15.48	Aug. 23, 1948	6.18	Jan. 7, 1949	7.64
18	14.48	Sept.21	6.43	Feb. 8	7.70
June 23	7.18	Oct. 20	6.13	Mar. 9	9.54
July 22	7.32	Dec. 3	8.45		

10-3-22aa2.

May 3, 1948	7.30	Aug. 23, 1948	6.50	Jan. 7, 1949	9.12
18	6.50	Sept.21	6.50	Feb. 8	9.20
June 24	9.00	Oct. 20	6.85	Mar. 10	10.75
July 22	8.40	Dec. 2	9.33		

10-3-22ab.

May 3, 1948	13.74	Aug. 23, 1948	5.55	Jan. 9, 1949	7.27
18	13.04	Sept.21	6.29	Feb. 8	7.00
June 24	6.44	Oct. 20	5.97	Mar. 10	8.83
July 22	7.01	Dec. 3	7.77		

h Well pumping.

 Table 5.--Records of water levels in wells in Helena Valley, Mont.--Con.

10-3-22ba.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 3, 1948	36.20	Aug. 23, 1948	31.80	Jan. 7, 1949	33.11
18	35.70	Sept.21	31.75	Feb. 8	33.72
June 16	33.90	Oct. 20	30.40	Mar. 10	33.86
July 22	32.90	Dec. 2	31.93		

10-3-22da.

May 5, 1948	67.25	Aug. 23, 1948	57.20	Jan. 2, 1949	(g)
18	64.65	Sept.21	55.11	Feb. 7	(g)
June 24	61.15	Oct. 20	56.55	Mar. 10	63.75
July 22	57.65	Dec. 2	59.65		

10-3-24cb.

May 7, 1948	42.00	Aug. 25, 1948	21.35	Jan. 8, 1949	32.28
20	40.80	Sept.22	24.54	Feb. 9	35.17
June 23	25.20	Oct. 22	27.25	Mar. 10	36.59
July 23	16.87	Dec. 4	29.50		

10-3-24dc.

May 5, 1948	17.95	Aug. 25, 1948	12.42	Jan. 8, 1949	28.33
20	15.45	Sept.22	19.15	Feb. 9	31.71
June 24	7.95	Oct. 21	18.52	Mar. 11	16.45
July 23	8.36	Dec. 4	25.50		

10-4-12da.

Apr. 27, 1948	11.54	Aug. 21, 1948	4.00	Jan. 5, 1949	6.45
May 17	8.74	Sept.20	4.46	Feb. 7	6.71
June 22	4.04	Oct. 19	5.37	Mar. 9	6.56
July 21	3.33	Dec. 1	5.75		

10-4-12dd.

Apr. 27, 1948	8.33	July 21, 1948	2.26	Sept.20, 1948	5.33
May 17	6.33	Aug. 21	5.15	Oct. 19	5.79
June 22	3.53				

g Road closed.

10-4-13ab.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 27, 1948	9.21	July 21, 1948	4.16	Oct. 19, 1948	7.87
May 17	7.01	Aug. 21	6.92	Dec. 1	7.93
June 22	1.21	Sept.20	8.26		

10-4-13da.

Apr. 27, 1948	8.43	Aug. 21, 1948	6.80	Jan. 5, 1949	8.52
May 17	6.33	Sept.20	8.46	Feb. 7	8.55
June 22	5.63	Oct. 19	8.37	Mar. 9	8.47
July 21	5.81	Dec. 1	7.89		

11-2-19db.

May 11, 1948	20.03	July 23, 1948	19.29	Oct. 21, 1948	19.85
20	20.13	Aug. 24	19.48	Dec. 4	19.96
June 24	20.53	Sept.22	20.17	Jan. 8, 1949	20.08

11-2-31ac.

May 10, 1948	8.09	Aug. 23, 1948	7.29	Dec. 4, 1948	8.11
20	8.59	Sept.23	8.14	Jan. 8, 1949	8.44
June 24	6.49	Oct. 21	8.08	Feb. 9	9.10
July 23	7.19				

11-2-31bc.

May 10, 1948	1.40	Aug. 24, 1948	2.70	Jan. 8, 1949	2.58
20	1.90	Sept.22	2.66	Feb. 9	2.79
June 24	2.00	Oct. 21	2.12	Mar. 9	2.02
July 26	2.34	Dec. 4	1.81		

11-2-31cc.

May 10, 1948	4.10	Aug. 24, 1948	4.05	Jan. 8, 1949	4.54
20	4.50	Sept.22	4.32	Feb. 9	(b)
June 24	3.80	Oct. 21	4.17	Mar. 11	4.49
July 26	4.03	Dec. 4	4.17		

b Frozen over.

 Table 5.--Records of water levels in wells in Helena Valley, Mont.--Con.

11-2-31cd1.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 10, 1948	5.20	Aug. 24, 1948	5.95	Jan. 8, 1949	6.37
20	5.40	Sept.22	6.19	Feb. 9	6.59
June 24	5.30	Oct. 21	6.10	Mar. 11	6.32
July 26	4.70	Dec. 4	6.06		

11-2-31cd2.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 10, 1948	2.50	July 26, 1948	1.63	Sept.22, 1948	1.72
20	2.60	Aug. 24	1.65	Oct. 21	1.69
June 24	2.40				

11-2-31db.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 10, 1948	20.65	Aug. 24, 1948	19.40	Jan. 8, 1949	20.53
20	20.75	Sept.22	20.11	Feb. 9	21.05
June 24	20.75	Oct. 21	20.08	Mar. 11	20.82
July 23	19.55	Dec. 4	20.14		

11-3-13cb.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 5, 1948	24.83	Aug. 23, 1948	20.61	Jan. 6, 1949	23.68
20	24.83	Sept.21	21.97	Feb. 9	25.22
June 23	24.43	Oct. 20	22.45	Mar. 10	25.45
July 23	21.64	Dec. 3	22.89		

11-3-13dd.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 5, 1948	5.80	July 23, 1948	3.77	Oct. 20, 1948	4.11
20	6.60	Aug. 23	2.32	Dec. 2	4.42
June 23	4.30	Sept.21	4.05		

11-3-14bb.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 5, 1948	60.70	Aug. 23, 1948	58.08	Jan. 6, 1949	58.86
20	62.80	Sept.21	57.92	Feb. 8	60.50
June 23	62.30	Oct. 20	58.22	Mar. 11	61.07
July 23	58.84	Dec. 3	58.99		

11-3-15bc.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 5, 1948	16.50	Aug. 23, 1948	9.26	Jan. 6, 1949	13.68
20	15.70	Sept.21	11.17	Feb. 8	14.70
June 23	10.50	Oct. 20	12.94	Mar. 10	14.68
July 23	8.42	Dec. 2	13.40		

11-3-15cb.

May 5, 1948	8.90	July 22, 1948	6.01	Sept.21, 1948	6.90
20	8.40	Aug. 23	6.02	Oct. 20	8.65
June 23	6.30				

11-3-15dd.

May 5, 1948	10.96	Aug. 23, 1948	8.56	Jan. 6, 1949	10.32
20	10.66	Sept.21	9.48	Feb. 8	11.26
June 23	10.56	Oct. 20	9.54	Mar. 10	11.11
July 23	8.67	Dec. 2	9.68		

11-3-16bc.

Apr. 30, 1948	32.30	June 22, 1948	29.40	Aug. 23, 1948	25.45
May 18	32.90	July 21	27.50	Sept.21	25.66

11-3-16cb.

Apr. 30, 1948	21.86	Aug. 23, 1948	12.42	Jan. 6, 1949	18.88
May 18	21.96	Sept.21	13.47	Feb. 8	19.91
June 22	17.64	Oct. 20	16.13	Mar. 9	20.51
July 21	10.84	Dec. 2	17.90		

11-3-16dd.

May 5, 1948	7.07	Aug. 23, 1948	6.01	Jan. 6, 1949	7.22
20	6.67	Sept.21	7.02	Feb. 8	7.49
June 22	7.07	Oct. 20	6.37	Mar. 10	7.92
July 22	6.21	Dec. 2	6.48		

11-3-17cd.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 30, 1948	25.40	Aug. 23, 1948	16.54	Jan. 6, 1949	19.97
May 18	25.60	Sept.21	17.88	Feb. 8	21.71
June 22	17.80	Oct. 20	19.27	Mar. 9	21.55
July 21	13.78	Dec. 2	20.40		

11-3-18dd.

Apr. 30, 1948	38.44	Aug. 23, 1948	33.77	Jan. 6, 1949	35.27
May 18	38.64	Sept.21	33.76	Feb. 8	35.73
June 22	36.94	Oct. 20	34.29	Mar. 9	36.17
July 21	34.97	Dec. 2	34.65		

11-3-19ad.

Apr. 30, 1948	34.73	Aug. 21, 1948	28.34	Jan. 6, 1949	31.35
May 18	34.83	Sept.21	30.49	Feb. 8	31.94
June 22	30.43	Oct. 20	30.15	Mar. 9	32.46
July 21	28.19	Dec. 2	30.49		

11-3-21ab.

May 5, 1948	1.00	July 22, 1948	1.10	Sept.21, 1948	1.39
20	1.20	Aug. 24	1.30	Oct. 20	.45
June 22	1.00				

11-3-21cd.

May 5, 1948	7.91	Aug. 23, 1948	6.33	Jan. 6, 1949	8.59
19	9.11	Sept.21	7.02	Feb. 7	9.31
June 23	8.41	Oct. 20	7.26	Mar. 9	7.61
July 22	5.64	Dec. 2	8.22		

11-3-21dc1.

May 5, 1948	8.49	Aug. 24, 1948	4.56	Jan. 1, 1949	8.05
19	8.29	Sept.21	5.78	Feb. 8	8.14
June 23	5.31	Oct. 20	7.06	Mar. 9	6.99
July 23	6.06	Dec. 2	7.51		

11-3-21dc2.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 5, 1948	10.15	July 23, 1948	9.58	Oct. 20, 1948	9.97
19	10.45	Aug. 23	9.41	Dec. 2	10.16
June 23	10.35	Sept.21	10.05		

11-3-21dd.

May 5, 1948	7.80	June 23, 1948	6.90	Aug. 23, 1948	7.12
19	7.80	July 23	7.87	Sept.21	5.27

11-3-22cb.

May 5, 1948	4.30	July 23, 1948	5.55	Oct. 20, 1948	6.00
19	4.20	Aug. 23	6.15	Dec. 2	5.22
June 23	4.50	Sept.21	6.30		

11-3-22cc.

May 5, 1948	7.40	Aug. 23, 1948	8.42	Jan. 6, 1949	8.20
19	7.10	Sept.21	9.12	Feb. 8	8.45
June 23	7.60	Oct. 20	8.76	Mar. 9	7.75
July 23	8.10	Dec. 3	8.25		

11-3-23bb.

May 5, 1948	5.70	June 23, 1948	4.50	Aug. 23, 1948	3.91
20	5.40	July 23	3.12	Sept.21	4.17

11-3-25dc.

May 10, 1948	5.70	July 26, 1948	6.29	Oct. 21, 1948	6.50
20	6.10	Aug. 24	7.28	Dec. 4	6.04
June 24	6.20	Sept.22	7.22	Mar. 11, 1949	5.47

11-3-26dd.

May 6, 1948	1.19	July 23, 1948	1.69	Sept.22, 1948	3.40
19	1.19	Aug. 24	2.69	Oct. 21	3.12
June 24	1.49				

 Table 5.--Records of water levels in wells in Helena Valley, Mont.--Con.

11-3-28ac.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
May 5, 1948	0.03	July 23, 1948	0.53	Oct. 20, 1948	1.52
19	.23	Aug. 23	1.23	Dec. 2	1.46
June 23	.13	Sept.21	2.11		

11-3-30ad1.

Apr. 29, 1948	9.60	Aug. 21, 1948	5.25	Dec. 2, 1948	7.30
May 17	8.80	Sept.21	5.88	Jan. 6, 1949	(b)
June 22	3.90	Oct. 19	8.87	Feb. 8	(b)
July 21	4.19				

11-3-30ad2.

Apr. 29, 1948	8.60	Aug. 21, 1948	5.47	Jan. 6, 1949	7.00
May 17	8.60	Sept.20	5.78	Feb. 8	7.69
June 22	4.40	Oct. 19	6.33	Mar. 9	7.02
July 21	4.04	Dec. 2	6.50		

11-3-30cc.

Apr. 29, 1948	26.30	Aug. 23, 1948	18.43	Jan. 9, 1949	23.36
May 17	25.20	Sept.21	19.00	Feb 8	24.21
June 22	18.20	Oct. 20	20.02	Mar. 9	24.80
July 21	17.02	Dec. 2	22.49		

11-3-30da.

Apr. 29, 1948	5.90	Aug. 21, 1948	4.66	Dec. 2, 1948	5.14
May 17	5.60	Sept.20	5.32	Jan. 6, 1949	5.44
June 22	4.20	Oct. 19	5.39	Feb. 8	(b)
July 21	3.54				

11-3-31bb.

Apr. 29, 1948	10.20	Aug. 23, 1948	5.80	Jan. 6, 1949	7.55
May 17	5.50	Sept.21	6.18	Feb. 8	8.20
June 22	5.60	Oct. 20	6.38	Mar. 9	8.24
July 21	4.00	Dec. 2	6.94		

b Frozen over.

11-3-31cc.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 29, 1948	11.07	Aug. 23, 1948	8.17	Jan. 6, 1949	9.35
May 17	10.87	Sept. 21	8.52	Feb. 8	9.78
June 22	9.37	Oct. 20	8.82	Mar. 9	9.84
July 21	8.62	Dec. 2	9.04		

11-3-31da.

Apr. 29, 1948	7.00	Aug. 21, 1948	5.82	Jan. 6, 1949	6.81
May 17	6.60	Sept. 20	6.60	Feb. 8	7.21
June 22	4.60	Oct. 19	6.58	Mar. 9	6.37
July 21	4.54	Dec. 2	6.44		

11-3-32cc1.

Apr. 29, 1948	11.40	Aug. 21, 1948	9.00	Dec. 2, 1948	10.35
May 17	10.90	Sept. 20	10.06	Jan. 9, 1949	10.56
June 22	7.70	Oct. 19	10.38	Feb. 8	(e)
July 21	8.75				

11-3-32cc2.

Apr. 28, 1948	11.20	Aug. 21, 1948	9.12	Dec. 2, 1948	10.30
May 17	10.70	Sept. 20	10.08	Jan. 6, 1949	9.40
June 22	8.60	Oct. 19	10.38	Feb. 8	(b)
July 21	9.07				

11-3-32db1.

Apr. 28, 1948	3.10	Aug. 21, 1948	2.65	Dec. 2, 1948	3.66
May 17	3.30	Sept. 20	4.40	Jan. 6, 1949	(b)
June 22	2.80	Oct. 19	4.06	Feb. 8	(b)
July 21	2.62				

11-3-32db2.

Apr. 28, 1948	2.10	Aug. 21, 1948	2.77	Dec. 2, 1948	2.40
May 17	2.40	Sept. 20	3.18	Jan. 6, 1949	(b)
June 22	2.00	Oct. 19	2.66	Feb. 8	(b)
July 21	2.20				

b Frozen over.
e Well covered for winter.

11-3-32dc.

Date	Depth to water level (feet)	Date	Depth to water level (feet)	Date	Depth to water level (feet)
Apr. 28, 1948	6.03	Aug. 21, 1948	6.43	Jan. 6, 1949	7.17
May 17	6.23	Sept.20	7.41	Feb. 8	7.64
June 22	5.53	Oct. 19	7.34	Mar. 9	6.90
July 21	4.43	Dec. 2	6.97		

11-3-33cc.

May 4, 1948	3.00	Aug. 24, 1948	3.92	Jan. 7, 1949	3.87
18	2.90	Sept.22	4.25	Feb. 9	(b)
June 23	2.50	Oct. 21	3.61	Mar. 9	2.82
July 22	3.30	Dec. 3	3.29		

11-3-34bc.

May 4, 1948	3.50	July 22, 1948	4.10	Sept.22, 1948	4.75
18	3.00	Aug. 24	4.61	Oct. 21	4.14
June 23	2.80				

11-3-35ac.

May 6, 1948	1.00	July 23, 1948	2.50	Sept.22, 1948	1.53
19	1.80	Aug. 24	1.53	Oct. 21	.85
June 24	1.40				

11-3-36cd.

May 5, 1948	2.70	Aug. 25, 1948	2.87	Dec. 4, 1948	2.47
19	2.90	Sept.22	3.05	Jan. 7, 1949	3.21
June 24	2.60	Oct. 21	2.54	Mar. 9	2.45
July 23	3.00				

b Frozen over.

Table 6.--Records of wells and springs in Helena Valley, Mont.

Well number: See text for description of well-numbering system.
Type of well: B, bored observation well; DD, dug and drilled well; Dr, drilled well; Du, dug well.
Depth of well: Measured depths are given in feet and tenths below measuring points; reported depths are given in feet below land surface.
Type of casing: C, concrete (brick, tile, or pipe); M, masonry; P, iron or steel pipe; W, wood.
Geologic source: Al, alluvium; Hls, Helena limestone; Lb, Tertiary "lake beds;" Msh, Marsh shale.
Method of lift: B, bucket; C, centrifugal pump; Cy, cylinder; F, natural flow; J, jet; P, pitcher pump.
Type of power: E, electric; G, gasoline; H, hand-operated; W, wind.
Use of water: D, domestic; I, irrigation; Ind, industry; N, not being used; S, stock.
Measuring point: L, land surface; Tca, top of casing; Tcu, top of curb; Tpf, top of platform; Tsg, top of staff gage.
Depth to water level: Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet.
Remarks: A, adequate supply; Ca, chemical analysis; F3, estimated flow in gallons per minute; In, inadequate; N, wells, mainly irrigation, that were not used during the 1948 season.

Well number	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Geologic source	Method of lift and type of power	Use of water	Measuring point: Description	Measuring point: Distance above (+) or below (-) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement (1948)	Remarks
10-2-5bc	B. O'Connell............	Dr	106.9	3	P	Lb	Cy,H,W	D	Tca	+0.50	3,778.29	95.38	9-25	A
-6ba	Holt....................	Du	10.1	48	M	Al	B	D,S	Tcu	+1.27	3,688.87	6.60	5-10	A
-6bb	L. Ramsey...............	Du	20.2	360	N	Al	C,G	I	Tpf	+2.44	3,684.76	2.90	5-10	N
-6bc	.....do.................	Du	18.7	420	N	Al	C,G	I	Tpf	-7.81	3,691.69	3.30	5-10	N
-6ca1	Munson Bros.............	Du	19.9	420	N	Al	C,G	I	Tpf	-8.30	3,692.70	3.30	5-10	N
-6ca2	Holt....................	Du	18.8	360	N	Al	N	I	Tsg	+8.12	3,695.90	2.00	5-11	N
-6cc	Munson Bros.............	Du	38.5	480	N	Al	C,G	I	Tpf	-12.76	3,701.14	4.90	5-11	N,Ca
-7bb	....	DD	19.7	4	C,P	Al	Cy,H	N	Tca	-1.05	3,615.46	15.97	7-13	
-8cd	....	Dr	60.1	4	P	Al	Cy,G	S	Tca	+.50	3,762.10	52.00	9-27	A
-15cd	....	Du	28.0	36	W	Lb	Cy,H	D,S	Tpf	+.20	....	24.85	9-27	A
-17ca	W. Huhnecruch...........	Du	67.4	30	T	Al	N	N	Tpf	.00	3,779.75	65.50	5-10	
-19cb	L. Ramsey...............	Du	45.5	36	C	Al	Cy,G,H	D,S	Tpf	+.20	3,827.18	41.13	7-13	A,Ca
-28dc	G. Diehl................	Dr	59.9	6	P	Lb	N	N	Tpf	+.50	3,971.51	40.05	8-18	
-30dc1	A. Chenkovich...........	Du	49.0	48	C	Al	J,E	D	Tpf	-6.12	3,871.08	37.50	5-10	A,Ca
-30dc2	J. Ptelene..............	Du	44.1	60	N	Al	N	N	Tpf	+.20	3,894.65	35.40	8- 9	
-31aa	S. Vosen................	DD	40.5	48	C	Al	C,E	S,I	Tpf	+.40	3,889.98	32.45	8-10	N
10-3-1cd	Gibson..................	Du	17.4	480	N	Al	N	N	Tsg	+9.82	3,695.58	2.00	5-11	
-2bb	M. Donaldson............	Du	8.2	36	W	Al	Cy,H	N	Tpf	+.50	3,691.81	4.00	5- 6	
-2cd	.....do.................	DD	19.6	48	W	Al	J,E	D,S	Tpf	+.20	3,715.30	10.90	5- 6	A
-2db1	E. Hilger...............	Du	12.1	48	W	Al	N	N	Tpf	+.20	3,705.31	5.90	5- 6	
-2db2	.....do.................	Du	9.2	48	W	Al	N	N	Tpf	.00	3,698.07	5.90	5- 6	
-3ba1	F. May..................	Du	8.2	24	C	Al	Cy,H	D	Tpf	+1.50	3,688.65	5.20	5- 4	A,Ca
-3ba2	.....do.................	Dr	26.1	6	P	Al	C,E	S	Tca	+.50	3,687.40	6.40	5- 4	A
-3bc	L. P. Barney............	Dr	33.0	6	P	Al	J,E	D,S	Tcu	+.50	3,691.04	5.00	5- 4	A
-3cb	G. E. Barney............	Dr	.....	6	P	Al	J,E	D	Tca	+.57	3,695.87	5.20	5- 4	A

-3cc	E. E. Stanfield.........	Du	8.5	24	C	Al	N	N	Tca	+.80	3,700.69	4.00	5- 4	
-4ab	McGowan................	Du	7.2	36	W	Al	N	N	Tpf	+.50	3,695.23	3.30	5- 4	
-4ba	H. E. Robinson..........	Du	8.5	30	W	Al	J,E	D,S	Tpf	-.50	3,697.62	3.80	5- 4	A
-4bd	.....do................	Du	6.5	72	W	Al	C,G	I	Tcu	+1.40	3,705.30	1.20	5- 4	N
-5aa	H. Ellis...............	D	8.4	36	W	Al	C,E	I,S	Tpf	+.50	3,705.94	5.10	5- 4	A
-5ad	.....do................	DD	21.8	60x90	C	Al	C,G	I	Tcu	.00	3,714.64	6.70	5- 4	A,Ca
-5ba	H. McCarl..............	Du	15.1	30	M	Al	P,H	S	Tpf	+.80	3,715.80	15.05	4-28	A
-5cb	R. Melugin.............	Du	24.1	24	M	Al	J,E	D	Tpf	+.00	3,736.61	17.00	4-28	A
-5dd1	Munger.................	Dr	33.6	6	P	Al	C,E	I	Tca	+.36	3,730.76	4.70	4-28	N
-5dd2	.....do................	Du	35.1	30	M	Al	Cy,H,W	S	Tpf	+.25	3,726.85	4.30	4-28	A
-5dd3	.....do................	DD	8.4	36	W	Al	J,E	I	Tpf	+.20	3,728.41	4.50	4-28	A
-6aa	J. Rummel..............	Du	22.6	48x72	W	Al	C,E	Ind	Tpf	-1.00	3,727.32	15.20	4-28	A
-6ac	Forest Vale Cemetary....	Du	35.4	72	C	Al	C,E	I	Tpf	+1.15	3,747.15	21.90	4-27	A
-6bd	.....do................	DD	44.0	72	C	Al	C,E	I	Tpf	+.74	3,748.04	23.50	4-27	A,Ca
-6ca	H. Posey...............	Du	26.7	40	W	Al	Cy,E	D,S	Tpf	+.50	3,754.85	23.70	4-27	A
-6da1	E. Ludtke..............	Du	22.9	28	W	Al	Cy,H	D,S	Tpf	+.38	3,738.28	17.90	4-28	A
-6da2	Fredricks..............	Du	17.8	30	C	Al	Cy,E	D	Tpf	-5.21	3,736.59	9.90	4-28	A
-6dd	Royston................	DD	47.2	48	P	Al	J,E	D	Tca	.00	3,743.87	13.70	4-28	A
-7aa1	Bryant.................	DD	17.7	48	W	Al	J,E	D	Tpf	.00	3,756.06	12.90	4-28	A
-7aa2	B. Menard..............	D	28.2	30	C	Al	Cy,J,E	D,S	Tpf	+.63	3,759.93	19.20	4-28	A
-7ac	Ashwood................	Du	20.1	48	W	Al	Cy,H	N	Tpf	+.75	3,769.75	15.40	4-27	
-7ad1	E. Hilger..............	Du	36.2	36	W	Al	C,G	I	Tpf	+1.00	3,766.92	10.80	4-27	A
-7ad2	J. Hatcher.............	Dr	42.6	6	P	Al	C,G	I	Tpf	.00	3,762.85	11.50	4-27	A
-7cd	Porter Bros............	Du	17.1	48	W	Al	C,E	I	Tpf	-.84	3,795.06	9.10	4-27	N
-7dc	McHugh Dairy...........	Du	33.1	72	P	Al	C,E	I	Tpf	.00	3,793.34	16.00	4-27	N
-8aa	G. Middlemas...........	Dr	35.5	6	P	Al	N	I	Tca	+.80	3,735.50	4.20	4-30	N
-8bc	.....do................	Du	13.8	72	W,M	Al	N	N	Tpf	+2.22	3,756.02	11.00	4-27	
-8cb	K. Monroe..............	Du	18.8	36	M	Al	Cy,H	D	Tpf	.00	3,762.22	10.70	4-27	A
-8cc	H. Lamb................	Du	31.4	72	W	Al	C,G	I	Tpf	+1.37	3,781.57	22.60	4-27	N
-8dd	.....do................	Du	11.7	48	W	Al	Cy,G,H	S	Tpf	+1.44	3,749.44	8.10	4-27	A
-9da	Cain...................	Du	3.0	16	P	Al	B	S	Tca	+.90	3,714.07	2.00	5- 3	A
-9dd	A. Olson...............	Du	7.6	24	M	Al	C,E	I	Tpf	+.50	3,717.84	4.60	5- 3	N
-10bb	T. Herrin..............	DD	26.4	30	C	Al	J,E	D,S	Tca	-1.12	3,706.88	5.00	5- 4	A
-10bd	.....do................	Du	6.2	72	W	Al	N	N	Tca	.00	3,722.16	4.80	5- 4	
-10cc1	C. Huber...............	Du	7.1	48	W	Al	B	S	Tcu	+.90	3,724.51	5.00	5- 3	A
-10cc2	.....do................	Du	7.2	60	W	Al	N	I	Tca	+1.10	3,721.40	3.20	5- 3	N
-10dd	M. Warren..............	Du	14.2	60	W	Al	C,G,B	D,I	Tpf	+.66	3,738.26	13.00	5- 3	A
-11ab1	E. Hilger..............	Du	36.5	72	C	Al	C,G	I	Tca	+.78	3,725.38	18.30	5- 6	N
-11ab2	.....do................	Du	37.6	72	C	Al	C,G	I	Tca	+1.12	3,725.62	19.60	5- 6	N
-11ba	Donaldson..............	Du	37.1	72	C	Al	C,E	I	Tpf	.00	3,722.90	15.80	5- 5	N
-11cc	C. Olson...............	Dr	54.7	12	P	Al	C,E	I	Tca	+.70	3,740.07	16.60	5- 3	N
-13bb	B. O'Connell...........	Du	61.1	53	P	Al	N	N	Tca	+.30	3,761.06	32.61	9-29	
-14cb	J. Rogan...............	Du	47.2	108	P	Al	N	I	Tpf	+.42	3,770.34	24.40	5- 3	N
-14db	E. Peterson............	Du	38.1	36	M	Al	Cy,H,G	D,S	Tpf	.00	3,773.40	29.40	5- 3	A
-15ab1	Burton.................	Du	7.5	40	P	Al	C,E	S	Tca	+.50	3,739.21	7.90	5- 3	A
-15ab2	Schwartz...............	Du	8.8	48	W	Al	C	N	Tpf	+.50	3,735.43	8.00	5- 3	A
-15ac	J. Rogan...............	Du	15.6	36	M	Al	Cy,H	S	Tpf	+.40	3,745.42	8.20	5- 3	A
-15ba1	M. Halverson...........	Du	12.5	72	W	Al	C	N	Tca	+.50	3,733.17	3.30	5- 3	A,Ca

Table 6.--Records of wells and springs in Helena Valley, Mont.--Continued

Well number	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Geologic source	Method of lift and type of power	Use of water	Measuring point: Description	Measuring point: Distance above (+) or below (-) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement (1948)	Remarks
10-3-15ba2	M. Halverson............	Dr	15.2	6	P	Al	J,E	D	Tca	-2.66	3,732.44	3.70	5- 3	A
-15bd	B. Lichtwardt...........	Du	11.5	48	C	Al	J,E	D,S	Tpf	+.30	3,737.79	4.70	4-30	A
-16ac	.....do.................	Du	20.8	30	M	Al	N	N	Tpf	+1.00	3,754.23	15.30	4-30	
-16bc	.....do.................	Dr	70.1	6	P	Al	C,G	I	Tca	+2.64	3,773.14	29.90	4-30	A
-16da	.....do.................	Du	10.8	16	P	Al	Cy,H	D,S	Tpf	+.60	3,743.26	4.50	4-30	
-17bc	Resurrection Cemetary...	Du	55.8	48	W	Al	C,E	I	Tpf	+.50	3,806.09	42.80	4-27	A,Ca
-17dd	....	Du	59.6	30	M	Al	N	N	Tpf	+.52	3,813.31	59.30	8-10	
-18ac	J. Yuhas................	DD	57.0	48	W	Al	Cy,H C,E	I,S	Tpf	+.63	3,825.73	38.20	4-27	A
-18ad	A. Wolf.................	Du	48.9	36	C	Al	Cy,H	N	Tca	+1.00	3,812.71	41.30	4-27	
-18cb	Lewis & Clark County....	Du	29.5	72	W	Al	C,E	I	Tpf	.00	3,834.00	4.78	8- 9	A
-19ad	....	Du	34.0	72	...	Al	B	D	Tpf	+2.10	3,881.47	28.45	7-16	
-20bc1	H. Hazeltine............	Du	17.0	30	M	Al	Cy,E	D	Tcu	+.30	3,878.24	9.38	7-16	A,Ca
-20bc2	W. Baumgard.............	Du	21.2	40	...	Al	Cy,H	D	Tpf	+.60	3,868.94	14.92	7-16	A
-20bc3	C. Belgarde.............	Du	21.9	60	...	Al	J,E	D,S	Tpf	+.10	3,866.49	12.22	7-16	A
-20bc4	Van Sickle..............	Du	38.3	40	C	Al	C,E	D,S	Tcu	+.30	3,883.98	24.65	7-16	A
-20bc5	D. Belgarde.............	Du	12.0	60	...	Al	Cy,H	D	Tpf	+.30	3,875.34	7.47	7-16	A
-20bd	F. Carr.................	Du	18.8	36	M	Al	Cy,H	D,S	Tpf	+.50	3,874.81	12.00	7-14	A
-20cb1	L. Fournier.............	Du	28.5	48	M	Al	J,E	D,S	Tcu	.00	3,888.34	16.27	7-14	A
-20cb2	Don Vincent.............	Du	20.4	48	W	Al	J,E	D,S	Tcu	+.20	3,886.53	14.30	7-14	A
-20da1	Cold....................	Du	15.5	48	C	Al	B	D	Tpf	+.30	3,874.59	6.07	7-14	A
-20da2	J. Dunn.................	Du	13.4	48	M	Al	B	D,S	Tpf	+.80	3,873.00	6.47	7-14	A
-20da3	J. Hamlin...............	Du	11.5	48	M	Al	Cy,H	D	Tpf	+.20	3,874.01	6.03	7-14	A
-20db	S. Bogard...............	Du	24.5	48	...	...	Cy,E	D,S	Tpf	+1.00	3,882.56	14.66	7-14	A
-22aa1	W. Lichtwardt...........	Du	24.3	36	...	Al	Cy,H	D	Tpf	+2.32	3,769.82	17.80	5- 3	A
-22aa2	.....do.................	Dr	56.2	6	P	Al	J,E	S	Tpf	+.50	3,769.36	7.80	5- 3	A,Ca
-22ab	G. Bompart..............	Du	17.9	36	W	Al	N	N	Tpf	+.36	3,764.76	14.10	5- 3	
-22ba	J. Bompart..............	Du	47.6	30	W	Al	Cy,E	D,S	Tpf	+.70	3,785.90	36.90	5- 3	A
-22da	Trutmau.................	Du	84.0	36	...	Al	Cy,H	D,S	Tpf	+1.75	3,825.15	69.00	5- 5	A
-24cb	L. Henry................	Du	46.5	30	C	Al	N	N	Tcu	.00	3,821.87	42.00	5- 7	
-24dc	S. Poe..................	Du	38.0	48	W	Al	B	S	Tpf	-.15	3,838.05	17.80	5- 7	A
-25bc1	F. Lamping..............	Du	22.5	48	W	Al	N	N	Tcu	+.50	3,850.08	10.95	8-10	
-25bc2	.....do.................	DD	32.3	30	W	Al	Cy,H	D,S	Tpf	+1.50	3,863.21	12.10	8-10	A
-26dd	Montana Power...........	Dr	103	6	P	Lb	Cy,E	D	Tpf	-6.00	....	63	9-27	A
-28cc	Greenyield..............	Dr	37	4	P	Lb	Cy,H	D	...	.00	4,035.20	16	9-27	
-30ca1	Dairyland Confectionary	Dr	184	9.5	P	Hls	N	N	...	.....	....	.....	....	
-30ca2	Eddy Bakery.............	Dr	127	6	P	Msh	N	N	...	.....	....	.....	....	
10-4-12da	A. Flacker..............	Du	19.2	40	W	Al	Cy,H	D,S	Tpf	+.16	3,801.86	11.70	4-27	A

-12dd1	J. Brass................	Du	12	15	M	Al	J,E	D,S	Tpf	-.83	3,810.17	7.5	4-27	A
-12dd2	.....do.................	Du	13.4	60	W	Al	C,G	I	Tpf	.00	3,811.94	4.55	9-27	N
-13ab	W. Harrer...............	Du	15.6	40	M	Al	B	D,S	Tpf	+.59	3,820.89	9.80	4-27	A
-13cc	City of Helena..........	Du	26	446	M	Al	C,E	D	L	.00	3,871.08	6.52	8- 9	In
-13da1	A. Moser................	Du	12.7	36	W	Al	N	N	Tpf	+.87	3,824.27	9.30	4-27	
-13da2	.....do.................	Du	28.1	72	W	Al	Cy,H	N	Tpf	+1.30	3,824.97	1.95	9-27	
-13dc1	L. Quackenbush..........	Du	25	24	M	Al	B	D,S	Tpf	+.50	3,863.54	21.67	7-14	A
-13dc2	V. Hodgrafer............	Du	10.5	72	W	Al	C,G	I	Tpf	+.50	3,856.01	5.35	7-14	N
-13dd	B. Rinda................	Du	40	6	P	Al	J,E	D	...	......	3,867.25	.....	....	
-23ab	S. Hartford.............	Du	9	36	W	Al	Cy,E	S	Tpf	+.30	3,904.31	5.00	8-13	A
-23ba	Montana Club............	Dr	510	8	P	Lb	C,E	D	...	......	....	.....	....	A,Ca
-23bb	Western Clay Mfg. Co....	Du	16.5	96	M	Al	C,E	Ind	Tpf	.00	3,909.31	9.57	8-13	A
-24ab	Home of Peace Cemetery..	Du	10.4	72	M	Al	Cy,H	D,S	Tpf	+.30	3,866.98	3.69	7-14	A,Ca
-24ad	P. Tongren..............	Dr	92	8	P	Al	C,E	I	...	......	....	.....	....	A
11-2-19db	R. Frey.................	DD	18.5	60	C	Lb	Cy,E	D,S	Tpf	-3.73	3,675.57	16.30	5-11	A,Ca
-30cc	O. Synness..............	Du	4.1	24	W	Al	N	N	Tpf	+.20	3,665.83	3.18	9-28	
-31ac	R. Austin...............	Du	16.9	24	C	Lb	N	N	Tca	+2.31	3,684.61	10.40	4-10	
-31bc	Munson Bros.............	Du	13.4	12	P	Al	Cy,H	S	Tpf	+.50	3,674.3	1.90	4-10	A
-31cc	L. Ramsey...............	Du	8.8	12	P	Al	P,H	S	Tca	+1.50	3,686.66	5.60	5-10	
-31cd1	Munson Bros.............	Du	18.5	12	C	Al	N	N	Tca	+1.50	3,685.41	6.70	4-10	
-31cd2	Holt....................	Du	24	420	N	Al	C,G	I	Tpf	+.50	3,685.57	3.00	5-10	N
-31db	C. Merritt..............	Du	24.5	30	M	Lb	Cy,H	D,S	Tpf	+.35	3,696.35	21.00	5-10	A
11-3-13cb	C. Vulk.................	Du	29	30	M	Al	N	N	Tca	+.87	3,686.67	25.70	5- 5	
-13dd	North Pumping Station...	Du	9.4	48	M	Al	N	D	Tpf	+1.00	3,658.41	6.80	5- 5	
-14bb	Miller..................	Du	65	36	M	Al	Cy,H	D	Tpf	+.20	3,746.40	60.90	5- 5	
-14bd	G. Winniker.............	Du	64.5	48	N	Al	N	N	Tpf	+1.00	3,745.34	57.00	8- 9	
-15bc	W. Darcy................	Du	17.6	48	C	Al	J,E	D,S	Tpf	-6.50	3,707.51	10.00	5- 5	A
-15cb	V. Proul................	Du	11.1	48	W	Al	P,H	D,S	Tpf	+.30	3,695.30	9.20	5- 5	A
-15dd	N. Stranberg............	Du	13.3	36x48	W	Al	N	N	Tpf	+.74	3,668.04	11.70	5- 5	
-16bc	E. Mote.................	Du	37.5	60	C	Al	Cy,E	D	L	.00	3,743.78	32.30	4-30	A
-16cb	D. Gentry...............	Dr	28.7	6	P	Al	J,E	D,S	Tca	+1.34	3,731.64	23.20	4-30	A
-16cc	....	Dr	.....	6	P	...	F	N	...	......	....	.....	....	
-16da	A. Thompson.............	Dr	82	4	P	...	F	S	...	......	....	.....	....	
-16dd	.....do.................	Du	8.7	24	C	Al	N	N	Tca	+.63	3,699.53	7.70	5- 5	
-17cd	Lutz....................	DD	25.4	48	M	Al	J,E	D,S	Tpf	+.20	3,739.63	25.60	4-30	A
-18dd	W. Taylor...............	Du	42.6	24	M	Al	Cy,H	D,S	Tpf	+.86	3,754.86	39.30	4-30	
-19ad	E. Charlton.............	Dr	63	6	P	Al	J,E	D	Tca	-4.23	3,744.67	30.50	4-30	A,Ca
-20bb	J. Agato................	Dr	165	11	P	Al	N	N	Tca	+1.35	3,751.37	30.41	8- 9	
-20bd	.....do.................	B	6	2	W	Al	N	O	Tca	+.10	3,699.91	4.50	8- 9	
-21ab	....	B	4	2	W	Al	N	O	Tca	+.10	3,682.80	1.80	5- 5	
-21cd1	Masonic Home............	Du	14.5	30	M	Al	Cy,E	Ind	Tpf	+2.19	3,681.29	10.10	5- 5	A
-21cd2	.....do.................	Dr	460	12.5	P	...	F	I,D	...	......	3,679.1	.....	....	A,Ca,F 125
-21dc1	.....do.................	Du	29.9	60	C	Al	N	N	Tpf	+2.61	3,680.91	11.10	5- 5	A
-21dc2	.....do.................	Dn	22.4	72	W	Al	N	N	Tcu	+1.25	3,681.35	11.40	5- 5	
-21dc3	.....do.................	Dr	408	8	P	...	F	I	...	......	....	.....	....	In
-21dc4	.....do.................	Dr	381	12	P	...	F	D	...	......	....	.....	....	In,F 70
-21dd	J. Jarvi................	DD	10.7	48x60	W	Al	J,E	D,S	Tpf	.00	3,669.92	6.90	5- 5	A
-22cb	....	Du	6.6	36	M	Al	N	N	Tca	.00	3,665.00	4.30	5- 5	

Table 6.--Records of wells and springs in Helena Valley, Mont.--Continued

Well number	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Geologic source	Method of lift and type of power	Use of water	Measuring point: Description	Measuring point: Distance above (+) or below (-) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement (1948)	Remarks
11-3-22cc	C. Siewert..............	Du	13.2	16	P	Al	Cy,H	N	Tpf	+1.00	3,667.42	8.40	5- 5	
-23bb	P. Clausen..............	DD	12	24	M	Al	Cy,H	D,S	Tpf	+.60	3,659.44	6.30	5- 5	In
-25dc	F. Miller...............	Du	12	72	W	Al	C,G	I	Tpf	+.50	3,672.94	6.20	5-10	
-26dd	....	B	4	2	W	Al	N	O	Tca	+.10	3,660.51	1.20	5- 6	
-28ac	J. Hurni................	B	4	2	W	Al	N	O	Tca	+.10	3,662.8	.30	5- 5	
-30ad1	W. Rositter.............	Du	11.9	36	M	Al	N	N	Tpf	+.50	3,718.81	10.10	4-29	
-30ad2	H. Ebert................	DD	10.2	36	M	Al	Cy,E	D	Tpf	-3.40	3,713.30	5.20	4-29	A
-30cc	Quist...................	Du	26.4	36	M	Al	Cy,H	S	Tpf	.00	3,741.98	23.30	4-29	A
-30da	L. Frank................	Du	16.0	36	M	Al	N	N	Tpf	+.40	3,711.99	6.30	4-29	
-31aa	F. Bader................	B	4	2	W	Al	N	O	Tca	+.10	3,703.5	1.08	4-29	
-31bb	.....do.................	Du	21.3	36	M	Al	C,G	N	Tpf	-2.00	3,723.19	8.20	4-29	
-31cc	Mills...................	Dr	110	6	P	Al	N	N	Tca	+.83	3,729.43	11.90	4-29	
-31da	J. Parent...............	Du	10.9	36	W	Al	Cy,H	S	Tpf	.00	3,715.45	7.00	4-29	A
-32cb	T. Evans................	Du	13.2	48x72	W	Al	N	N	Tpf	+.00	3,716.00	7.40	4-29	
-32cc1	R. Ehlers...............	Du	12.3	48	C	Al	Cy,E	D	Tpf	-5.70	3,715.80	5.70	4-29	A
-32cc2	.....do.................	Du	17.2	60	W	Al	N	N	Tpf	-1.00	3,719.29	10.20	4-28	
-32db1	R. Kelly................	Du	60	48	W	Al	N	N	Tcu	+6.00	3,706.33	3.10	4-28	Ca
-32db2	.....do.................	Du	8.2	60	W	Al	N	N	Tpf	+1.00	3,704.55	3.10	4-28	
-32dc	A. Schatz...............	Du	15.9	36	C	Al	C,E	I	Tca	+1.87	3,713.77	7.90	4-28	N
-33cc	W. Thiel................	Du	7.9	30	M	Al	C,G	S,I	Tpf	+.60	3,699.81	3.60	5- 4	A
-34bc	State of Montana........	Du	6.2	30	W	Al	N	N	Tpf	+.60	3,674.26	4.10	5- 4	
-34cc	.....do.................	Dr	341	8	P	...	F	D	...	......	....	.....	....	A,F 150
-35ac	....	B	4	2	W	Al	......	O	Tca	+.10	3,671.50	.95	5- 6	
-36cd	D. Gibson...............	Du	9.2	48	P	Al	Cy,H	S	Tpf	+.70	3,682.06	3.40	5- 5	A
11-4-36db	H. Phillips.............	Dr	89.1	4	P	...	N	N	Tca	+.62	3,763.67	44.50	8- 9	