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GEOLOGY AND WATER RESOURCES OF THE MUD LAKE REGION, IDAHO

INCLUDING THE ISLAND PARK AREA

BY

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Prepared in cooperation with the

UNITED STATES DEPARTMENT OF THE INTERIOR GENERAL LAND OFFICE, IDAHO DEPARTMENT OF RECLAMATION, and IDAHO BUREAU OF MINES AND GEOLOGY

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GEOLOGY AND WATER RESOURCES OF THE MUD LAKE REGION, IDAHO, INCLUDING THE ISLAND PARK AREA

By Harold T. Stearns, Lester L. Bryan, and Lynn Crandall

ABSTRACT

This report relates primarily to the area that contributes water to Mud Lake through surface or underground channels, but the entire area covered is somewhat more extensive. The purpose of the investigation was to determine the source of the water supplying Mud Lake and its safe yield for irrigation. Prior to about 1900 Mud Lake was an intermittent pond that seldom if ever covered more than a few hundred acres. Beginning about that time the lake increased in size, until in 1921 the aggregate area of Mud Lake and a group of smaller lakes that had come into existence reached 17,520 acres; moreover, tracts of swampy land in 1921 aggregated about 10,000 acres. The special objective of the investigation was to determine the cause of this phenomenal increase in the water supply, the quantity and permanence of this supply, and the best methods of conserving and utilizing it.

The mountains bordering the basin are made up of pre-Tertiary sedimentary rocks with complicated structure, and Tertiary rhyolites, pyroclastic rocks, and related rocks, most of which have relatively low permeability. Covering the plains area are extensive flows of Quaternary basalt and the cones from which they were derived. These flows attain a thickness of about 1,000 feet, are extremely permeable, and constitute the chief aquifers of the area. Depressions in these basalts are filled by the ancient lake beds that underlie and surround Mud Lake and Market Lake. Because of their low permeability, these lake beds give rise to perched water tables. Artesian water occurs in parts of the area where the basalt flows are intercalated with these beds. Overlying and interfingering with the basalt along the foot of the mountains are extensive alluvial deposits, and at Camas Meadows there are pre-Wisconsin glacial deposits.

The report contains data as to the discharge of the streams, their contributions to the water table, the area and capacity of the several lakes, the losses from them by diversion and evaporation, and the losses by transpiration from the swampy areas. It contains descriptions and water-level records of nearly 600 wells and analyses of 17 samples of water collected in the area. It describes the principal springs and the water tables in the Mud Lake area, Camas Meadows, Island Park Basin, Market Lake Basin, and Egin Bench and gives an inventory of the water supply.

The investigation showed that the large increase in the water supply has resulted from percolation of water used in irrigation on the Egin Bench, about 30 miles away, which caused the water table to rise and the springs to become perennial. Mud Lake reached its maximum volume in 1923. As the rate at which water percolates from the Egin Bench is nearly constant, the ground-water supply to the lake now fluctuates in response to changes in precipitation and run-off from the tributary drainage area. Methods are described for increasing the use of the water supply of the area by drilling wells and utilizing the underground reservoir formed by the water-bearing basalt.

INTRODUCTION

LOCATION AND AREA

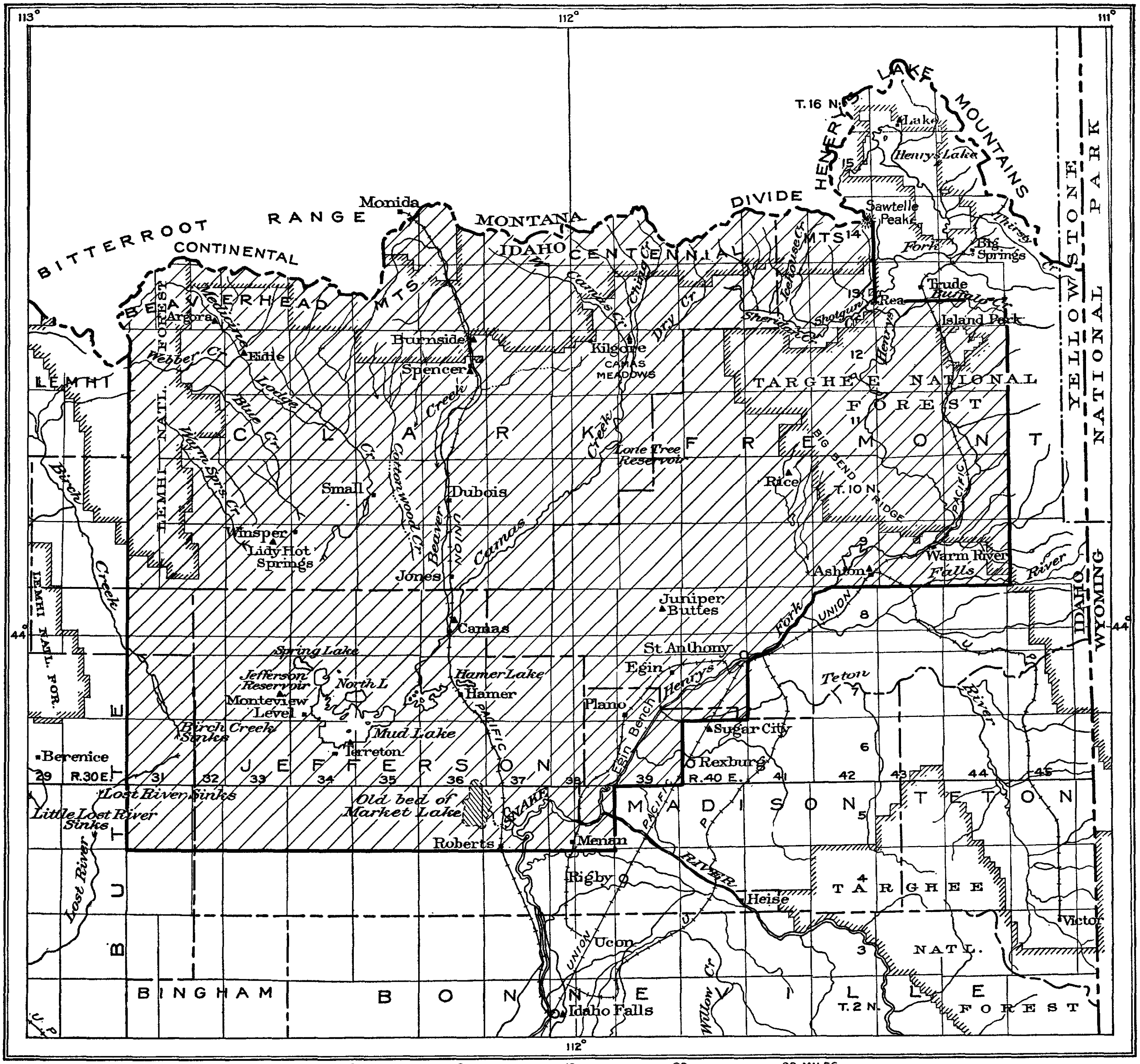
This report relates primarily to the area that contributes water to Mud Lake through surface or underground channels. The entire area covered by the report is, however, somewhat more extensive. It lies a short distance north of Idaho Falls, Idaho, and includes the northeastern part of the Snake River Plain, in which Mud Lake is situated, the mountainous area to the north whose drainage is more or less tributary to Mud Lake, and a part of the drainage basin of Henrys Fork of the Snake River, including the so-called Island Park Basin. For convenience the entire region thus described and shown on plates 1 and 3 is in this report called the Mud Lake region. It extends about 80 miles from east to west and about 60 miles from north to south, and covers about 4,000 square miles. It is crossed by the 112th meridian and the 44th parallel and includes most of Clark, Jefferson, and Fremont Counties and small parts of Madison County.

PURPOSE AND HISTORY OF THE INVESTIGATION

Prior to 1921 Carey Act inspectors of the United States General Land Office had made several short investigations relative to the water supply of Mud Lake. Their manuscript reports were filed in the General Land Office and for the most part were held confidential. With these exceptions almost no systematic study of the water problems of this region had been made. Russell's fundamental paper[1] touches only briefly on this region, although he passed through it and noted its outstanding features.

The problems relating to the proper administration and development of the land in the vicinity of Mud Lake were especially difficult because of the fact that the water in Mud Lake had increased greatly, mainly through percolation of ground water not susceptible of direct measurement. Consequently a detailed study of the water resources of the entire region was undertaken by the United States Geological Survey, with the cooperation of the General Land Office, the Idaho Department of Reclamation, and the Idaho Bureau of Mines and Geology. The investigation was conducted under the technical supervision of O. E. Meinzer, geologist in charge of the ground-water division, and C. G. Paulsen, district engineer, both of the Geological Survey. The geologic work was assigned to H. T. Stearns, and the hydraulic engineering to L. L. Bryan. Part of the data in regard to surface and ground water has been compiled and interpreted by Lynn Crandall.

[1] Russell, I. C., Geology and water resources of the Snake River Plains of Idaho: U. S. Geol. Survey Bull. 199, pp. 14, 29, 108, 109, 130, 1902.



MAP OF MUD LAKE REGION AND ADJACENT PARTS OF IDAHO, SHOWING AREA COVERED BY THE GEOLOGIC MAP.

▲ Precipitation stations.

Field work was begun in March 1921. Systematic records were obtained of precipitation, temperature, wind movement, stream flow, seepage losses and gains, pumpage from the lake, evaporation from land and lake pans, evaporation and transpiration from a tule pan, water levels in Mud Lake and several of the smaller lakes, and water levels in about 400 wells, whose relative altitudes were determined by leveling. A plane-table traverse was made of Mud Lake and adjoining lakes, sloughs, and swampy areas, and soundings were made to determine the capacity of the lake at different stages. A geologic map of the region (pl. 3) was made. This map is in general more detailed for the vicinity of Mud Lake than for outlying parts of the region. A contour map of the water table was also constructed. (See pl. 12.) With these data the source, movement, and disposal of the ground water were largely determined, and inventories were made of the total water supply.

Every effort has been made to keep those interested in the development of the region informed as to the results obtained in the course of the investigation. In June 1922 a mimeographed report covering the first year's work was made public. During the summer of 1923 Mr. Stearns studied the Island Park reservoir and dam site for the United States Bureau of Reclamation, and most of the data then obtained are incorporated in the present paper. Numerous decisions regarding Carey Act and desert-land filings in this region were made by the General Land Office in 1923 and 1924 on the basis of data supplied by Mr. Stearns. A preliminary report summarizing the principal results of economic importance of the work accomplished to the end of March 1924 was published in 1925.[2] In 1930 a manuscript report embodying later data was made available for inspection at certain offices of the United States Geological Survey.

Intensive field work was brought to an end in the summer of 1922, but arrangements were made to continue to obtain records on precipitation, evaporation, stream flow, pumpage from the lake, and water levels in wells. In 1929 most of the wells were remeasured by W. G. Steward, and a water-table map showing conditions in that year was made by Mr. Stearns. (See pl. 12.) An investigation of the entire Snake River Plain, started in 1928, has increased the knowledge of the movement of ground water in this region. Data obtained since 1929 have been studied chiefly by Mr. Crandall.

ACKNOWLEDGMENTS

Special acknowledgments are due to the Idaho Department of Reclamation for the free use of its reports, maps, and instruments and for assistance rendered in preparing the report. Acknowledgments

[2] Stearns, H. T., and Bryan, L. L., Preliminary report on the geology and water resources of the Mud Lake Basin, Idaho: U. S. Geol. Survey Water-Supply Paper 560, pp. 87–132, 1925.

are also due to the canal companies and individual water users in the vicinity of Mud Lake for their active cooperation in reading gages and furnishing records of their pumping operations. Valuable information was furnished by W. R. Armstrong, assistant chief engineer of the Oregon Short Line Railroad, who permitted the use of alinement maps and contributed data on railroad wells. Records of the United States Weather Bureau and maps and records of the United States Forest Service were used throughout the investigation. The residents of the region gave hearty support to the investigation, and valuable data were furnished by drillers in regard to wells and by several old settlers in regard to the history of the region. W. O. Hazard, of the United States Geological Survey, made the excellent photographs of the specimens illustrated herein. The authors are especially indebted to O. E. Meinzer and C. P. Ross, of the Geological Survey, for much helpful advice and constructive criticism in the preparation of the report.

HISTORICAL SUMMARY

Some of the early fur traders and explorers traversed the borders of this region. It is reported [3] that the first American trading post on the Pacific slope was Fort Henry, erected in 1810 at Egin, by Andrew Henry, of the Missouri Fur Co. This post was soon abandoned. In 1870 a stage station on the route from Salt Lake City to Butte was established at Sand Hole Lake. About 10 years later settlement began with the establishment of a few cattle ranches along Camas, Beaver, and Medicine Lodge Creeks, on which considerable hay was raised. At that time, according to early inhabitants, Mud Lake was a more or less intermittent pond, never covering more than a few hundred acres, whereas Sand Hole Lake never went dry. About 1895 irrigation began on the terrace southwest of St. Anthony, known as the Egin Bench. About 1900, according to several witnesses, water was noticed standing in pools just east of the railroad about 1 mile north of the present site of Hamer.

It appears from Russell's account,[4] based on a visit to Mud Lake in 1900, that there were then numerous ephemeral lakes in the eastern part of Snake River Plain. Of these, Mud Lake was the only one that did not dry up every summer. He stated that Mud Lake fluctuated in area from month to month and at its maximum had an area of 40 to 50 square miles, and added that the lake was dry in the summer of 1891 and was lower in the summer of 1900 than it had been at any other time in the 9 years since 1891.

Surveys made at intervals from this time on give more accurate data as to the fluctuations of the lake and indicate that the extremes

[3] Rees, J. E., Idaho chronology, nomenclature, bibliography, p. 11, Chicago, W. B. Conkey Co., 1918.

[4] Russell, I. C., op. cit., p. 130.

have not been as great as those indicated by Russell. In May and June 1899 a meander survey of Mud Lake by the General Land Office showed a water surface of 2,460 acres and dry lake beds to the south and west of Mud Lake occupying about 3,000 acres. From 1899 to 1908 the lake rose very little, if at all. In 1908 a survey of the lake by O. E. Peterson showed practically the same area covered by water as was shown by the General Land Office survey in 1899. Mr. Peterson found all except one of the original Land Office monuments around the lake. From 1908 to 1914 the lake rose about 5 feet, as indicated by a survey made by D. P. Olson in 1914, which showed a water surface of about 14,200 acres. This is the latest survey of any consequence until the present investigation was begun in 1921. Unfortunately, no gage readings to show the rise and fall of Mud Lake were made prior to 1921.

In 1908 the first water filing was made on Mud Lake for irrigation, and in 1921 more than 150,000 acres was included in several projects for which it was planned to obtain water from Mud Lake and nearby lakes and sloughs. This acreage was divided among two large Carey Act projects aggregating about 30,000 acres and numerous private irrigation enterprises. Dry farming has been attempted in several parts of the region and has been partly successful on the high slopes north of Dubois, between Medicine Lodge and Camas Creeks, and in the vicinity of the Juniper Buttes. Close to Mud Lake it has met with failure.

During recent years the cattle industry of the Mud Lake region has been largely replaced by the sheep industry, until now about a quarter of a million sheep are raised here annually. The United States Government has established an experiment station at Dubois, where efforts are being made to breed sheep that will be good for both mutton and wool.

The Wood Live Stock Co., with headquarters at Spencer, and the Wool Growers Association, of Sugar City, control most of the range. They usually feed the sheep in the winter at the irrigated tracts, such as Egin Bench, Roberts, or Mud Lake, and graze them in the spring on the lava plains at the foot of the Centennial Mountains. Later, as the grass dries and water becomes scarce, the sheep are driven into the mountains for the summer. In the fall they return over the same route, using the spring range on the way to the feeding ground. Several large branding and shearing corrals are located in the region.

The principal towns within the region, with their population in 1930, are St. Anthony, 2,778; Ashton, 1,003; Dubois, 312; and Roberts, 297. Of these only Dubois lies within the drainage basin of Mud Lake. Other villages within the drainage basin are Camas, Hamer, Spencer, and Kilgore. The Lidy Hot Springs are also in this drainage basin.

The annual inflow into Mud Lake, which reached a peak of 83,000 acre-feet in 1923, gradually declined thereafter until 1929 and 1930, when it was only about 40,000 acre-feet. This decrease in water supply resulted in the abandonment of the lands holding the later water filings and a gradual decline in the population of the area in the vicinity of Mud Lake.

GEOGRAPHY

TOPOGRAPHY

The part of the Snake River Plain covered by the present report is an area of low relief, dotted by buttes and rimmed on the north by rugged mountains (pl. 3). Mud Lake on June 10, 1921, had an altitude of 4,784 feet above the sea. Except for some of the buttes, the plain throughout the region lies below an altitude of 4,900 feet, and much of it is below 4,800 feet. North of the plain are the Centennial and Beaverhead Mountains, with peaks that rise to about 10,500 feet above the sea. The Centennial Mountains are east of the low pass utilized by the Oregon Short Line, and the Beaverhead Range is west of this pass. There are mountains also along the eastern boundary of Idaho, beyond the valley of Henrys Forks of the Snake River. The Big Bend Ridge and the Juniper Buttes lie on the west side of the valley of Henrys Fork and separate it to some extent from the plain in which Mud Lake lies. The Big Bend Ridge extends from Henrys Fork near Ashton, for about 18 miles to the wide valley of Sheridan Creek, which separates it from the Centennial Mountains. The ridge attains a maximum altitude of about 7,500 feet. The Juniper Buttes, west of St. Anthony and southwest of the Big Bend Ridge, reach an altitude of about 6,200 feet.

From the edge of the Beaverhead and Centennial Mountains a smooth alluvial slope extends toward the lower parts of the Mud Lake drainage basin with constantly decreasing gradient, but this slope is interrupted in places where the underlying lava rock appears at the surface. The part of the region lying east of the railroad that passes through Hamer and Dubois consists largely of undulating lava plains with numerous lava buttes. The lowest part of the Mud Lake drainage basin consists of a depression in the lava rock, overlain in part by ancient lake beds which form a nearly level surface. South of the lake there is an extensive area underlain by lake beds that slopes very gently northward. The southern border of the drainage basin is formed by a low irregular swell in the lava surface.

Mud Lake occupies a shallow but definite depression which was formed, at least in part, by wind erosion of the more ancient lake beds. Some of the numerous lakes, ponds, and sloughs north and east of Mud Lake occupy depressions made by the wind, and others occupy original depressions in the lava rock.

Stretching southwestward from St. Anthony, in the left bank of Henrys Fork, is a river terrace, the Egin Bench. It is about 14 miles long and 4 miles wide, is underlain by gravel and sand, and has an average gradient of about 10 feet to the mile. It lies outside of the Mud Lake drainage basin but within the region covered in this investigation, and, as is shown later in this report, it contributes water undergound to the Mud Lake Basin.

FAUNA

The wild life in the region offers considerable sport for the hunter. In the Centennial Mountains there are bear, deer, elk, moose, mountain goats, sheep, and mountain lions. During the earlier part of the investigation in 1921 and 1922 numerous bear, deer, and elk were seen. In the years when berries are scarce in Yellowstone National Park the bear migrate in large numbers into this region. During one of these years bear were killed near Ashton and in the Juniper Buttes. In 1922 many of the sheep herders returning from the summer range had their camps pilfered by bear. Brown and black bear are the commonest, although occasionally a grizzly is encountered.

Among the smaller animals in the mountains, coyotes, porcupines, gophers, and squirrels predominate, although timber wolves are sometimes reported. Bounties on coyotes, wolves, and lions do much to keep their numbers checked.

On the plains coyotes, bobcats, antelope, and badgers are sometimes seen. One large herd of antelope lives on the alluvial fan of Medicine Lodge Creek. They are protected by law and hence are very tame. Coyotes and rabbits, which were numerous in 1921, have been nearly exterminated by trappers because of the increase in the value of furs. There is abundant bird life on the plains. Sage hens occur in large numbers, and in the winter flocks of several hundred may be seen. Mud Lake is noted for its thousands of water fowl. During the hunting season hundreds of people go to Mud Lake for duck shooting, and usually a special train is sidetracked at Hamer. Sixty-seven species of birds were noted during 1921 and 1922. Among them are many migratory water fowl that can be seen only during certain months.

FLORA

Numerous plants were collected during the investigation and were sent to the United States Department of Agriculture for identification. Sagebrush (*Artemisia tridentata*) is the most abundant native plant, growing luxuriantly almost everywhere except in swampy tracts where it has been killed by the rise of the water table. White or sweet sage (*Eurotia lanata*) is common on Sweet Sage Flat, northwest of Monteview. Sheep and cattle will feed on white sage; hence areas covered with it make a fair fall and spring range. Rabbitbrush (*Chrysothamnus* *pumilus*) and Russian thistle or tumble weed (*Salsola pestifer*) are also common throughout the region. The former provides food for jack rabbits during the winter; the latter, which seems to grow most abundantly on cleared land, serves as winter fodder for hungry sheep when better feed is not available. As its specific name implies, Russian thistle is a pest to the farmer. In the Juniper Buttes grows a tall weed locally called the umbrella weed, which is even more of a pest than the Russian thistle. Above an altitude of 4,500 feet buckbrush (*Symphoricarpos symphoricarpus*) and chaparral are found. The berries and tender shoots of buckbrush provide feed for deer and sheep. Around Mud Lake and the adjacent sloughs luxuriant growths of marsh grass and tules flourish during years when the water table is high. Where the sagebrush has been killed by the rise of the water table, greasewood (*Sarcobatus vermiculatus*), wild rye (*Elymus condensatus*), and squirreltail (*Hordeum jubatum*) have found a place.

The mountain areas support good stands of Douglas fir and lodgepole pine. On Camas Creek, in the Targhee National Forest, two sawmills were producing Douglas fir lumber in 1921. The lodgepole pine farther east is used extensively for making railroad ties. The shipping point for the ties is Island Park. Small patches of mountain mahogany are common on the foothills in the northwestern part of the Mud Lake region. All timber lands are included in the Targhee National Forest except a small area in the northwest corner, which is in the Lemhi National Forest. (See pl. 1.)

SOIL

Where fresh lava does not lie at the surface, the Snake River Plain in this region is generally covered with a fine sandy or clayey loam soil, most of which has been deposited from dust-laden winds sweeping across the desert. Where this soil is irrigated it produces excellent crops, and it is also a good soil for dry farming. Where it is not cultivated it produces native grass and sagebrush in abundance. If it were not for this loesslike soil, tens of thousands of acres of rather recent lava, which are now so valuable for sheep grazing, would be barren and worthless.

The soil south and west of Mud Lake is a clayey loam derived from the ancient lake beds and is productive when irrigated. It is remarkably free of coarse material and does not vary notably as to texture except where the clayey material is covered by wind-blown sand. In the area north of Monteview the soil is a clayey loam with a few streaks of pea-sized gravel.

The Mud Lake Basin does not contain much alkali soil. Except in the vicinity of Spring Lake and along the sloughs in other localities, alkali has not been brought to the surface in such quantities as to be detrimental.

The Juniper Buttes are largely covered with a heavy loam that in some years yields cereal crops without irrigation. Thousands of acres in the vicinity of the Juniper Buttes, however, are covered with migrating sand dunes of the cusp type, some of which reach heights of 200 feet.

The upper part of the Egin Bench consists of loam underlain by gravel, but toward the south and west this soil changes progressively to a sandy loam and a black sand. On account of the great permeability of the soil and subsoil the Egin Bench requires a very heavy use of water for successful cultivation. The entire bench is subirrigated by building up the water table.

CLIMATE

TEMPERATURE

The mean annual temperature for the year ending March 31, 1922, was 38° F. at Mud Lake, 42.8° at Idaho Falls, 36.2° at Lake, on Henrys Lake, and 40.9° at Lost River. The mountains on the borders of the region have a colder climate, but temperature data for them are lacking. In the vicinity of Mud Lake the temperature seldom reaches 100° but occasionally falls to 30° or more below zero. In most years the first killing frost in the autumn occurs before the middle of September, and the last killing frost in the spring during the last part of May or the first part of June.

PRECIPITATION

Precipitation records have been obtained for periods of years by the United States Weather Bureau at several places in or near the Mud Lake region, and in connection with this investigation at Mud Lake, Camas, Monteview, Juniper Buttes, and Argora. (See pl. 1.) The Mud Lake station is at the First Owsley pumping plant, about 1 mile east of Terreton and about 1 mile south of Mud Lake (pl. 2, A.) The monthly records at these stations are given in the following table except those for the Mud Lake station, which are given, in connection with other records, on page 91.

Monthly and annual precipitation, in inches, at stations in or near the Mud Lake region, Idaho

[From records of U. S. Weather Bureau and U. S. Geological Survey. See pl. 1]

Argora (altitude 7,000 feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1922	------	------	------	------	------	------	1.08	2.52	0.09	Tr.	1.20	1.85	------
1923	1.08	0.17	0.32	1.88	3.18	3.14	1.34	2.16	.45	1.90	.04	.83	16.49
1924	.08	.25	.51	Tr.	.24	.41	1.12	.22	1.16	1.47	.07	.97	6.50
1925	.52	1.45	------	------	------	------	------	------	------	------	------	------	------
1929	------	------	------	.77	------	1.07	3.87	.95	1.25	1.33	1.38	------	------
1930	1.40	1.21	.27	1.62	------	------	------	------	------	------	------	------	------
Average	.77	.77	.37	1.07	1.71	1.54	1.86	1.46	.74	1.57	.70	1.22	13.78

Monthly and annual precipitation, in inches, at stations in or near the Mud Lake region, Idaho—Continued

Ashton [1] (altitude 5,100 feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1897	------	3.75	2.56	1.51	0.70	1.64	1.80	0.10	0.80	2.34	2.12	3.60	------
1898	3.40	1.90	1.90	.47	.29	.15	1.80	.05	.09	.61	------	------	------
1899	2.02	.72	1.50	.95	2.33	1.04	.75	.34	[2] .10	1.66	.47	.96	12.84
1900	.62	.51	.38	1.87	1.08	.24	.23	------	------	------	------	------	------
1901	------	------	------	------	1.44	1.09	.06	1.36	.55	.82	.52	.60	------
1902	.32	.67	.95	.45	1.08	.53	1.42	Tr.	[2] .20	.35	1.90	[2] 1.10	8.97
1903	1.87	.62	1.53	3.09	3.02	.77	.19	.20	1.91	.95	1.70	1.18	17.03
1904	1.47	1.85	4.22	1.53	1.30	1.20	Tr.	.58	Tr.	.75	.11	1.01	13.82
1905	.40	.30	.73	.25	[2] 3.50	[2] 1.00	.07	.58	.95	.35	.50	1.00	9.63
1906	.95	2.62	2.88	1.83	4.66	1.64	.75	.72	1.20	.77	1.35	2.87	22.24
1907	3.55	.75	3.11	.41	1.05	4.29	.60	.77	.03	.75	.20	2.54	18.05
1908	1.00	1.00	1.50	.73	2.30	2.18	.25	1.75	.13	.50	.57	1.67	13.58
1909	2.74	1.60	.52	.31	1.52	.85	.82	Tr.	3.36	.64	3.41	2.03	17.80
1910	2.15	2.54	.56	.85	1.73	.05	.04	Tr.	.74	2.49	2.77	1.68	15.60
1911	3.88	1.29	.44	.93	2.62	3.02	.50	.08	.95	3.74	1.00	1.38	19.83
1912	2.30	1.05	2.27	1.65	3.30	2.48	1.83	2.30	1.43	3.13	.96	1.05	23.75
1913	.87	1.31	.73	1.64	2.39	2.62	5.60	.09	1.04	.66	1.38	.17	18.50
1914	1.40	1.45	------	------	------	------	.47	.00	2.33	2.25	------	------	------
1915	1.70	------	.74	1.75	5.51	.93	1.67	.30	2.15	.55	1.90	------	------
1916	3.55	1.77	------	1.15	1.75	1.12	.77	.89	.18	1.83	1.02	3.38	------
1917	1.66	1.46	------	2.60	2.93	------	.51	.34	2.16	.07	1.03	1.68	------
1918	3.30	2.50	1.03	2.10	1.97	3.16	1.27	.64	1.93	1.97	.22	.43	20.52
1919	.87	1.59	.82	.31	.56	.00	.39	.19	1.94	1.53	.62	.76	9.58
1920	.13	.32	.61	1.45	1.28	.51	.29	.98	1.02	1.61	1.87	2.51	12.58
1921	2.63	1.30	.83	.57	3.98	.59	.69	.84	1.03	.42	.62	2.16	15.66
1922	2.47	1.96	.62	.65	1.24	1.13	1.39	1.49	.00	.59	.63	1.42	13.59
1923	1.12	.51	.91	1.59	1.46	2.43	1.47	.60	.40	.99	.62	1.10	13.20
1924	.92	.99	.27	.18	.20	.40	1.39	.07	1.39	2.86	.69	2.19	11.55
1925	4.45	.62	.92	2.44	1.18	2.28	.97	1.07	2.85	1.23	1.76	2.15	21.92
1926	1.56	2.43	.02	.54	.88	.68	.14	.61	1.09	.23	2.32	1.96	12.46
1927	1.75	1.50	.29	1.14	3.43	1.23	.18	.49	2.81	2.53	2.96	2.07	20.40
1928	.91	.79	.88	.25	1.11	1.90	.44	.40	.42	.63	1.85	.92	10.50
1929	2.51	1.23	.54	2.22	.53	2.53	.33	.46	1.55	1.11	.54	.46	14.01
Average	1.89	1.38	1.18	1.20	1.92	1.31	.88	.57	1.15	1.28	1.25	1.59	15.73

Burnside (altitude 5,500 feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1896	------	0.03	1.35	0.27	3.59	1.49	1.49	0.66	Tr.	1.00	0.73	1.13	------
1897	0.37	1.05	.32	.02	.78	1.41	Tr.	.11	1.59	2.45	.51	.93	9.54
1898	.64	.36	.05	.10	2.92	1.79	1.53	1.44	Tr.	.50	1.28	.30	10.91
1899	1.10	.47	.65	.57	.35	1.13	1.36	1.35	------	.42	.82	.71	------
1900	.05	.20	.55	1.81	.85	[2] .30	.23	.15	.75	.70	.90	.25	6.74
1901	1.40	.35	.75	1.20	.97	1.24	.20	.82	.60	.50	.25	1.45	9.73
1902	.55	1.25	.55	.75	2.33	[2] .60	1.59	.45	.05	.15	1.90	1.30	11.47
1903	.60	.10	2.00	1.15	2.25	2.47	.50	.40	1.26	1.90	.70	.50	13.83
1904	.30	2.10	2.40	------	.05	.14	.14	.50	.50	------	------	------	------
1905	.17	.04	1.81	.57	2.10	3.20	.75	.39	.39	------	------	------	------
Average	.58	.60	1.04	.72	1.62	1.38	.78	.63	.57	.95	.89	.82	10.58

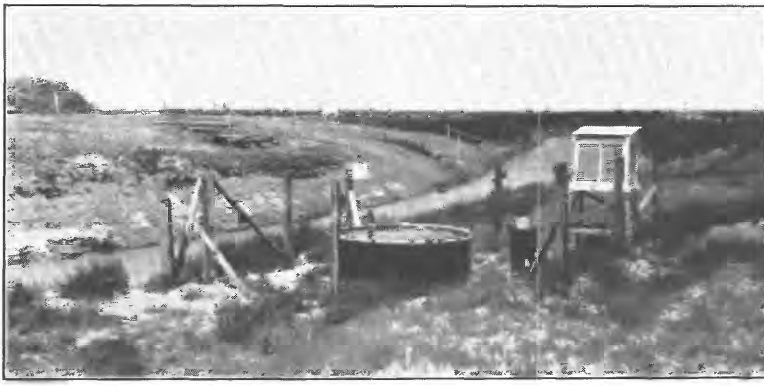
Camas (altitude 4,817 feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1908	0.47	0.71	1.04	------	------	------	------	0.68	0.61	------	------	------	------
1909	.47	.71	1.04	0.22	2.06	0.54	0.50	1.40	3.27	0.69	1.89	0.48	13.27
1910	1.11	.91	.03	1.44	.49	.01	.93	.00	2.37	------	------	------	------
1911	.68	.62	.19	.99	.41	1.29	.10	.04	------	1.98	.63	1.00	------
1912	.21	.22	.63	.82	------	------	------	------	------	------	------	------	------
1921	------	------	------	------	------	------	------	.75	.47	.46	.11	4.06	------
1922	1.40	.38	1.17	------	------	------	------	------	------	------	------	------	------
Average	.77	.61	.47	.87	.99	.61	.51	.57	1.68	1.04	.88	1.85	10.85

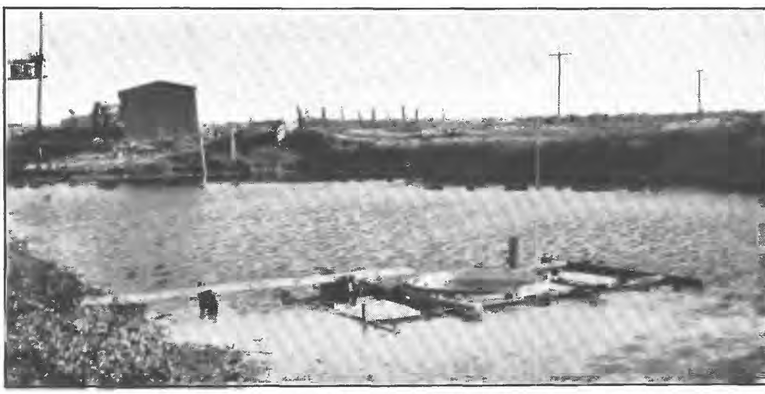
Eidie (altitude about 6,500 feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1909	------	------	------	------	------	0.39	1.29	0.85	3.47	0.66	1.24	0.42	------
1910	1.32	0.18	0.32	1.40	0.93	Tr.	1.77	.00	.83	.85	.48	.31	8.39
1911	1.07	.09	Tr.	.91	2.52	5.05	.09	.68	------	------	------	------	------
Average	1.20	.14	.16	1.16	1.72	1.81	1.05	.76	2.15	.76	.86	.36	12.13

See footnotes at end of table.



A. STANDARD WEATHER BUREAU STATION AT TERRETON.
Photograph by L. L. Bryan.



B. FLOATING EVAPORATION PAN NEAR THE MOUTH OF CAMAS CREEK.
Photograph by L. L. Bryan.

C. TULE PAN AT MUD LAKE.
Photograph by L. L. Bryan.

Monthly and annual precipitation, in inches, at stations in or near the Mud Lake region, Idaho—Continued

Idaho Falls (altitude 4,705 feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1880	------	------	------	------	------	------	------	------	------	------	------	4.50	------
1881	3.66	5.14	0.97	3.13	0.74	1.09	1.21	0.95	0.00	1.71	1.91	.80	21.31
1882	4.41	1.25	3.45	3.35	.30	.52	.30	.07	1.17	1.50	.49	1.24	18.05
1883	2.08	2.38	.41	.76	1.12	------	------	------	------	------	------	------	------
1892	------	------	------	------	------	2.05	.48	.20	.43	1.77	.74	2.10	------
1893	.93	1.78	1.38	.44	.42	.06	Tr.	.36	1.25	.14	1.29	.59	8.64
1894	1.81	1.16	2.24	1.55	1.34	2.27	.07	.58	1.13	1.28	.03	1.16	14.62
1895	1.22	.05	1.93	.39	1.82	1.30	.16	.11	.45	.06	.70	1.01	9.20
1896	1.56	.46	3.41	1.13	2.78	.65	1.16	1.08	.30	.58	3.25	.82	17.18
1897	.67	2.58	3.84	1.35	.84	.77	.20	Tr.	.55	1.48	1.90	1.59	15.77
1898	1.76	.34	1.33	.19	1.74	1.33	.93	.34	.03	.49	1.34	.76	10.58
1899	.70	.53	1.07	.44	1.50	.65	------	------	------	------	------	------	------
1904	------	------	------	------	------	------	------	------	------	------	------	.78	------
1905	.54	.56	1.37	.84	1.90	2.00	1.12	.91	.70	.33	1.16	.56	11.99
1906	1.07	1.05	2.87	1.10	2.99	1.94	.27	.83	.31	.32	.62	1.01	14.38
1907	1.28	.70	3.59	.72	1.51	2.70	.62	4.09	.75	.68	.27	1.52	18.43
1908	.63	.52	.59	.88	3.70	2.45	.39	1.18	1.13	2.87	.31	1.10	15.75
1909	1.11	1.38	.59	.09	1.60	.84	.98	.77	2.78	.75	1.26	1.17	13.32
1910	1.50	.47	.20	.60	.75	.14	.11	Tr.	1.30	1.15	1.09	.40	7.17
1911	4.18	.85	.63	.95	2.29	2.67	.30	.07	.67	2.50	1.47	1.30	17.88
1912	1.16	1.00	.95	1.94	1.36	.89	1.60	2.28	.44	3.74	.53	.43	16.32
1913	1.24	.25	.59	.35	2.39	2.99	1.86	.08	.88	1.18	.80	.93	13.54
1914	1.14	.54	.25	1.26	1.37	3.88	.45	.30	2.51	1.45	.04	.49	13.68
1915	1.35	.53	1.09	1.72	3.24	1.16	1.15	1.00	2.43	.10	.76	1.10	15.63
1916	2.31	1.47	1.52	.38	1.78	.24	.53	.80	Tr.	.66	------	------	------
1917	------	------	1.35	.90	2.71	.20	.25	.14	1.02	.05	.43	.17	------
1918	1.81	.79	1.38	.61	2.06	.79	.98	.88	.72	1.96	.32	.25	12.55
1919	.30	1.52	.51	.65	.38	.00	.65	.12	1.45	1.32	.44	1.05	8.39
1920	Tr.	.90	.92	1.67	.31	.14	.18	.85	1.63	1.51	.35	3.42	11.88
1921	.82	.68	.41	.89	1.36	.57	.60	.52	.12	.48	.45	1.50	8.40
1922	.92	1.65	.10	.85	.40	1.05	.60	1.85	.10	.25	.46	1.19	9.42
1923	.50	.17	.37	.21	1.28	1.26	1.41	.50	[2] .70	[2] 2.00	.10	.50	9.00
1924	.08	.56	.31	.68	.34	.60	.55	Tr.	.44	.47	.36	1.65	6.04
1925	1.39	.72	.55	2.10	.65	1.33	1.20	.40	1.68	1.19	1.19	1.22	13.62
1926	.92	.77	.22	.74	.32	.06	.14	.17	.64	.54	.82	.77	6.11
1927	1.00	1.38	.75	.88	1.90	.48	.29	.63	1.04	1.03	1.52	.89	11.79
1928	.57	.39	.79	.08	.79	2.03	.29	.25	.14	1.26	1.78	1.28	9.65
1929	1.38	.68	.69	1.75	.49	1.42	.20	.33	.97	.35	.13	.37	8.72
Average	1.35	1.04	1.22	1.00	1.44	1.21	.66	.67	.88	1.09	.86	1.13	12.55

Juniper Buttes (altitude 5,400 feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1922	------	------	------	------	------	------	1.00	2.54	------	------	------	1.65	------
1923	1.90	1.02	0.85	------	1.79	1.87	1.80	.80	0.40	1.87	[2] 0.30	------	------
1924	.10	1.55	------	0.45	.29	.26	1.12	.20	------	------	------	------	------
1925	------	------	------	2.40	1.42	2.45	.94	.97	2.20	1.85	1.11	------	------
1926	1.50	------	------	.35	.62	1.39	.12	.30	.25	.55	1.54	------	------
Average	1.17	1.28	.85	.80	1.03	1.49	1.00	.96	.95	1.76	.98	1.65	13.92

Kilgore (altitude 6,325 feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1912	------	------	------	------	------	------	------	------	------	------	------	1.12	------
1913	3.61	1.00	1.97	3.55	0.85	6.02	8.00	0.95	5.00	6.35	------	1.50	------
1914	3.09	------	------	------	------	------	2.52	.03	1.73	.61	------	1.57	------
1915	1.06	1.19	------	1.96	------	1.17	2.12	.84	1.17	.29	0.99	------	------
1916	3.01	------	------	.73	------	.75	1.44	.86	------	------	------	------	------
1922	------	------	------	------	------	------	1.87	3.13	------	------	------	------	------
Average	2.69	1.10	1.97	2.08	.85	2.65	3.19	1.16	2.67	2.42	.99	1.40	23.89

See footnotes at end of table.

Monthly and annual precipitation, in inches, at stations in or near the Mud Lake region, Idaho—Continued

Lake (altitude 6,700 feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1890	------	------	------	------	1.21	7.90	1.40	1.68	0.40	0.99	0.02	0.78	------
1891	0.91	4.29	1.40	0.07	------	1.91	.71	.42	1.55	.55	2.55	3.00	------
1892	2.00	1.00	1.90	1.10	2.26	1.10	Tr.	Tr.	.65	.81	2.50	2.70	16.02
1893	.85	3.20	.75	.60	.35	.58	.31	.56	2.26	.20	2.45	3.45	15.56
1894	4.05	.85	2.90	.95	1.72	2.02	1.11	1.20	.72	1.10	.20	3.00	19.82
1895	4.80	2.20	1.40	.00	.34	1.22	.10	------	.20	------	1.40	3.60	------
1896	3.00	1.40	2.00	1.30	2.50	.50	------	------	------	1.36	3.40	1.40	------
1897	.30	2.00	1.50	.00	.26	1.35	------	.00	------	1.15	1.40	1.50	------
1898	2.00	1.30	2.00	.35	1.07	1.21	.35	.60	.00	[2] .75	.80	1.50	11.93
1899	6.50	4.70	2.20	1.20	1.87	.92	.33	.58	[2] .20	2.05	.80	1.00	22.35
1900	.30	1.40	2.60	1.80	1.00	.35	.65	.45	.40	[2] .75	1.40	1.30	14.12
1901	2.60	1.30	2.40	2.70	1.40	.82	.40	1.45	[2] .75	.92	.60	2.90	18.24
1902	.30	.70	2.60	.80	1.50	.83	1.30	------	------	------	------	------	------
1903	2.20	.80	2.40	2.10	1.30	1.20	1.80	.50	2.10	.85	.90	1.90	18.05
1904	3.40	2.70	6.10	1.00	------	------	.50	.10	------	------	Tr.	.70	------
1905	.40	.00	------	1.20	------	------	1.00	------	------	.80	2.40	2.10	------
1906	2.10	2.40	2.80	1.05	3.60	1.75	.50	1.00	.45	.80	1.14	4.30	21.89
1907	4.60	.90	4.85	.80	1.52	3.25	Tr.	2.25	.50	1.50	.70	.80	21.67
1908	.90	2.10	1.50	1.35	3.20	3.66	1.12	1.70	.50	1.65	.70	.95	19.33
Average	2.29	1.85	2.43	1.02	1.57	1.80	.68	.83	.70	1.16	1.22	2.05	17.60

Monteview (altitude 4,786 feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1921	------	------	------	------	------	------	------	0.31	0.14	0.11	0.07	1.28	------
1922	1.18	0.38	0.96	0.45	0.80	0.48	0.66	1.92	Tr.	.25	.65	.75	8.48
1923	.82	.53	.14	1.00	.81	1.37	1.56	1.74	.27	1.22	.17	.19	9.82
1924	.18	.50	.45	.11	.17	.10	1.14	Tr.	.61	.78	.19	.72	4.95
1925	1.01	.74	1.26	1.25	1.06	1.51	.82	.99	1.11	1.88	.28	.74	12.65
Average	.80	.54	.70	.70	.71	.86	1.04	.99	.43	.85	.27	.74	8.63

Rice (altitude 5,600 feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1915	------	------	------	------	------	------	------	------	------	------	1.60	4.21	------
1916	6.43	2.66	------	1.20	1.47	1.37	0.68	0.65	0.22	1.83	1.92	------	------
1917	2.46	------	2.11	3.12	3.23	1.34	.46	.54	1.44	Tr.	1.58	1.55	------
1918	2.44	1.18	.56	.86	2.62	1.61	1.90	.84	2.32	1.76	.80	1.33	18.22
1919	.77	4.65	2.14	1.43	.60	.10	.40	.03	1.70	2.04	.40	1.50	15.76
1920	.05	.55	2.40	1.64	1.44	1.55	.72	.65	3.16	2.00	2.58	3.42	20.16
1921	4.37	1.77	.82	1.02	4.63	.71	1.85	.43	.73	.58	.48	2.74	20.13
1922	3.57	3.55	1.26	1.80	1.82	.95	2.09	1.79	.26	.58	1.00	2.71	21.38
1923	2.77	------	------	------	2.94	1.77	1.63	1.20	.18	1.11	1.18	1.56	------
1924	.76	------	------	1.05	.26	.41	1.33	.19	1.25	3.02	.48	1.52	------
1925	4.37	2.14	1.85	3.92	------	------	------	------	------	------	------	------	------
Average	2.60	2.36	1.59	1.68	2.11	1.09	1.23	.70	1.25	1.44	1.20	2.28	19.53

Spencer (altitude 5,883 feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1915	------	------	------	------	------	------	------	------	------	------	------	1.90	------
1916	4.24	0.44	1.58	0.45	3.37	1.01	1.36	0.74	0.16	3.21	1.32	1.87	19.75
1917	.97	------	------	1.33	2.37	1.17	.17	.49	2.51	Tr.	------	1.06	------
1918	1.10	1.82	1.58	.94	3.88	.51	5.04	1.11	1.88	2.34	.70	1.10	22.00
1919	.54	2.73	1.11	1.24	.62	.03	.39	.57	1.94	1.52	.04	1.80	12.53
1920	.07	1.56	1.23	1.34	2.14	1.03	.43	1.09	1.89	.97	1.59	2.83	16.17
1921	3.45	.72	.84	.58	4.38	.90	.72	1.47	1.22	.64	1.05	3.25	19.22
1922	2.29	1.29	2.08	1.05	2.02	.40	.93	2.77	.03	.34	1.25	2.92	17.43
1923	1.90	.51	.55	1.61	2.95	3.06	2.32	1.43	Tr.	1.91	------	------	------
1924	.75	1.67	2.82	.85	.32	------	------	------	------	1.02	1.00	2.53	------
1925	1.51	2.09	5.27	3.96	------	3.70	2.37	------	------	------	------	1.89	------
Average	1.68	1.33	1.90	1.34	2.44	1.32	1.53	1.21	1.20	1.33	.99	2.11	18.38

See footnotes at end of table.

Monthly and annual precipitation, in inches, at stations in or near the Mud Lake region, Idaho—Continued

Sugar City (altitude 4,892 feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1907	------	------	------	------	------	------	------	0.62	0.64	1.31	0.07	1.05	------
1908	0.57	0.65	0.60	0.72	3.18	3.22	0.47	.80	.96	3.14	.45	1.05	15.81
1909	1.57	1.16	.52	.20	4.83	1.00	1.07	.75	3.02	.57	2.39	2.16	19.24
1910	2.00	2.40	.44	.62	1.35	.11	.29	.15	1.20	.93	1.23	1.07	11.79
1911	1.24	.49	.17	.68	1.44	2.72	.11	.03	1.23	2.45	.99	.73	12.28
1912	.89	.35	1.73	1.01	1.76	1.06	2.02	1.66	1.01	2.67	.39	.32	14.87
1913	.76	.24	.61	.81	2.91	3.25	2.74	.30	1.26	.84	.58	1.49	15.79
1914	1.30	1.39	.22	.55	.70	3.99	.53	.02	1.72	1.46	.03	.90	12.81
1915	.88	.45	.60	1.37	6.12	1.03	1.18	.07	2.12	.41	.69	1.07	15.99
1916	1.14	.96	1.53	.45	1.24	.55	.17	.94	1.06	------	.17	1.50	------
1917	1.49	.68	.46	.78	1.35	.38	------	.15	.90	Tr.	.45	.27	------
1918	1.50	.80	1.29	.67	1.72	.68	1.31	.65	.86	------	.22	.12	------
1919	.21	1.29	.37	.75	.12	.00	.46	.05	1.73	1.22	.37	.96	7.53
1920	.04	.41	.99	1.28	.31	.16	.16	.51	.11	.85	.45	2.22	7.49
1921	1.28	.35	.32	.83	2.02	.28	.31	.64	.54	.38	.32	1.69	9.06
1922	2.41	1.20	.46	.64	.90	.46	.84	.97	.16	.30	.69	1.00	10.03
1923	.92	.26	.42	1.26	1.32	1.83	.50	.35	.50	.65	.20	.84	9.05
1924	.38	.65	.16	.49	.13	.39	.87	Tr.	.82	2.41	.12	2.69	9.11
1925	2.03	.85	.98	2.23	.78	1.14	1.26	.68	1.32	1.17	1.00	------	------
1926	1.01	1.27	.11	.67	.49	.05	.58	.24	.71	.06	.63	1.33	7.15
1927	.90	.48	.23	.82	1.59	.31	.01	.13	1.20	1.25	------	------	------
1928	.49	Tr.	.39	Tr.	.52	2.17	.37	.34	.09	.44	1.55	.16	6.52
1929	1.50	.99	.55	.63	.21	1.41	.15	.17	.90	.95	.01	.23	7.70
Average	1.12	.79	.60	.79	1.59	1.20	.73	.44	1.05	1.12	.59	1.08	11.10

[1] From 1897 to 1900, the record was made at Marysville, about 1 mile east of Ashton. From 1901 to 1914 the record was made at Vernon, about 4 miles southwest of Ashton.
[2] Estimated from records at surrounding stations.

Tr.=trace—less than 0.10 inch rain or melted snow.

The records indicate low precipitation in the vicinity of Mud Lake and somewhat greater precipitation at higher altitudes. There was a pronounced deficiency in precipitation in the Mud Lake region, in common with the rest of Idaho, in 1924, but a relatively high precipitation in 1925. From 1926 to 1929 the precipitation was each year lower than in 1925, but in none of these years was it as low as in 1924. The long-time precipitation records for Idaho Falls, Sugar City, and Ashton, show that from 1919 to 1929 the precipitation in this part of Idaho was above normal in only a few years. In other words, this region has been experiencing a long-continued period of deficient precipitation.

EVAPORATION, INCLUDING TRANSPIRATION [5]

It was necessary to determine as closely as possible the heavy losses due to evaporation from Mud Lake and the large adjoining water-covered and marshy areas and to transpiration from the rushes, or tules, that grow in these areas. A land evaporation pan, as shown in plate 2, *A*, was installed at the First Owsley pumping plant, in connection with other Weather Bureau instruments, on April 27, 1921. The pan is 6 feet in diameter and 30 inches high, is made of galvanized iron, painted black on the outside, and has a covered 2-inch stilling

[5] For more detailed statement see Stearns, H. T., and Bryan, L. L., Preliminary report on the geology and water resources of the Mud Lake basin, Idaho: U. S. Geol. Survey Water-Supply Paper 560, pp. 96–102, 1925.

well on the outside of the pan. It rests on 1-inch planks laid flat on the ground. It was kept filled daily with water within 2 or 3 inches of the top.

A floating evaporation pan, shown in plate 2, *B*, was installed on August 3, 1921, near the mouth of Camas Creek, in the backwater of Mud Lake, at Magill's ranch, about 2 miles southwest of the West Hamer Bridge, 5 miles west of Hamer, and 5 miles northeast of the land evaporation pan. The pan is made of galvanized sheet iron, 4 feet in diameter and 3 feet deep, with covered stilling well 2 inches in diameter outside. The pan was floated on a raft made of 2- by 12-inch timbers. The top or rim was about 2 inches above the water surface.

When Mud Lake is at high stages the tule-covered parts of the lake and the adjoining marshlands together occupy about three times as much area as the tracts of open water where there is no vegetation, and they discharge large quantities of water by transpiration. To aid in determining this loss a pan in which tules were grown was installed on June 13, 1921, in a marsh 1 mile north of the land evaporation pan. This pan, shown in plate 2, *C*, is made of heavy galvanized sheet iron, is 4 feet in diameter and 4 feet deep, and has a covered stilling well 2 inches in diameter inside the pan. The pan was sunk in the mud with the rim only about 4 inches above the ground surface and was filled with earth and water to a level 6 inches below the outside ground surface. Clumps of tules in about the same density as found in the surrounding area were transplanted into the pan, care being taken to damage the roots as little as possible. The pan was next filled with water and allowed to stand a day before readings were commenced. Daily readings were not obtained on account of the isolated location of the pan, but readings were made weekly, and after each reading the pan was refilled within 3 inches of the rim. The tules in the pan showed about the same growth as the plants in the adjoining marsh during 1921 and 1922. During 1923 the plant growth in the pan was below normal, and in 1924 the tule pan was abandoned because of the lowering of the water table at this place. In 1926 this marsh was reclaimed, and it is now irrigated. The results of the observations on the three pans are shown graphically in figure 1.

The evaporation from the floating pan was only about 75 percent as much as that from the land pan. The difference is explained partly by the fact that the temperature of the water was appreciably higher in the land pan than in the floating pan, and partly by the fact that the inner side of the land pan above the water surface was warmer than the sides of the floating pan, causing a larger loss from evaporation when windy weather resulted in splashing. Moreover, the floating pan was east of the lake, on the leeward of the prevailing southwest winds and therefore in the belt of comparatively high humidity,

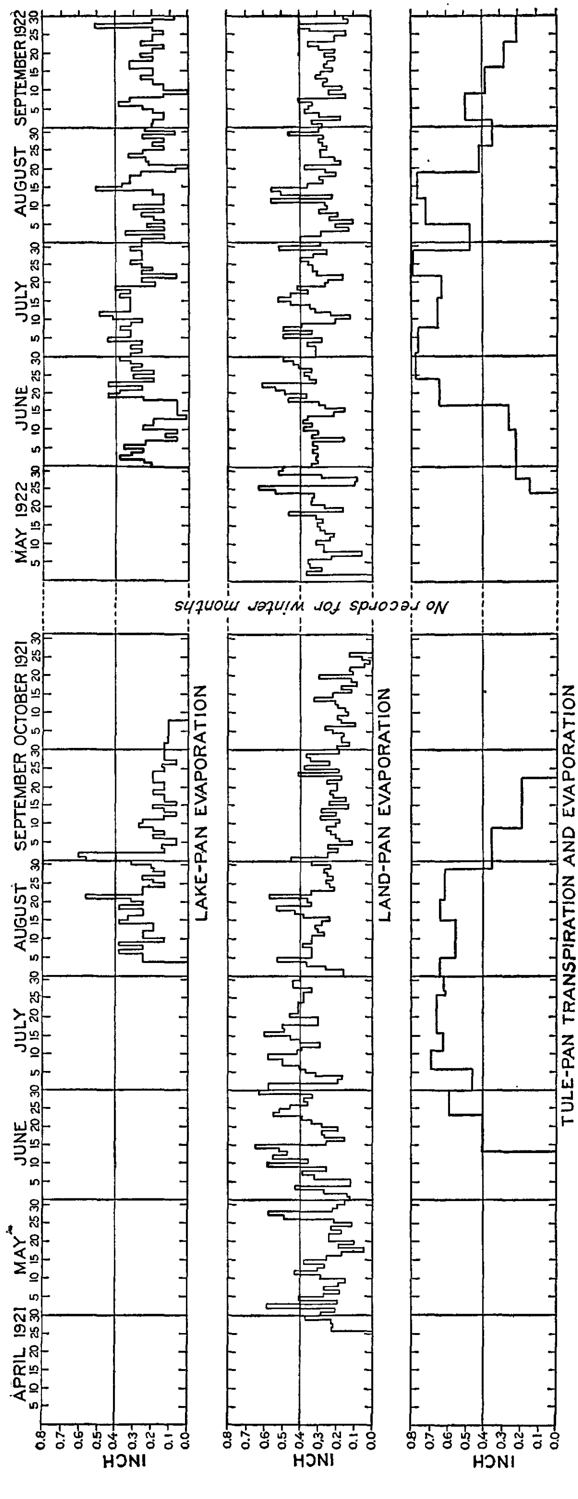


FIGURE 1.—Graphs showing evaporation from lake pan, land pan, and tule pan, Mud Lake, Idaho.

whereas the land pan was on the south side of the lake and received the dry southwest winds before they touched the lake.

The evaporation from the lake surface is believed to be even less than that from the floating pan, because the humidity is greater over the body of the lake than at the shore, thereby tending to lessen evaporation, and on the other hand the evaporation from water in the pan splashing against the heated sides of the pan above the water surface is greater. In other words, the pan had a much greater proportion of hot shore line. The effect of the wind on the lake surface in increasing evaporation is not believed to be large enough to balance the conditions that favored more rapid evaporation from the floating pan.

The ratio of the evaporation from open water to the evaporation from a 4-foot floating pan is estimated by Mead [6] to be 0.83. To reduce the land-pan records to evaporation from the lake surface it would accordingly be necessary to apply a coefficient of 0.83 multiplied by 0.75 or 0.62. A coefficient of 0.65 was somewhat arbitrarily adopted and was applied to the land-pan records in determining the loss from the open-water areas throughout the region under investigation—that is, the water areas without tules or other vegetation. This coefficient is close to the one determined by Sleight [7] for land pans of class A type of the United States Weather Bureau.

The evaporation from the land pan from April 1 to November 30, 1921, was 4.84 feet (including estimates for April 1–23 and October 28 to November 30, when records were not obtained). Applying the coefficient 0.65 to this figure shows that the loss by evaporation from the open water of Mud Lake during the same period was 3.15 feet. The evaporation from the land pan from April 1 to November 30, 1922, was 4.74 feet (including estimates for April 1 to May 2 and November 1–30, when records were not obtained). Applying the coefficient 0.65 shows that the loss from the open water of Mud Lake during the same period was 3.08 feet.

During the season of plant growth the total evaporation, including transpiration, from the marsh and tule-covered water areas is considerably larger than evaporation from the open-water surfaces. Thus in July 1921 the loss was about 12.6 inches from the land pan and 19.0 inches from the tule pan, and in August 1921 it was about 9.8 inches from the land pan and 18.0 inches from the tule pan. From June 13 to September 23, 1921, the loss was about 34.2 inches from the land pan and 51.4 inches from the tule pan.

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[6] Mead, D. W., Hydrology, p. 151, 1919.

[7] Sleight, R. D., Evaporation from the surfaces of water and river bed materials: Jour. Agr. Research, vol. 10, p. 237, 1917.

GEOLOGY AND OCCURRENCE OF GROUND WATER

The mountains bordering the Mud Lake region are composed largely of sedimentary rocks, now much altered and deformed. Most of them have received no detailed study, but they appear to include representatives of all the Mesozoic systems, most of the Paleozoic systems, and possibly some pre-Cambrian rocks. Large areas in the mountains and the greater part of such subsidiary elevations as the Big Bend Ridge are composed of lava flows, chiefly rhyolitic, and related pyroclastic rocks, doubtless of Tertiary age. Locally these rocks are overlain by or interfinger with gravel. By far the greater part of the Mud Lake region is underlain by flows of basalt and related andesite with minor amounts of pyroclastic rocks, masked here and there by still more recent products of the action of glaciers, streams, lakes, and the wind. These rocks are younger than the rhyolitic flows and are believed to range in age from early Pleistocene, or possibly Pliocene, to Recent. The ground water in this region moves mainly in the materials younger than the rhyolitic flows, and an understanding of the complicated interrelations of these different formations is therefore essential in a study of the water resources. There appears to have been so little crustal deformation since the rhyolitic flows were erupted that variations in the original characteristics and forms of the materials subsequently laid down exert a major influence on the ground water in them. Modification in surface form through the agencies of water and wind has also played a part, although neither water nor wind has had a profound effect on the existing topography.

THE ROCKS AND THEIR WATER-BEARING PROPERTIES

General section of rocks of Mud Lake region

Age	Name	General character	Relation to the occurrence of water
Recent.	Dune sand and loess.	Wind-blown sand, mostly built up into dunes.	Generally above the water table and consequently dry. Where wells are sunk in it caving becomes a problem. The finer loess is only slightly permeable.
Early (?) Pleistocene to the present.	Alluvium.	Mainly gravel with a few cobbles. Volcanic sand is locally included. In coalescing fans on the borders of the foothills and along streamways.	Very permeable. A satisfactory source of water to wells where it extends below local water table. So permeable as to make irrigation on its surface difficult.
	Lake beds.	Largely clay and silty clay. Locally sandy where stream deposits are included.	Yields water to wells only in the local sandy parts. Mostly nearly impervious.
Pleistocene (pre-Wisconsin).	Glacial deposits.	The mapped glacial deposits are bedded sand and gravel, commonly overlain by gumbo clay, in an outwash plain.	Except where clayey, yield water copiously to shallow wells.

General section of rocks of Mud Lake region—Continued

Age	Name	General character	Relation to the occurrence of water
Early Pleistocene, or possibly Pliocene, to early Recent.	Basalt flows and related cones.	Mainly basaltic lava; some andesite. Flows are locally mantled with loess. Many of the minor buttes on the plains are cones belonging to this period of eruption.	Highly permeable because of openings along contacts between flows and cooling cracks.
	Tuff.	Beds of tuff and unconsolidated lapilli interbedded with basalt in and near Menan Buttes.	Yields water satisfactorily to wells where suitably situated.
Pliocene or older.	Tertiary sedimentary rocks.	Mainly gravel, locally tuff and calcareous material. Mostly deposited in alluvial fans.	Permeable; would yield water readily to wells if suitably situated, but most of it is not in places where wells are needed.
	Rhyolite and related pyroclastic rocks.	Mainly banded light-colored rhyolite tuffs and flows with some agglomerate. Locally flows of basalt and andesite.	Commonly not good water bearers, with local exceptions
Cretaceous and older.	Pre-Tertiary sedimentary rocks.	Mostly sandstone, limestone, and quartzite. Some conglomerate. Far more deformed than any of the younger rocks.	With local exceptions, do not permit the ready passage of water. Springs locally issue along fissures in them.

PRE-TERTIARY SEDIMENTARY ROCKS

During the present investigation several trips were made by the senior author into the mountains with the object of tracing the streams toward their sources and of getting information as to the possibility of water from the many lakes on the Montana side of the divide finding its way through the mountains into the Mud Lake drainage basin. Some observations on the geology were made in connection with these trips.

Marble and quartzite, possibly of pre-Cambrian age, were observed in the vicinity of Sawtelle Peak, southwest of Henrys Lake. (See pl. 1.) Numerous quartzite boulders occur in the Tertiary sedimentary rocks on the mountain flanks east of Medicine Lodge Creek. These boulders differ from any rocks known to crop out in the neighboring mountains but resemble early Paleozoic rocks in the mountains to the west and southwest,[8] the nearest known exposures of which are on the east side of Birch Creek,[9] about 20 miles southwest of the outcrop of the Tertiary beds referred to.

Carboniferous beds, mainly limestone, occupy large areas in the Centennial and Beaverhead Mountains. Published data [10] indicate

[8] Umpleby, J. B., Geology and ore deposits of Lemhi County, Idaho: U. S. Geol. Survey Bull. 528, pp. 32–33, 1913; Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, pp. 23–25, 1917.

[9] Shenon, P. J., Geology and ore deposits of the Birch Creek district, Idaho: Idaho Bur. Mines and Geology Pamph. 27, pp. 5–7, 1928.

[10] Condit, D. D., Relations of late Paleozoic and early Mesozoic formations of southwestern Montana and adjacent parts of Wyoming: U. S. Geol. Survey Prof. Paper 120, pp. 116–117, 1919. Kirkham, V. R. D., A geologic reconnaissance of Clark and Jefferson and parts of Butte, Custer, Fremont, Lemhi, and Madison Counties, Idaho: Idaho Bur. Mines and Geology Pamph. 19, pp. 19–21, 1927. Shenon, P. J., op. cit., pp. 7–8.

that beds of upper and lower Mississippian, Pennsylvanian, and Permian age are included. The lower Mississippian (Madison) age of beds in the eastern part of the Centennial Mountains is confirmed by fossils collected in thinly laminated shaly limestone near the south side of Spread Eagle Peak, half a mile east of the Idaho-Montana iron milepost marked "676.036", and identified by G. H. Girty.

Shale, sandstone, and other rocks of Triassic, Jurassic, and Cretaceous age are exposed in the Centennial Mountains, in the general vicinity of Sheridan Creek, and elsewhere.[11] In the course of the field work in 1922 thick-bedded red sandstone and conglomerate with some thin limestone layers were found on Red Mountain, at the headwaters of Irving Creek, in the Beaverhead Mountains. A member of the General Land Office surveying crew in 1921 found some fossils in these beds, which were described by Mr. Girty as coming from the Thaynes limestone, of Lower Triassic age.[12] In 1928 the senior author visited this locality in company with G. R. Mansfield and W. B. Lang and found similar fossils in pebbles in the conglomerate. Therefore this formation is composed in part of material derived from the Thaynes limestone and must be younger than that formation. Mansfield correlated the conglomerate on lithologic grounds with the Ephraim conglomerate, of Cretaceous (?) age. Light-colored soft shale, sandstone, and conglomerate exposed along the Continental Divide at the head of Camas Creek and extending eastward beyond the limits of the region have been assigned to the Cretaceous by Mansfield.[13] During 1928 he visited outcrops of well-consolidated pepper and salt sandstone a few miles east of Humphrey and correlated them tentatively on lithologic grounds with the Wayan formation, of Cretaceous age. On the summit of the divide north of Spencer are exposed soft unconsolidated sediments similar to those east of Humphrey but apparently consisting of detritus derived from the Wayan and deposited in a Tertiary (?) lake. Kirkham [14] mapped them as Cretaceous but showed Tertiary (Pliocene?) deposits not far to the west, extending all the way to Red Mountain, on Irving Creek.

In general these pre-Tertiary rocks are so thoroughly cemented that they are nearly impermeable. Consequently it is probable that they do not conduct any appreciable amount of water toward or under Mud Lake. Such water as is present in these rocks is largely confined to joints and fissures, and the small springs that issue from them at numerous places probably originate in such openings. It is probable that comparatively impermeable rocks similar to those just described underlie the Tertiary formations throughout the region.

[11] Mansfield, G. R., Coal in eastern Idaho: U. S. Geol. Survey Bull. 716, pp. 129–130, 1921. Condit, D. D., op. cit., p. 113. Kirkham, V. R. D., op. cit., pp. 21–22.

[12] Stearns, H. T., and Bryan, L. L., op. cit., pp. 92–93.

[13] Mansfield, G. R., Coal in eastern Idaho: U. S. Geol. Survey Bull. 716, p. 129, 1921.

[14] Kirkham, V. R. D., op. cit., pl. 4.

and form an essentially watertight basement. It may thus be assumed that practically all movement of ground water in the region is in the more permeable members of the Tertiary and later rocks.

TERTIARY RHYOLITE AND RELATED ROCKS

Large areas in the Centennial Mountains and somewhat smaller ones in the Beaverhead Mountains are underlain by rhyolite flows and associated strata. Essentially similar rocks compose most of Big Bend Ridge and the Juniper Buttes and emerge from a cover of later material in several other places. These and similar rocks in this part of Idaho have been mapped and described by Kirkham.[15] Their representatives in the Mud Lake region are mapped with greater detail in plate 3.

Most of these rocks along the northern and northwestern borders of the Mud Lake region are light-colored flow-banded rhyolite and welded tuff. The most conspicuous members are a purple platy rhyolite about 50 feet thick and a honeycombed pink rhyolite of similar thickness. Locally these flows give place to compact brown glassy rhyolite and obsidian. Some of them appear to have fallen as hot ash and pumice, the fragmental texture being subsequently destroyed by welding and flowage.

Several specimens of rhyolite from the hills just north of Lidy Hot Springs, in T. 9 N., R. 33 E., and one from Warm Creek Butte, 1½ miles to the southwest, have been petrographically examined by E. S. Larsen. They are all fine-grained and largely glassy. Phenocrysts make up as much as 25 percent of one of the rocks, but in most of the others they are much less abundant. The rock with plentiful phenocrysts show local micrographic intergrowth. The ground mass is commonly fluidal and locally spherulitic. The minerals identified in the phenocrysts in different specimens include tridymite, quartz, orthoclase, plagioclase ranging in composition from albite to andesine, and rare biotite and hornblende. The rocks containing the more calcic varieties of feldspar are probably quartz latite rather than true rhyolite. Striking variations of these rhyolitic rocks, such as are illustrated in plate 4, occur locally.

Indian Creek Butte, in sec. 31, T. 12 N., R. 35 E., and sec. 36, T. 12 N., R. 34 E., consists of rhyolitic material dipping away from the summit. This structure was at first thought to indicate a rhyolite cone but is more likely the result of pyroclastic deposits mantling a former hill. Another prominence in the rhyolite lies 3½ miles to the east, but whether it is a cone or a warp in the lava series could not be ascertained. In the southeast corner of T. 13 N., R. 35 E., a mass of rock projects through the gravel formation and may prove to be a cone. It was seen only from a distance.

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[15] Kirkham, V. R. D., op. cit., pp. 33–38, pl. 4.

A. LITHOPHYSAE IN PINK RHYOLITE FROM WELL 592.
Photograph by W. O. Hazard.

B. SPHERULITIC OBSIDIAN FROM SEC. 5, T. 10 N., R. 41 E.
Photograph by W. O. Hazard.

Big Bend Ridge, on the west side of the Island Park Basin, is made up of massive rhyolite and light-colored tuff and agglomerate, as a whole different in physical appearance from those in the Centennial Mountains. On the west side of the ridge, about half a mile northwest of the Bishop ranch, on Blue Creek in sec. 5, T. 10 N., R. 41 E., occurs a volcanic agglomerate containing blocks of spherulitic obsidian, many over 1 foot in diameter, in a matrix of rhyolitic ash. Explosion blocks as large as these are not to be expected many miles from their source. It is suggested on page 29 that vents in the neighboring Island Park Basin may have been the source of this material.

The Juniper Buttes are inliers of the early lava. Their structure is complicated, apparently by faulting, but they constitute essentially an arch in the series. They are made up of alternating beds of rhyolite and spherulitic obsidian, capped by a basalt flow which must have originated at about the same time, because it is distinctly older than the basalt that surrounds the buttes. Pumice and other pyroclastic materials such as characterize acidic volcanoes are absent; hence these buttes were probably not a source of the rhyolite flows. The undrained depression in their midst is caused by eruptions of later basalt on the east and west sides of a narrow valley.

Massive, dense basalt, usually as a single flow, conformably caps the acidic series in several places, notably south of Frazier Reservoir on West Camas Creek and in the foothills near Warm Creek, northeast of the Reno ranch.

At an altitude of about 9,000 feet near the East Fork of Camas Creek a basalt plug was observed that evidently was the source of some of the earlier basalt nearby. Covering several square miles west of Small, basalt forms the conspicuous member of the Tertiary lavas, although farther west, in the vicinity of Blue Creek, beds of light-colored silicic pyroclastic rocks predominate. The lower 5 miles of the Medicine Lodge Canyon near Small is walled with several beds of olivine basalt having a thickness of 100 feet, above which in most places is a bed of pink rhyolite (or rhyolitic tuff) only 15 feet thick. For some distance above the mouth of the canyon this cap of rhyolite has broken into large blocks, which lie in a position similar to cakes of ice along the banks of a stream in the winter, when the flow of the stream has decreased and the ice collapsed. In sec. 12, T. 11 N., R. 33 E., half a mile downstream from a large ranch house, near the point where the road crosses Medicine Lodge Creek, a cinder cone, partly dissected by the creek, is exposed beneath a layer of basalt. This cone doubtless gave rise to some of the basalt in this old series of lavas. Above the basalt at this locality the acidic flows attain a thickness of nearly 400 feet. About 3½ miles farther upstream the basalt is absent and the rhyolite rests on marly limestone overlain by a thin veneer of quartzite gravel. On the trail to Spread Eagle Peak, in the eastern Centennial Mountains, is a red andesite belonging to this series, and doubtless detailed studies will bring to light other local varieties.

The Tertiary eruptive rocks of the Mud Lake region when studied under the microscope may be found to contain welded pumice, because some of the beds are very thin and extensive and lack the brecciated phase of lava flows. Friable pumice deposits of this series were not seen in the region. At the present time the Tertiary flows extend beneath the basalt of the plains, and at the head of Camas Creek they pass over the Continental Divide at an altitude of 10,000 feet. The total thickness of the series is unknown but in some places probably exceeds 2,000 feet, for nearly this much is exposed in the cirque wall above Aldous Lake, at the head of a tributary of Cottonwood Creek, north of Camas Meadows. The beds are gently flexed, as if they had been gradually arched by the uplift of the mountains that followed their extrusion. If, as is probable, some of these beds are composed of welded pumice, the apparent arching may have resulted from accommodation of the pumice as it fell during eruption to the surface of a ridge that is now buried.

In the Snake River report [16] a hypothesis is set forth that the rhyolite cone remnants making up Big Southern Butte and East Butte are the summit peaks of a former range of rhyolitic volcanoes which produced the acidic eruptives and were then depressed by the Snake River downwarp in late Pliocene (?) time and subsequently almost completely buried by the floods of basalt.

Only a few wells have ended in the Tertiary rhyolite and related rocks, but wherever these rocks are exposed they contain fissures, which if below the zone of saturation would yield small supplies of water for domestic purposes and stock. Only a few small springs issue from them in the mountains; hence they are in general poor aquifers and should be avoided if possible when a well is being located. The ash beds intercalated with these flows are practically impermeable and prevent the free circulation of water. Some of the rhyolite flows are thick and near the base so free from joints as to be impermeable. Fortunately, except in the Juniper Buttes and in the mountains, these rhyolites lie far below the surface. In the Juniper Buttes well 409, in sec. 14, T. 8 N., R. 39 E., was drilled 446 feet into rhyolite and obtained water. It is reported that the water rose to a level 354 feet below the surface. The driller stated that he found a little trickle of water at 100 feet and clay 150 feet thick in the bottom of the well. This clay may be rhyolite tuff. The water level in this well stands 125 feet above the water table in the basalts surrounding it, probably indicating local recharge and a perched con-

[16] Stearns, H. T., Crandall, Lynn, and Steward, W. G., Geology and ground-water resources of the Snake River Plain in southeastern Idaho: U. S. Geol. Survey Water-Supply Paper 774, pp. 41–42, 1938.

dition. The well is reported to have yielded only small quantities of water.

In this older lava series there are a few obsidian flows that are intricately fractured and are capable of carrying large volumes of water. The driller of well 589 reports that water was found in obsidian in this well at a depth of 550 feet. However, the fact that the driller reported beds of cinders between beds of obsidian 3 to 4 feet thick makes it questionable whether acidic obsidian exists in this well. The entire flow (about 185 second-feet) of the Big Springs, in the Island Park Basin, issues from obsidian and rhyolite. Buffalo River Springs issue from pyroclastic rocks belonging to this series of older lavas and other springs in this same basin issue from them, showing that some of these rocks are good water bearers. The physical process of extrusion that produces obsidian and glassy rhyolites is conducive to brecciation or to the forming of numerous joint cracks. Some of the fissures at the Big Springs are 3 inches across, and a stick 6 feet long can be poked into them. The rhyolite exposed in the east wall of the canyon of Henrys Fork below Mesa Falls exhibits well-defined columnar jointing, which would permit the passage of water.

TERTIARY SEDIMENTARY ROCKS

The mountains for several miles east of Medicine Lodge Creek are flanked by extensive uplifted and dissected alluvial fans which are distinctly older than other alluvium in the area. This material has been distinguished on plate 3. In the vicinity of Delta Butte, in sec. 3, T. 13 N., R. 34 E., a thickness of about 500 feet of this formation is exposed. It consists entirely of poorly consolidated fanglomerate. Mansfield,[17] who visited these fans with the senior author in 1928, stated that in his opinion they might be correlative with the Salt Lake formation, of Tertiary (Pliocene?) age. Along Middle Creek, about 3 miles south of Delta Butte, three distinct terraces are carved in the gravel of which the highest is about 200 feet above the flood plain of the creek. In the upper part of the canyon of upper Medicine Lodge Creek there are deposits of consolidated gravel, tuff, and calcareous material that may belong to this formation. These gravel deposits clearly overlie the rhyolitic beds previously described in exposures along Middle Creek, in the SE¼ sec. 36, T. 11 N., R. 34 E., in Indian Creek Canyon near Indian Creek Butte, and in Thunder Gulch. In the first two localities there is less definite evidence suggestive of interfingering of the rhyolite and gravel. Kirkham[18] regards the Tertiary gravel of this part of the region as overlain by the rhyolitic flows.

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[17] Mansfield, G. R., op. cit. (Prof. Paper 152), pp. 110–112.
[18] Kirkham, V. R. D., op. cit., p. 22.

Pieces of completely fossilized bone from well 592, in the NW¼ sec. 9, T. 11 N., R. 35 E., were identified by the late J. W. Gidley, of the United States National Museum, as being parts of a metapodial of an extinct camel, probably of the *Procamelus* type, and therefore suggesting Pliocene age for the deposit from which they came. The bone fragments rested in gray ash, according to J. Rock, owner of the well. The log of the well, which is given below, indicates that the bones came either from the basal part of the sedimentary beds or from the uppermost member of the underlying rhyolitic beds.

Log of well 592

	Thickness	Depth
	Feet	*Feet*
Gravel and quartzite cobbles	12	12
Light-colored clay	10	22
Brown sand	36	58
Gray ash containing bones	5	63
Honeycomb (lithophysae) rhyolite	16	79

The Tertiary sedimentary rocks, as shown on plate 3, lie mostly in the mountain areas, where there is no need for wells and where the formations are deeply dissected and drained by streams flowing away from the mountains. Near Small, in the vicinity of Medicine Lodge Creek, well 599 penetrated 96 feet of the gravel of this age and is dry. The gravel is coarse and should be an excellent water bearer if found below the water table. It is so permeable, however, that water sinks to low levels in it and drains away.

QUATERNARY BASALT AND RELATED ROCKS

FLOWS

The lowland areas in the Mud Lake region appear to be underlain throughout by basalt, which rests unconformably on the rhyolitic rocks just described and is locally mantled by and interfingered with sediments of several different kinds. Here and there small amounts of andesite and other rocks are intercalated in the basalt. The basalt-floored plains are plentifully sprinkled with small hills, most of which bear evidence of being the cones from which the basalt flows issued. Some cones are composed of lava, others of cinders and spatter, and a few of tuff. The flows and craters are distinguished on plate 3.

Reconnaissance trips into the surrounding mountains, beyond the limits of the geologic mapping, afford evidence that similar basalt fills some of the larger stream valleys. For example, Beaver Creek from a point near Humphrey to the plain is bordered here and there by remnants of a former thick lava fill unconformable on the rhyolite. Between Spencer and Highbridge remnants of this flow form a bench about 40 feet above somewhat later basalt, which has flowed up the valley from cones on the plains. About 1 mile east of Spencer a basalt neck projects through the rhyolite, and nearby are uneroded cones which afford impressive evidence of the duration of this last basic volcanic cycle. Much basalt is exposed in Birch Creek Valley, but it has been little eroded by the creek and consequently is not dissected like the basalt in Beaver Canyon.

Both the facts just noted and the interrelations of the flows on the plains indicate that eruptions took place intermittently over a long period. In some places there is evidence of the lapse of considerable time between eruptions. The flows buried under the thick lake beds near Mud Lake are doubtless much older than those in adjacent areas which still remain almost bare. For instance, slight differences in the weathering of the lava around the vents indicate a lapse of some time between the formation of Antelope and Circular Buttes, west of Mud Lake, and that of the Mud Lake Craters. The overlapping of flows, the interfingering of the basalt and alluvial deposits, and the variation in soil cover all give indications that the lava was not poured out in concurrent eruptions. Near Camas Meadows basalt flows derived from uneroded and slightly weathered cones pass beneath glacial outwash. Many of these flows are only sparingly covered with loess, and a comparison of this soil cover with that on the latest basalt suggests that eruptions ceased in this area prior to the last glacial stage. Many of the flows are so little modified in appearance as to seem recent, but in this semiarid region the details of their surface features would undoubtedly persist for thousands of years.

The uninterrupted sequence of lake beds near Mud Lake is ample proof that the intervals between eruptions in this particular locality were long, yet the numerous cones to the north and east indicate that eruptions proceeded elsewhere in the region during the time of formation of the lake beds. Studies of the Snake River Plain as a whole have proved that basaltic eruptions continued from earliest Quaternary to comparatively recent times.

The basalt flows in the plain include both aa and pahoehoe, but the aa makes up an extremely small percentage of the whole. The usual features of ropy surface, pressure domes, blisters, lava tubes, and natural bridges common in all pahoehoe flows are found in the flows of the Mud Lake area. Lava tubes are very numerous in the "land of the lava tunnels", north of St. Anthony, and a few of them contain ice throughout the year. Some fine caverns or tubes occur in the vicinity of Dubois. In one of these caves in sec. 22, T. 11 N., R. 36 E., there is a remarkably pure but small deposit of niter that owes its origin to the leaching of sage-hen guano from the roof of the cave.[19]

[19] Stearns, H. T., The origin of a niter deposit near Dubois, Idaho: Am. Mineralogist, vol. 9, pp. 135–137, 1924.

The surface of the later lava flows that occupy a belt extending eastward from Dubois to Big Bend Ridge is in many places exceedingly rough, because of the pressure ridges, cracks, and collapsed portions of the crust. The younger flows have pronounced margins that are readily discernible from high points. These margins are generally not over 25 feet high, and the basalt flows, except where they have filled preexisting depressions, average about this thickness. A few inclusions of foreign rocks were found in the basalt flows, but they gave no clue to the rocks of the underlying basement, because they were not different from the igneous rocks exposed in the region. The total thickness of the basalt as indicated by well borings in a few localities is about 900 feet, but adequate data on this point are lacking.

Practically all the basalts are blue to black, and many are vesicular. Of the 200 specimens examined about 90 percent had megascopically recognizable olivines and feldspars. Some have diabasic texture. A few, especially those in the recent lava fields north of St. Anthony and in one flow west of Mud Lake, are porphyritic. Some of these porphyritic lavas, especially those associated with the cinder cones north of St. Anthony, might be classed as andesites. On many of the cinder cones the phenocrysts of feldspar in the red scoria reach unusual dimensions, as, for example, the large crystals that have weathered free from their matrix of scoria on Crystal Butte, in sec. 11, T. 11 N., R. 40 E.[20]

The rocks are rather fresh, and secondary minerals are usually not present in the vesicles except where caliche is abundant, but much of the olivine is altered to iddingsite. Mechanical disintegration has produced little effect except in the flaking of the glassy crusts of the pahoehoe. Much of the color of the scoria is original, although alteration of the iron has changed the original bright red and black of the cinders to a dull reddish brown.

The andesites have been mapped with the basalts because they differ so little from basalt as to be distinguishable only microscopically. These andesites do not in any way resemble the older andesites associated with the rhyolitic lava, and they are in general the product of the latest eruptions in this area. Their flows were slightly more viscous than the basaltic flows and hence commonly thicker and less extensive, and none of them built lava domes, so far as known.

CONES

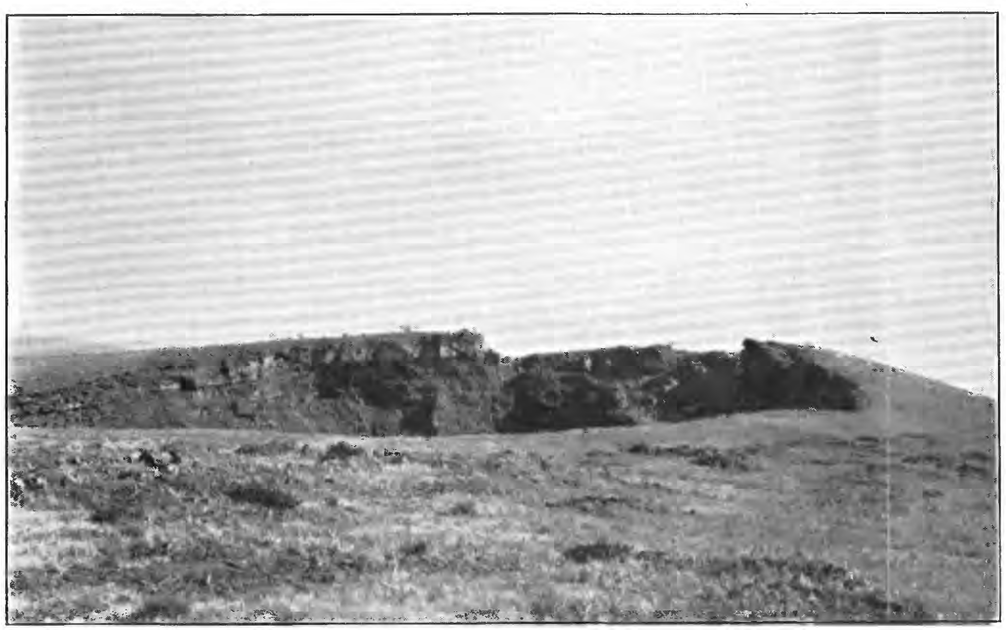
LAVA DOMES AND THEIR CALDERAS

The cones of the Mud Lake region can be classified into five groups—lava domes and their calderas, lava rings, driblet cones, cinder cones, and tuff cones.

[20] Shannon, E. V., The minerals of Idaho: U. S. Nat. Mus. Bull. 131, pp. 275–276, 1926.

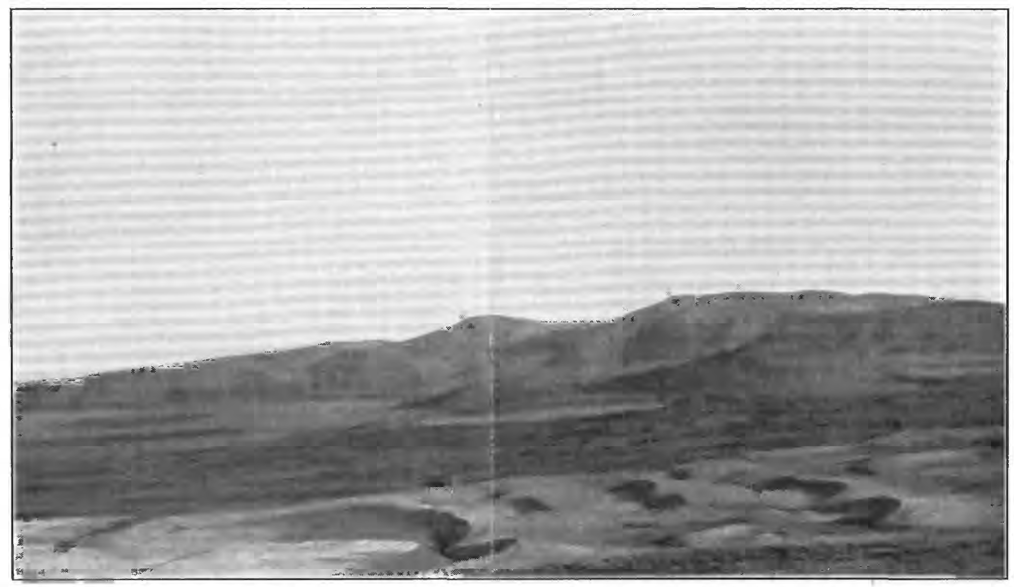
A. VIEW ACROSS LONE TREE RESERVOIR, ON CAMAS CREEK, SHOWING VOLCANIC CONES.

The one on the right is a driblet cone; the one in the middle background, S. P. Butte, is a lava dome. Photograph by H. T. Stearns.



B. BIG CRATER, IN THE SUMMIT OF BIG CRATER DOME, SOUTHEAST OF IDMON.

The break in the rim is caused by the collapse of a large lava tube that leaves this side of the crater. Photograph by H. T. Stearns.



C. SAND DUNES 75 FEET HIGH ON THE SOUTH SIDE OF THE JUNIPER BUTTES.

Photograph by H. T. Stearns.

Lava domes are smooth, low hills composed mainly of bedded basalt and resulting from eruption either from a tubular vent or from a fissure. Although erosion has not yet revealed the shape of the feeders in this region, the linear arrangement of the orifices suggests and in many places proves that the vents were fed by a fissure subsequently masked by the flows. Many cones have one or more craters on the summit, although in some there is no indication as to where the lava was emitted. The basalt of the domes is commonly of the pahoehoe type, in flows 5 to 50 feet thick. Ash beds are rare. The time interval between the flows from any particular vent appears commonly to have been short, and most of the cones appear to have been built during a single eruption.

A few of the lava domes warrant description. S. P. Butte, in sec. 31, T. 11 N., R. 39 E., covers an area of 3 square miles and is about 150 feet high. (See pl. 5, *A*.) On its summit is a sunken oval crater half a mile long, about 600 feet wide, and 120 feet deep. The crater is not visible until its rim is reached. On the south rim of the crater there is a small driblet cone with a crater 8 feet deep. The north slope of the cone has been partly buried by later flows. Numerous tubes and caves south of the crater indicate that many of its flows were of the pahoehoe type. Only the last lava stream from this cone can be distinguished, as the older ones are covered with soil. This flow spread southward over the plain as far as the Juniper Buttes, a distance of about 12 miles. The oval shape of the crater and the occurrence of cones nearby suggest that this dome was built over a fissure. The crater was doubtless occupied by a lava lake similar to the lava lake of Kilauea Volcano, Hawaii, and the collapse after the last subsidence of the lava column caused the crater.

Little Grassy Butte, in Tps. 6 and 7 N., Rs. 37 and 38 E., covers an area of about 100 square miles and rises only 300 feet above the plain. Its slopes are so gentle that the fact that it is a volcanic vent which has poured out over a cubic mile of lava is difficult to realize. On its top are half a dozen craters 50 to 60 feet deep. Practically no cinders or bombs can be found in the craters or on the slopes of the cone; hence the basalt must have welled out quietly. The flows on the surface of this cone are all pahoehoe.

The lava dome with Big Crater on its summit, in sec. 30, T. 11 N., R. 40 E., is another dome-shaped cone. Its crater is about 150 feet deep, and its walls consist of many thin beds of lava together with a slight amount of spatter and cinders, as shown in plate 5, *B*. The last lava from Big Crater flowed mainly through a tunnel that extended southward for about 12 miles.

Table Butte, a long low dome in Tps. 7 and 8 N., R. 35 E., was built up by successive outflows of basalt from numerous craters on its summit. It covers an area of about 50 square miles. Needle Butte, the highest cone of its summit, rises more than 400 feet above the surrounding plain. In its south and east sides are a group of depressions locally termed the Mud Lake Craters. On its west side there is a line of driblet cones and craters. All these features point toward a more complicated history for this lava cone than is usual for vents of this region. Northward it merges with Cedar and Camas Buttes, two other lava cones. The linear arrangement of this assemblage of volcanic features suggests its origin over a persistent but slightly shifting volcanic fissure or over a series of successively opening parallel fissures.

The surface of the dome surmounted by Little Crater, in sec. 30, T. 11 N., R. 40 E., consists largely of pahoehoe lava that has buckled into large pressure domes. However, the east flow from the crater was pahoehoe that changed toward the end to aa. A small depression a few yards across forms Little Crater. This depression opens into a lava tunnel which was the conduit of the last lava flow that drained southward from the vent. A sluggish stream of pahoehoe also flowed into Big Crater, 1 mile to the east, indicating that Little Crater was the later of the two to cease activity. The presence of this large dome of lava crowned with so small a depression as Little Crater, caused largely by the collapse of the lava tunnel leading away from the summit, seemed at first unexplainable, but the senior author has seen, on Kilauea Volcano, Hawaii, a similar lava cone, called Maunaiki, with a large output of lava and two small craters on its summit, the larger of which is due largely to a collapsed lava tunnel.[21] A larger crater did not develop because practically no collapse occurred after the cessation of activity. Osborn Butte, a lava cone in the Island Park Basin, likewise has no visible crater on its summit.

Calderas.—Morgan Crater indents a large lava dome in sec. 8, T. 11 N., R. 38 E. It has an east-west diameter of nearly 1 mile and a maximum depth of about 200 feet and is the largest crater in the area. It was undoubtedly the source of considerable lava, for its cone covers many square miles.[22] A crater of this size is on the border line between a crater and a caldera. It is probably too large to have ever been entirely occupied by a boiling lake of lava at any one time, and as no ash or explosive ejectamenta occur nearby, this depression was doubtless formed largely by subsidence following a long period of activity; hence it is probably a miniature collapse caldera.

Island Park Basin is a broad and relatively flat depression north of Ashton with a maximum east-west width of about 14 miles and a maximum north-south length of about 18 miles. It is crossed from

[21] Stearns, H. T., and Clark, W. O., Geology and water resources of the Kau District, Hawaii: U. S. Geol. Survey Water Supply Paper 616, pp. 120–121, 1930.

[22] Stearns, H. T., Igneous geology of the Mud Lake Basin, Idaho: Washington Acad. Sci. Jour., vol. 14 p. 381, 1924.

north to south by Henrys Fork of the Snake River, and the east side is drained by the Warm River, which rises in the basin. It is bounded on the northwest by Aspen Ridge and on the west and southwest by Big Bend Ridge. Together, these two ridges form a crescent-shaped upland that extends from the Buffalo River on the north to the mouth of the Warm River on the south. (See pl. 3.) This crescentic upland has a steep east front, but on the west side it slopes gradually toward and passes beneath the basalt. The crest of the ridge rises toward the middle from both ends of the curve and reaches a maximum height of about 7,500 feet at the volcanic cone called High Point. The basin is bounded on the east by the steep bluffs of the Yellowstone Plateau, which rises toward the east to a height of about 8,500 feet above sea level at the Continental Divide. The rocks that make up the rim of the basin are all rhyolite and related pyroclastic rocks except near High Point, where there is a thin veneer of Quaternary basalt.

The crescentic ridge forming the west side of the basin may be the nose of a broad anticline in the rhyolite. The structure is largely concealed by vegetation, and a study of the strike and dip of the lamination of the rhyolite on a traverse across the ridge sheds no light on it. The strike and dip of the laminae were greatly disturbed during the motion of the mass subsequent to the cooling of the crust. The ridge contains considerable obsidian, tuff, and explosion breccia, as well as flow rocks, and the whole assemblage may have originated close by. Elk Butte, an inlier on the basin floor, is a coarsely crystalline rock and apparently is a neck that may have supplied some of the material.

The floor of the basin is an undulating lava plain with a cover of wind-blown soil that is generally from 1 to 5 feet thick. On some of the youngest lava beds, however, the soil is much thinner, and in some places it is entirely absent. There appear to have been 14 separate flows within the basin. A few isolated volcanic cones and rhyolite inliers break the monotony of the floor. The cones are typical lava domes and were the sources of the basalt that veneers the basin floor.

The basalt flows on the floor appear to have continually pushed the river westward until now in its lower reaches most of its course lies along the contact of the basalt and rhyolite. Such a westward shifting of the channel is indicated by the mutual relation of the flows, so far as can be judged. About 100 second-feet of ground water issues from basalt in Henrys Fork at the lower end of the basin. This water probably follows one or more ancestral lava-filled canyons that lie east of the present channel in the Harriman ranch area. This lateral shifting of the river is probably responsible for the excavation of the basin. However, the basin may have had its origin by the down-faulting of the rhyolite, earlier than the basaltic eruptions, although direct evidence of faulting is lacking.

LAVA RINGS

A comparatively small number of the cones in the Mud Lake region are of the type known as lava rings. As defined by Daly,[24] a lava ring is a greater driblet cone formed by the symmetrical upbuilding of the walls of a lava lake by the congealing of intermittent thin overflows of the lake. Edith Crater, in the NW¼ sec. 3, T. 11 N., R. 39 E., falls into this class. The crater covers about 1 acre and is slightly breached on the north and south sides. The smooth floor of the ring is covered with soil, and the many obsidian flakings on it indicate that it has been used by Indians for a camp site. The walls of the crater doubtless afforded these migratory people shelter and protection from hostile bands or severe storms. A few red cinders about the rim of the crater suggest lava fountains during the time of its activity. The rim is at no place more than 10 feet above the level of the surrounding plain. As it seems to be older than the surrounding craters, it may represent a nearly complete buried cone. On its outer slope are numerous grooves in the basalt like those shown in plate 6. Similar grooves have been seen in Kilauea Volcano and are caused by the breaking away of a piece of crust from a flow and by its sliding several feet on the underlying still viscous rock. The grooves, until weathered, have many jagged bristles of glassy material projecting from their surface and are usually crossed by irregular but nearly parallel cracks. Slickensides of this kind were observed also on Slickenside Butte.

Another lava ring of about the same size occurs near Edith Crater, in sec. 34, T. 12 N., R. 39 E. A lava ring was also observed near the top of Bouiegard Butte, in sec. 23, T. 11 N., R. 38 E., where thin-bedded basalt forms the rim. In sec. 29, T. 11 N., R. 40 E., on a fissure leading away from Big Crater, there is a depression 30 feet deep that appears to have been the site of a lake of lava. Vegetation prevents the determination of its origin, but it is probably a lava ring.

Needle Butte, in sec. 28, T. 8 N., R. 35 E., is intermediate between a lava ring and a driblet cone. It forms the highest point on the lava dome Table Butte. The crater was doubtless the site of fountains and overflows, for its walls consist of thin beds of vesicular basalt and spatter.

DRIBLET CONES

The driblet or spatter cone consists entirely of lava and is made up of the spatter of lava fountains. Driblet cones in the area mapped range in height from 10 to 50 feet. They are steeper in profile than the lava domes and usually have a more rugged profile and are smaller than the cinder cones, which resemble them in origin. The craters rarely exceed 20 feet in depth.

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[24] Daly, R. A., Igneous rocks and their origin, p. 135, New York, McGraw-Hill Book Co., 1914.

Spatter Cone, in sec. 17, T. 11 N., R. 39 E., only a few hundred feet west of the Kilgore-St. Anthony road, is a notable driblet cone. It rises 30 feet above the surrounding region and has two small craters a few feet wide on top. Although nearly covered with soil and vegetation, the lava itself still retains the original blue glazed surface formed by the quick chilling at the time of extrusion. Plate 7, *A*, shows a specimen from this driblet cone which illustrates clearly the nature of spatter. The remains of two small driblet cones occur in the Mud Lake Craters, in T. 7 N., R. 35 E. Thimble Butte, in sec. 31, T. 8 N., R. 35 E., illustrates the topographic form of a symmetrical driblet cone. A view of this cone has already been published.[25]

Many of the Mud Lake Craters are depressions in cones intermediate in type between lava and driblet cones. The north rim of the southernmost crater consists of four dense blue basalt flows 10 to 12 feet thick, interbedded with red scoriaceous spatter. Between two of the flows that form ledges is a natural shelter made by the caving away of the spatter. Numerous bones and charcoal on the floor of the shelter indicate its long habitation by Indians. It was probably a stopping place on their annual migrations to the mountains.

CINDER CONES

The cinder or scoria cone is the most common type of cone in the area, but there are few of them on the plains far away from the mountains. The reason for this areal distribution is not evident. Some of the cinder cones in the "land of the lava tunnels" and near Big Bend Ridge consist of andesite, indicating a difference in the chemistry of the magma which may account for the intense frothing that produced them. Most of the cinder cones were built by the later outbreaks— a fact which may also have influenced their distribution. The cinder cones are composed essentially of coarse scoriaceous or pumiceous fragments which are separate and not stuck together like driblet lava. Such cones are the products of fountainlike pyroexplosions [26] similar to those which form driblet cones except that the action is more violent and the material ejected more frothy, resulting in an aggregation of discrete particles instead of coalescing spatter. The ejectamenta frequently cool in the air, so that they retain their shape upon falling. Breadcrust and spiral bombs intermingled with pumice and spatter can be found on many of these cinder cones. Occasionally bombs are found that consist of an older basalt picked up by the rising magma and ejected with a coating of the erupting lava. A view of one of these bombs is given in plate 7, *B*.

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[25] Stearns, H. T., Volcanism in the Mud Lake area, Idaho: Am. Jour. Sci., 5th ser., vol. 11, fig. 2, p. 355, 1926.

[26] Stearns, H. T., and Clark, W. O., Geology and water resources of the Kau district, Hawaii: U. S. Geol. Survey Water-Supply Paper 616, p. 132, 1930.

The characteristic feature of the cinder cones is their smooth, rounded outlines. They are usually symmetrical, but some are made up of several heaps, their shape depending on whether the ejecta accompanying the jet were affected more by the wind or by the jet. Compound cinder cones formed by the union of two or more fountains are seen here and there. With the subsequent oxidation of the iron in the cinders, these cones have changed in color to deep red or brown. They differ from lava cones in having slopes of 25° to 40°, whereas the lava cone has slopes of 2° to 10°. To the practiced eye, the smooth, regular outlines of the cinder cone distinguish it from driblet or lava cones at great distances.

The cinder cones in the Mud Lake region range in height from 25 to 200 feet and in area from a few square yards to half a square mile. They consist of very vesicular lava such as is shown in plate 8. The cones that belong to this class are Egg, Round, Red Top, Jones, Macs, Snowshoe, Crystal, Fogg, Swan, High Point, and others.

The most symmetrical simple cinder cone is High Point, in sec. 19, T. 11 N., R. 42 E., which because of its location is visible for many miles. There are many others in the region. Crystal Butte, so called from the large feldspar crystals lying on its surface, is a cinder cone of the compound, breached type. It has been formed by several fountains playing together, for it is made up of several heaps of cinders and is crowned with two distinct craters. After the fountaining ceased, lava welled up in the eastern crater and solidified there. The highest point on Crystal Butte is about 275 feet above the adjacent plain. Most of the cinder cones in the region have been breached at places where lava flows poured out of them and eroded channels in their sides or maintained a channel during the life of the fire fountains.

TUFF CONES

Here, as in most other parts of the Snake River Plain, there is relatively little evidence of violent explosive activity in connection with the Quaternary basaltic eruptions. Only six cones of explosive character consisting largely of tuff have been recognized in the Mud Lake region, and all but one of them are close to the confluence of Henrys Fork and the main Snake River, in and near T. 5 N., R. 38 E. (See pl. 3.) At this locality by far the largest mass of tuff is in the two weathered cones known as the Menan Buttes. There is a much smaller cone in sec. 29, T. 6 N., R. 38 E., and Road Butte, in and near secs. 32 and 33, T. 5 N., R. 38 E., is composed of the remnants of two cones now much modified by erosion.

The Menan Buttes cover roughly 8 square miles and rise about 500 feet above the plain. The southern one is crowned with a symmetrical crater about half a mile in diameter and about 150 feet deep. The northern one has a crater only about 100 feet deep. The buttes are partly covered with grass and sagebrush, and a few stunted junipers dot their slopes. The crest of the northern one is practically bare of soil and is slightly scoured by wind action. The lower slopes are generously mantled with soil, which is mostly weathered ash washed down from the upper parts of the cones and mixed with loess from distant sources. Beyond, around the outer base of the cones, black volcanic sand predominates.

The cone north of the Menan Buttes, composed of similar material, is 75 feet high and is entirely surrounded by basalt from Little Grassy Butte. Lava from Little Grassy Butte extended far enough to lap up on the west and north sides of the Menan Buttes, but on their south and east sides they are bordered by the alluvium of the Snake River. Road Butte, farther south, is about 100 feet high. The attitude of the bedding in this butte suggests that it is made up of small remnants of the rims of two craters whose centers were originally on the west side of the butte.

A large part of the material composing the cones is basic ash, in part pisolitic. The curved shards that make up much of this ash show clearly that it was derived from the walls of vesicles of the glassy froth of an expanding gas-charged basaltic magma. The ash is evenly bedded, as shown in plate 11, *A*, and is black to dark brown except on the south rim of the north Menan Butte, where it has a light-brown color induced probably by palagonitization. The beds dip away from the summit of the cones at angles of 20° to 30° and then become practically horizontal near the periphery. Likewise the beds dip inward from the rims toward the center of the craters; hence the bedding is similar to that of tuff cones in other regions. The tuff is partly indurated but is soft when freshly exposed, for in Tanner's quarry, on the southwest side of the south Menan Butte, it is easily cut with saw or ax. At this place it has for years been quarried for building stone, and the output was reported by Mr. Tanner in 1922 as about 16,500 cubic feet a year. It is sold for 5 cents a cubic foot at the quarry. It is used considerably for building in the vicinity of Menan and makes a durable stone for foundations, but gives a rather somber appearance when used for entire houses, unless trimmed with some light-colored stone.

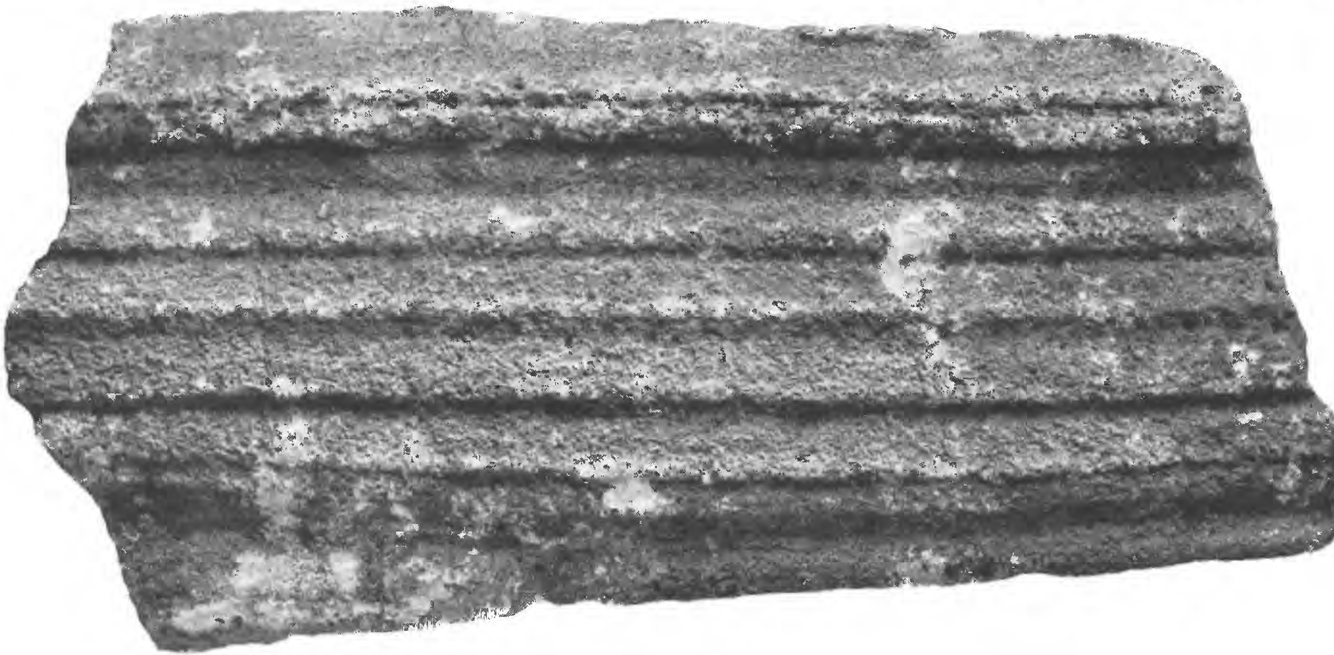
The amount of extraneous material included in the tuff increases progressively from north to south. Thus the small hill north of the Menan Buttes consists mostly of magmatic ejecta with only slight amounts of foreign debris. The north Menan Butte contains a large number of basalt blocks. The variation in texture and the weathered angular surfaces of these blocks indicate that they were derived from earlier basalt flows at depth. The tuff weathers down into fine fragments that are readily removed by wind and rain, so that these heavier basalt blocks have been left behind and in places are so concentrated as to form a protective surface. Besides the basalt blocks on this cone there are some quartzite pebbles and fragments of other sedimentary rocks. A close scrutiny of many of the ash beds reveals small amounts of angular quartz grains.

The south Menan Butte contains a somewhat larger proportion of gravel and sand, and slightly less of the blocks of older basalt. In Tanner's quarry it is possible to see where these larger fragments have fallen into the ash and depressed the bedding while the ash was still soft. A fragment of quartzite in the pisolitic ash from this quarry is shown in plate 9, *A*. The more northerly vent in Road Butte produced chiefly fine cinders and pumice, together with considerable foreign material, whose light color renders it conspicuous. The beds are 4 to 10 feet thick. The comparatively coarse material here is much less thoroughly indurated than the fine-grained tuff at Tanner's quarry. This unconsolidated material has been extensively excavated for road surfacing.

The south vent at Road Butte produced chiefly river gravel. The beds are light brown and, as shown in plate 9, *B*, closely resemble conglomerate. In fact, the senior author has taken several geologists to this exposure, and were it not for the artificial cut in the north end of the hill, where beds of cinders are exposed, he would have been hardly able to convince them that these beds were not of sedimentary rather than of volcanic origin. The pebbles of quartzite in this butte display features that shed light on the physical conditions of the explosion which produced the butte. In plate 10 the lower right pebble is a water-worn quartzite cobble similar to many others in the nearby alluvium. The surface of the lower left pebble, however, has been largely destroyed by exfoliation, which suggests that the pebble has been subjected to strong heat. The upper pebble shows a percussion figure, common on many of the cobbles and suggestive of impact either by falling on some hard surface or by concussion with other pebbles.

No bread-crust or well-formed magmatic bombs were found except near well 52, between the Menan Buttes, where an excavation revealed small bombs and spatter presumably produced by a lava fountain at the end of the catastrophic phase of eruption. No lava flow is known to have issued from these vents, but such flows might have been poured out and now be deeply buried by ash, later lava, or alluvium. The cones are older than anything else exposed on the surface in their vicinity, but the presence of basalt and gravel in the ejecta show that some basalt flows and alluvium underlie them.

The tuff cones in this locality consist of five vents oriented along a northwest-southeast line 7 miles long, and explosions appear to have been approximately simultaneous at all five vents. These conditions suggest that the basaltic magma ascended toward the surface through a fissure 7 miles long. The absence of ejecta derived

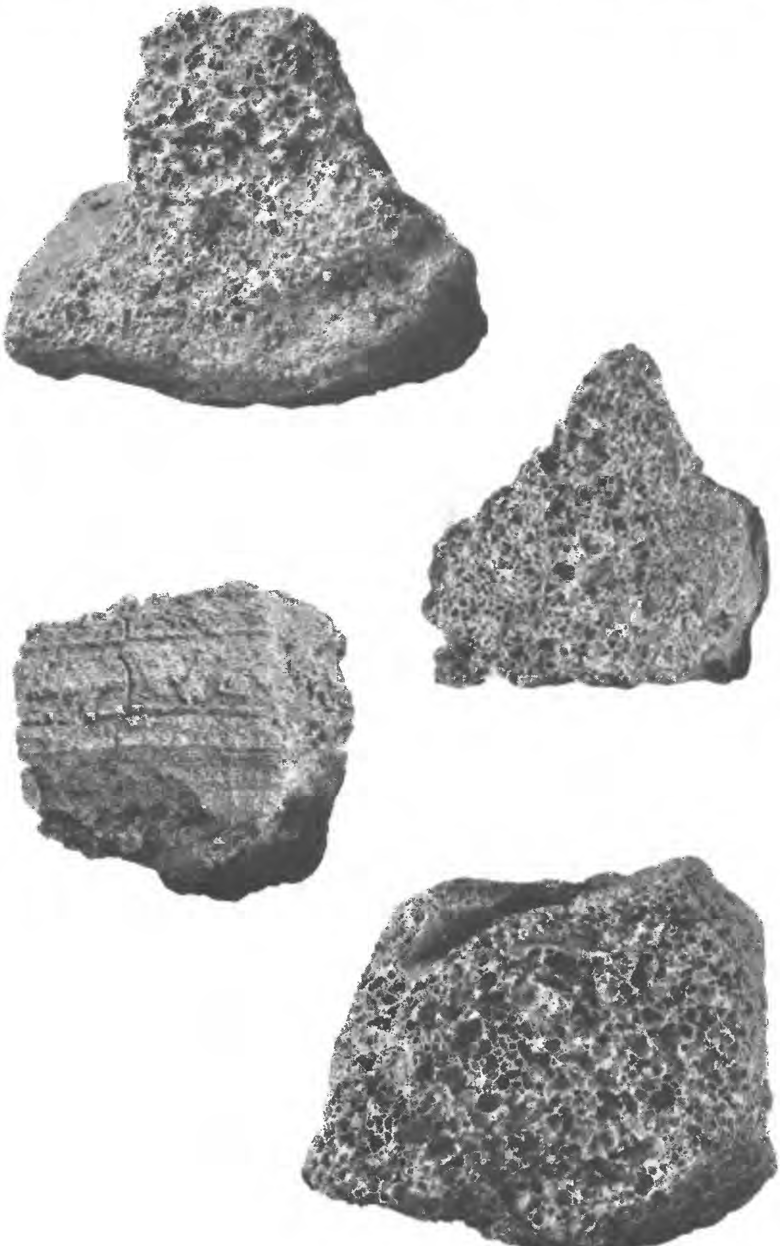


GROOVES IN BASALT ON THE SIDE OF SLICKENSIDE BUTTE, SOUTHEAST OF IDMON.

Caused by the slipping of a crust of viscous lava. Natural size. Photograph by W. O. Howard.

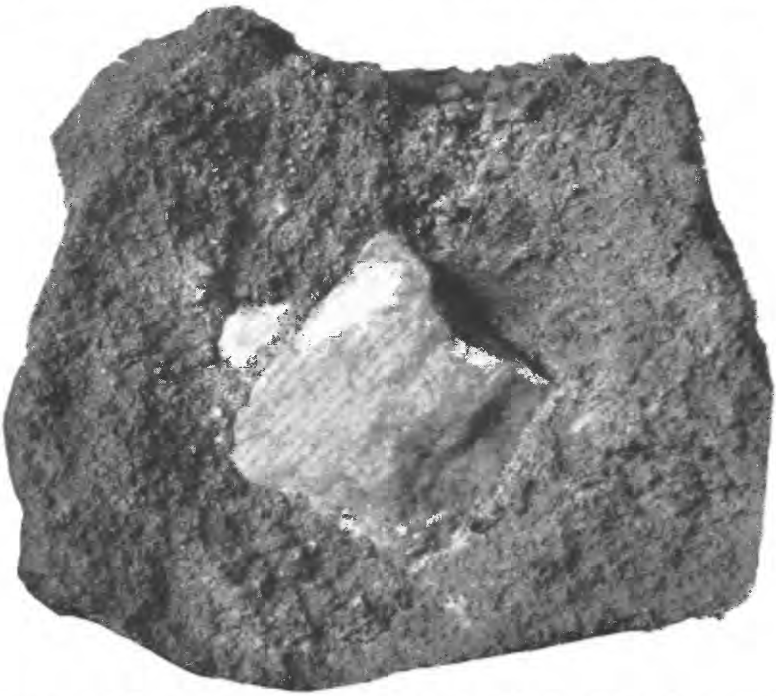
A. BASALTIC SPATTER FROM DRIBLET CONE NEAR IDMON.
Natural size. Photograph by W. O. Hazard.

B. HEAVY BOMB FROM ONE OF THE MUD LAKE CRATERS.
Rind is broken open to show inclusion of older vesicular basalt. Natural size. Photograph by W. O. Hazard.



CINDERS FROM WELL DRILLED IN THE NORTH FORK OF THE SNAKE RIVER AT THE ISLAND PARK DAM SITE.

Natural size. Photograph by W. O. Hazard.

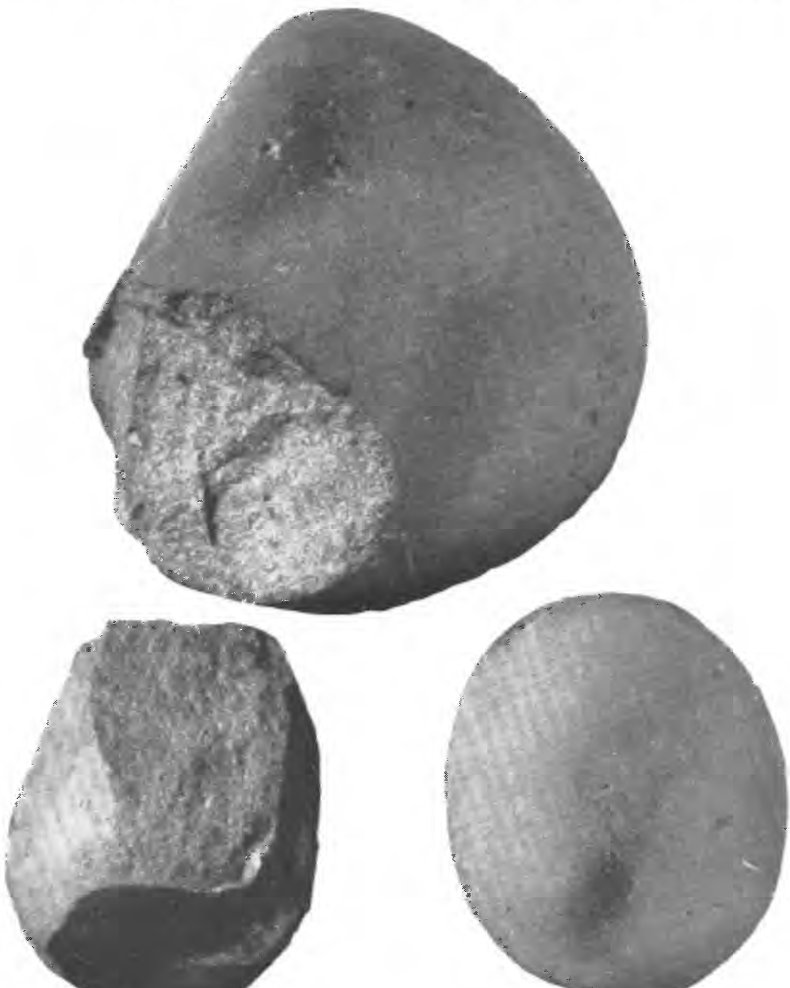


A. QUARTZITE PEBBLE EMBEDDED IN PISOLITIC TUFF FROM TANNER'S QUARRY, MENAN BUTTE.

The curved bottom surface of the specimen is a bedding plane depressed by the impact of the pebble. Natural size.

B. BED OF VOLCANIC AGGLOMERATE ON SOUTH SIDE OF ROAD BUTTE.

Shows quartzite cobbles embedded in basaltic tuff. Photograph by H. T. Stearns.



QUARTZITE PEBBLES FROM BEDS OF TUFF ON SOUTH SIDE OF ROAD BUTTE.

Upper, shows percussion figure; lower left, shows heat exfoliation; lower right, unaffected. Natural size

A. EVEN-BEDDED TUFF IN TANNER'S QUARRY ON THE SOUTH MENAN BUTTE.
Photograph by H. T. Stearns.

B. XENOLITH OF BAKED CLAY IN THE BASALT WALL OF ONE OF THE MUD LAKE CRATERS.

Note the cavities in the basalt above the clay caused by the moisture given out by it. Photograph by H. T. Stearns.

from the pre-Quaternary rocks underlying the basalt and gravel filling of this valley indicates that the explosions originated at shallow depths. The relatively small size of the material ejected likewise shows that the explosions were not very powerful. The presence of different amounts of gravel in successive beds points to spasmodic explosions with periodic collapse of the confining walls of the fissure, feeding in new supplies of gravel and sand. The rising magma, if abnormally charged with gas, could have caused explosions wherever it reached the surface, but this gas would soon have been dissipated and have been followed by a normal outflow of lava. The absence of such a flow leads to a search for some other supplemental cause for the explosions. The great volumes of ground water in the saturated gravel above the ascending magma provide the necessary agent. Rapid heating of this water by the rising magmatic gases would cause steam explosions. Under most circumstances the local supply of ground water would have been quickly dissipated, but at this particular spot ground water is so abundant that it would not be exhausted by many explosions. Near these buttes several hundred second-feet of ground water now issues from the alluvium in the form of spring-fed sloughs; hence strong underflow was possible at that time. Furthermore, the entire surface flow of Henrys Fork and the Snake River would have been available; hence ample water to induce steam explosions would have been there throughout the duration of the eruption. The lack of extremely violent explosions and the supposed occasional slumping of gravel into the conduits lead to the belief that it was mainly ground water that entered the conduits at each recession of the lava column. The pisolites are thought to have been formed by drops of water falling through a dust-laden atmosphere, the water having originated either from simple condensation of the steam-explosion cloud, from local thunderstorms produced by convection currents set up by the rising dust column, or from both.

Olivine Butte, in sec. 7, T. 12 N., R. 43 E., is the only place in the region outside of the locality just described in which tuff is abundant. This butte contains a shallow saucer-shaped crater on its summit and is intermediate between a lava cone and a tuff cone. It is the source of several olivine-rich basalt flows which cover the surrounding area. The entire crater rim with the exception of the south side is covered with sandy limonitic bedded tuff containing a few layers of pisolites. Included in this tuff are water-worn pebbles, bits of volcanic glass, fragments of older basalt, and scoriaceous lava. In a few places there are small faults in the tuff, indicating that there was slight movement in the beds after their deposition. This faulting may have accompanied the collapse of the crater rim subsequent to the explosions that deposited the ash. On the east side of the crater rim a small heap of spatter marks the site of a lava fountain. A clot of lava buried in the ash at the time of the explosion is surrounded by a coating of glass, which shows that incandescent ejecta accompanied the explosion. It appears that the magma found its way to the surface at this place through a gravel fan saturated with water. The contact of the ground water with the magma or its gases probably initiated the explosion, which, once begun, accelerated gas ebullition of the magma. The pahoehoe flows surrounding the cone suggest a quiet type of extrusion interrupted and complicated by ground water. The fact that the tuff overlies the lava on the rim indicates that the explosion was later than the lava flows. If so, then the explosion may have been due to the entrance of ground water into the fissure shaft immediately after the withdrawal of the lava. A similar explosion in Hawaii has been described elsewhere.[27] No tuff cones other than Olivine Butte and the Menan Buttes were found in the Mud Lake region.

WATER-BEARING PROPERTIES OF THE VOLCANIC ROCKS

The basaltic lava is one of the most permeable materials in the region. Wells that penetrate such rock to depths below the water table yield water abundantly. Yields as high as 1 cubic foot a second (450 gallons a minute) for each foot of draw-down have been obtained from shallow wells ending in basalt. The permeability is so great that a depth of only 5 or 10 feet of water in wells in basalt is commonly sufficient for an adequate supply for irrigation by pumping.

Basalt itself, except where full of vesicles, is not permeable, but because it accumulated as thin flows with cavernous and slaggy contacts and during cooling was broken into blocks by shrinkage, water moves through it readily. Besides these crevices, the pahoehoe flows contain numerous tubes and caverns, as much as 30 feet in diameter, which are sometimes encountered during drilling. Mr. Melton reports that when his well (no. 177) was being drilled, one of these tubes was penetrated at 241 feet and fence posts dropped into the well disappeared. He states that he pumped green and dried leaves from his well on several occasions, and as this well is many miles from any trees the water must have been moving through the well freely.

In some of the wells fine-grained, dense basalt is encountered which yields practically no water and which slows down the rate of drilling greatly. Hard, impermeable rock of this character commonly forms the lower part of a flow. Water is frequently found immediately below such rock along the contact between it and the next succeeding flow below.

The pyroclastic materials associated with the lava flows are not generally compacted and are very permeable. However, most of

[27] Stearns, H. T., The explosive phase of Kilauea Volcano, Hawaii, in 1924: Bull. Volcanologique, nos. 5 et 6, pp. 1-16, 1925.

them are restricted to cones of comparatively small area, considerable parts of which are at altitudes above the water table. Consequently such material, in this area, is of little significance with relation to water supply Wells 51, 52, and 53 obtain water from cinders and tuff. Well 53 yields enough to irrigate a garden, although it has only 7 feet of water in the bottom.

LAKE BEDS NEAR TERRETON

The lake beds near Terreton occupy a depression supposed to have been formed as a result of eruptions of lava from vents south of Mud Lake and later accentuated by faulting. (See p. 43.) Camas, Beaver, and Medicine Lodge Creeks discharged into this depression. At one stage in its history, presumably during glacial time, the lake thus formed apparently exceeded 140 square miles in area. At its maximum stage it extended westward into the Lost River sink. Lake beds corresponding to this former connection now lie in the southern part of T. 6 N., R. 32 E., at an altitude of about 4,800 feet above the sea. In most places they are covered with a thick deposit of loess and small sand dunes, and hence their boundary could be mapped only approximately. Northward they interfinger with the alluvial deposits.

Some of the lava flows surrounding the depression were poured out during the existence of the lake, for they are intercalated with the sediments, as shown by the logs of wells in the vicinity of Hamer. It is this structure which gives rise to the artesian wells in that locality.

Logs of wells in the vicinity of Dubois and on the fan of Medicine Lodge Creek indicate that the lake may once have extended over that area and may later have been displaced by the encroachment of lava flows. The detached masses of clay in the walls of the Mud Lake Craters, as shown in plate 11, *B*, suggest that the lake existed prior to the eruption of lava from these craters, but Antelope and Circular Buttes, which form the west boundary of the basin, are much weathered and appear to antedate the lake.

The absence of any outlet channel other than that into the adjacent enclosed basin just mentioned indicates that the water which was not dissipated by evaporation and transpiration escaped underground through the enclosing lava. During the maximum stage of the lake numerous lava boulders were apparently plucked from its shore, rafted by ice into the lake, and finally dropped when the ice melted. It is thought that the isolated angular lava boulders now strewn over the floor of the lake may have been distributed in this manner.

A few fossil bones collected from wells entering the upper members of the lake beds shed some light on the age of the lake. In a clay deposit 45 feet below the surface in well 337, in sec. 15, T. 7 N., R. 33 E., several petrified bones were unearthed, one of which was identified by the late J. W. Gidley as a portion of a toe bone of an extinct species of camel. He states that its presence indicates that the beds are of early Pleistocene or late Tertiary age. The owner of the well reports that there were numerous bones in this bed and that he removed only a part of them. It is a deposit worth prospecting, as the surface material could be readily stripped or a tunnel could be driven into the side of the well. The beds are less consolidated and the bones were less fossilized than those from the Hagerman lake beds, of Pliocene age. For this reason these lake beds are assigned to the Quaternary system. The lake was probably formed in early Quaternary (Pleistocene) time and has continued into Recent time, being now represented by the much smaller Mud Lake.

The Lost River and Birch Creek sinks, mostly beyond the area included on plate 3, are of similar age and origin but were fed by different streams. The beds in these sinks have the same appearance and during the high stages of Terreton Lake were united with those in that lake.

LAKE BEDS OF MARKET LAKE

North of Roberts is a broad flat, the Market Lake bottoms, where formerly the flood waters of the Snake River overflowed. With the construction of the railroad embankment the flood waters were shut off from the bottoms, and Market Lake dried up. Later, irrigation on the Egin Bench caused water to rise in these bottoms and form the Market Lake of today. (See pp. 59–60.) The earlier Market Lake occupied a much larger area. Its deposits consist of unconsolidated sand, silt, and clay, and well logs indicate a maximum thickness of 148 feet. Their areal extent is shown on plate 3. The basin is almost completely hemmed in by lava flows, most of which are older than the lake deposits, although one recent lava flow has encroached upon it, and another, intercalated with the sediments, gives rise to artesian conditions. Crossing the bottoms is a black sand ridge about 10 feet high, which is a shore feature of the former Market Lake.

The only known fossil obtained here is the bone of a large mammal found enclosed in a basalt flow during the blasting for the Butte-Market Lake Canal. The fragment is so small as to be unidentifiable. It is rare for any part of the carcass of an animal engulfed in lava to escape destruction by the heat. The unconsolidated condition of the beds and their relation to the basalt and to the surrounding topography suggest that they are of Quaternary age.

WATER-BEARING PROPERTIES OF THE LAKE BEDS

The lake beds are more effective as confining beds than as sources of water supply. They support perched water in both the Mud Lake and the Market Lake depressions and are also functional in producing artesian conditions. The beds in the general vicinity of Mud Lake are so clayey as to yield water very slowly, and there is little downward percolation through them. Shallow dug wells have obtained meager domestic supplies from these beds in the irrigated area adjacent to Mud Lake. The perched water table (see p. 50) does not, however, extend far south of the lake. The prevailing silt and clay beds characteristic of the southern part of the former lake become interleaved toward the north with sandy foreset beds of the ancient deltas of Medicine Lodge and Camas Creeks, and still farther north, in the vicinity of Monteview and Camas, sand and gravel of the old fans of these streams appear in the wells and yield water copiously.

The lake beds near Market Lake, although sufficiently tight to maintain a perched water table, are as a whole more sandy than those near Terreton, because of their proximity to the Snake River, from which in former years the area annually received sediments. Shallow dug wells obtain adequate domestic supplies from these beds.

GLACIAL DEPOSITS

During the Wisconsin or latest glacial stage, glaciers existed at the heads of most of the major streams in this region, at altitudes above 8,000 feet. That these glaciers did not move far from their cirques is shown by the fact that few of the terminal moraines are much lower. The steep glacial cirques on the headwater tributaries of Camas Creek are visible for many miles, and an arduous climb leads to beautiful clear blue lakes nestled away in these high, ice-scoured basins. Glaciers also existed at the head of Irving Creek, a tributary to Medicine Lodge Creek, and in the mountains east of Camas Prairie, especially in the vicinity of Spread Eagle Peak. These glacial features were not mapped and hence are not differentiated on plate 3.

Prior to the Wisconsin stage there was an earlier glaciation which left its deposits out on the plains. These deposits are now found at altitudes as low as 5,300 feet in the vicinity of Ashton, and excellent exposures of this early glacial debris were seen in 1923 during the construction of the Warm River grade on the Yellowstone Highway east of Ashton. In this glacial stage, named the Buffalo stage by Blackwelder,[28] who first observed these deposits, a great ice sheet from the Teton Mountains advanced to Henrys Fork at the Warm River. Here the ice terminated against the south end of the Big Bend Ridge.

Prior to this glacial stage Henrys Fork discharged from the Island Park Basin through Bear Gulch into what is now the Warm River Canyon. During the Buffalo glacial stage the ice ponded Henrys Fork at the mouth of the Warm River and diverted it westward over the end of the Big Bend Ridge. The ice and debris remained long enough in the old valley to give the river time to establish itself per-

[28] Blackwelder, Eliot, Post-Cretaceous history of central western Wyoming: Jour. Geology, vol. 23, p. 328, 1915.

manently in this new canyon, which parallels the Warm River from Bear Gulch to Warm River railroad station.

Camas Meadows (see pl. 3) is a pitted outwash plain of a pre-Wisconsin glacial stage, consisting of bedded sand and gravel, in most places covered with a layer of gumbo clay several feet thick. The kettle holes are especially numerous near the lower end of the meadows where the deposit reaches an altitude of 6,175 feet. Presumably the icebergs that formed the kettle holes were floated here during the Buffalo glacial stage, but direct evidence of age is lacking.

Beneath the surface soil of the glacial outwash plain in the Camas Meadows lie clean sand and gravel, which yield water copiously. Ground water occurs only a few feet below the surface in the meadows; hence driven wells only 10 feet deep obtain adequate supplies from this formation. Beneath the outwash near the lower end of the meadows are clay deposits, which cause a perched water table.

ALLUVIUM

Extensive deposits of alluvium, mostly in the form of broad, coalescing alluvial fans, border the foothills on the outskirts of the Mud Lake region. The gravel is made up chiefly of older sedimentary rocks, which crop out in the mountains, although quartzite pebbles probably derived from the dissection of the older Pliocene (?) fans and cobbles of acidic and basic lava are not uncommon. Many large basalt cobbles, locally known as "niggerheads", whose vesicularity gives them a low density, are included in the gravel some distance out on the plain, where most of the pebbles of other rocks have been reduced to the size of nuts.

Camas Creek, unlike most other streams, has produced two fans. The upper fan occurs in Camas Meadows, where the stream leaves the mountains. The lower fan is in the vicinity of Camas, where the creek reaches the Mud Lake Basin, and it may be in part a delta formed during former high stages of the Terreton Lake.

In the Island Park Basin considerable gravel has been deposited by Henrys Fork of the Snake River, and Shotgun Valley is filled with alluvium from streams tributary to it. The river near Rea post office and also southwest of St. Anthony is bordered by terraces of older alluvium, which differs from the Recent flood-plain deposits mainly in its topographic position. The Egin Bench, the older alluvial terrace southwest of St. Anthony, is made up partly of black volcanic sand. The older and younger alluvium were not differentiated on plate 3, because elsewhere in the area they are not separable.

Some of the alluvium is contemporaneous with and interstratified with the lake beds near Terreton, as the tributary creeks built deltas into the lake. In other places the alluvium is contemporaneous with glacial deposits and was formed by the debris-laden waters discharging from ice margins. Cloudbursts and spring freshets still contribute to the fans. Thus the alluvium is of Pleistocene and Recent age, and some of it may be even older. Fragments of petrified bone from a gravel pit in sec. 28, T. 8 N., R. 33 E., near Monteview, were identified by the late J. W. Gidley as belonging to the lower jaw of a large proboscidian, apparently *Elephas* sp., and therefore not younger than Pleistocene and not older than upper Pliocene.

The Quaternary alluvium is as a rule coarse and clean and forms an excellent water bearer. Numerous wells are supplied from this formation on the Medicine Lodge fan and elsewhere in the area. Well 459 yields sufficient water to irrigate about 80 acres of land with a draw-down of about 6 feet. The static head during pumping is about 26 feet. The well is 34 feet deep. Several other shallow dug wells of large diameter have yielded irrigation supplies from the gravel near Monteview. Well 470 obtained an excellent supply of water at 40 feet. In the Island Park Basin, in the vicinity of Camas, and on the Egin Bench wells penetrating alluvium yield copiously. The volcanic sand interbedded with the alluvium of the Egin Bench is so permeable that of necessity subirrigation is used.

SAND DUNES

Large areas of drifting white quartz sand occur in the vicinity of the Juniper Buttes, as shown in plate 5, *C* These dunes are largely bare of vegetation, and some of them reach a height of 200 feet. They are traveling northeastward with the prevailing winds and have migrated over the summit of the Juniper Buttes Roads crossing them are continually displaced, and during windstorms it is impracticable for man or beast to cross them. They have left a trail of sand behind them, showing that they have migrated from the vicinity of Mud Lake and were derived from the lake deposits typically developed near Terreton and the sinks farther west. Similar dunes of smaller extent lie northeast of the Big Lost River sink.

Elsewhere in the Mud Lake region, especially near Camas and Hamer, sand dunes 2 to 10 feet high are abundant. These dunes are of darker color than those described above and support considerable vegetation. They were not mapped with the sand-dune pattern on plate 3, because to do so would obscure much important geology. Agricultural expansion is continually leveling them down.

The sand dunes are essentially surface deposits above the zone of saturation and hence are not important as a source of water. Near Hamer shallow wells obtain water from wind-blown sand, but it has a tendency to cave in when saturated. Such sand is frequently encountered in small amounts in deep wells between lava rocks and often causes considerable trouble by running into the well.

STRUCTURE

The complex structure of the pre-Tertiary rocks in this part or Idaho has received little study. The rocks have been folded and locally faulted and overthrust during several periods of deformation. The Tertiary and later beds conceal the structure of the older rocks over large areas. In spite of the intricacy of their structure and the variety of rocks included in them, the pre-Tertiary rocks permit the passage of ground water so slowly that, for present purposes, they may be regarded as an essentially watertight mass, which presumably everywhere underlies the younger rocks of the Mud Lake region and encloses them on three sides. This implies that the Mud Lake region can receive ground-water supplies only from the region topographically tributary to it and that water can escape from it underground only along its southern border, where the old rocks do not rise to altitudes sufficiently great to cut off the escape.

The Tertiary rhyolitic flows and associated rocks are flexed much less intensely than the older rocks but are probably everywhere more deformed than the beds that overlie them. They are supposed to have been bent into a structural depression corresponding roughly to the topographic depression around whose borders they are plentifully exposed.[29] The irregularities in the surface of these rocks, which locally cause them to appear through the cover of basaltic flows, as in the Big Bend Ridge and Juniper Buttes may, in part, record minor anticlines. On the borders of the Island Park Basin there is some evidence of such structure.

The basaltic and other rocks that are younger than the rhyolite appear nowhere to have suffered more than minor and local deformation. The characteristics that govern their interrelations and their effect on the movement of ground water are mainly those of original deposition. The aggregation of so large a mass of lava, pyroclastic materials, and sediments inevitably produced sharp and irregular variations in the attitude and other characteristics of the resulting rocks. Eruptions from numerous sources modified the topography and interfered with the streams throughout the periods of volcanic activity.

The fact that Birch, Medicine Lodge, Beaver, and Camas Creeks no longer reach the Snake River may result in part from disturbance of the previously established drainage by lava flows. It is thought that the slight elevation in the Snake River Plain which forms the southern boundary of the Mud Lake Basin originated from flows of basalt from an east-west line of vents inferred to have existed south of the present Mud Lake.

Similarly it appears that basalt flows in Shotgun Valley may have turned Henrys Fork of the Snake River into the Island Park Basin

[29] Kirkham, V. R. D., op. cit., pp. 24-27.

from a possible former southwestward course. Whether it formerly flowed north or south of the Juniper Buttes could not be determined, but it probably flowed first on one side and then on the other, its course depending upon the topography produced by the many lava flows. After Henrys Fork had been diverted into the Island Park Basin, lava flows issuing from vents in that basin displaced it westward from its natural course, and ground water now following its buried channels returns to the river above Mesa Falls, and some of it may find its way to the Warm River. Hardly any extensive lava flow issued without affecting the drainage, because, following the laws that control its movement, lava seeks the preexisting natural depressions and drainage channels.

Minor deformation affected the basalt and associated beds in some places. The longest fault of which definite evidence is available extends along the north side of Mud Lake. This fault has a length of 4 miles and a maximum displacement of about 50 feet on the east end. It strikes east, with a downthrow to the south. A smaller north-south fault appears to bound the east side of the block. Even-bedded, finely laminated, practically horizontal light-colored lake-bed clays are exposed in the eastern part of the escarpment, but toward the west they give way to blue basalt that was uplifted at the same time. The basalt is tilted downward to the north, and North Lake now occupies the depression formed by this movement. As the fault produced a scarp that has been only slightly modified by erosion and weathering, and as it breaks both sediments and basalt, it is probably late Quaternary. It is probable, however, that the depression occupied by the lake beds near Terreton was produced in part by faulting along this line and that the present escarpment was produced by only the latest movements. In 1911 a rancher living only a mile from the escarpment experienced a sharp earthquake, which may have been caused by renewed movement on this fault.

The conditions that have locally resulted in sufficient artesian pressure to cause water to flow from wells without pumping are the result of variations in original deposition and are not due to subsequent tilting. Here and there in the Mud Lake region permeable basalt is enclosed between tight beds of clay in such fashion that water seeping into the basalt is held under pressure. These conditions, necessarily local, permit the development of artesian wells. The impervious clay beds intercalated in the basalt in this region are of greater practical value in preventing water from sinking, thus forming perched water bodies, than in creating artesian conditions. Information in regard to artesian wells is given on pages 69–73.

Some areas in the Mud Lake region are underlain by great deposits of sand and gravel with interfingering beds of clay, such as in other regions have yielded local artesian supplies. No evidence of artesian water has yet been found in these areas, but so few wells have gone very deep below the water table that it is possible that flowing wells may yet be obtained from deeper parts of these deposits. However, the great depth to the water table to the south and west is distinctly unfavorable.

SURFACE WATER

The streams that contribute to the water supply of the Mud Lake Basin are Camas, Beaver, Dry, Cottonwood, and Medicine Lodge Creeks and a number of intermittent streams. Beaver Creek is a tributary of Camas Creek. Camas Creek is the only stream that discharges surface water into Mud Lake or into the adjoining lakes and sloughs. Blue, Warm, Crooked, and Birch Creeks were also investigated to determine their relation to the ground-water problem.

CAMAS CREEK

Camas Creek heads in several branches that rise in high and heavily timbered parts of the Centennial Mountains and flow into the high basin known as the Camas Meadows (pl. 3). In this basin there are numerous springs and the water table is very close to the surface, as is shown by natural meadow lands and shallow wells. At a point about 5 miles south of Idmon the basin narrows, forming a lava canyon, above which all the branches unite to form Camas Creek. This canyon extends to a point a few miles above Camas. Below the canyon the creek flows over sand and gravel to Rays Lake, where lava crops out in some places. From Rays Lake it flows to Mud Lake over sand and clay.

Stream-flow records were obtained at two principal gaging stations on Camas Creek and are published in water-supply papers of the United States Geological Survey on the Snake River Basin. At the upper station, in sec. 13, T. 11 N., R. 38 E., 2 miles above Lone Tree Reservoir and 19 miles northeast of Dubois, the creek has a drainage area of 216 square miles. Water is diverted from Camas Creek and tributaries above the station for stock watering and irrigation. The lower station was in sec. 34, T. 9 N., R. 36 E., 5 miles northeast of Camas and about 23 miles downstream from the upper station. In 1925 the lower station was moved 5 miles farther downstream, to a point in sec. 21, T. 8 N., R. 36 E., at Camas. There are some diversions for irrigation and stock watering between the upper and lower stations, but even when these are considered the records show that heavy losses occur between the two points. For instance, in 1921 only about 5,730 acre-feet was diverted from Camas Creek between the Dubois and Camas gaging stations, yet the yearly run-off at the lower station was 56,920 acre-feet less than at the upper station. Complete records of these losses in other years are given in the table on page 75.

A considerable part of the loss of water from Camas Creek occurred in the Lone Tree Reservoir, about 2 miles below the upper gaging station. The reservoir, which has a capacity of about 3,000 acre-feet, was constructed by the Wood Livestock Co. for watering stock. Owing to heavy losses the reservoir has been abandoned for storage purposes, and the water is now allowed to flow through it without regulation. Losses in this reservoir are given on page 76.

The Frazier Reservoir, on West Camas Creek, stores about 2,500 acre-feet for stock watering.

About 15,000 acres in Camas Meadows, above the upper station, is under cultivation. This is mostly hay land, which is largely watered by subirrigation. As the ground water is near the surface it evidently does not have free escape to the south, although some water may thus find its way to the lower lands adjacent to Mud Lake.

Two ditches diverted about 8,670 acre-feet during 1922 from Camas Creek above the upper station and carried the water several miles out into the lavas, where it was used for stock watering and most of it was lost by percolation.

The water master on Camas Creek reports that about 870 acres is irrigated by diversions from that stream below the station 5 miles northeast of Camas, of which about 500 acres is partly subirrigated. The water table is 25 feet below the surface at this gaging station and comes progressively nearer the surface downstream until it forms sloughs in the vicinity of Hamer.

BEAVER CREEK

Beaver Creek, which heads in the high peaks along the Continental Divide, flows in a canyon to a point some distance below Spencer and thence in a lava gorge about 50 feet deep to Dubois, where the stream commences to lose water rapidly in coarse gravel. During the spring flood period the creek usually flows for about 2 months all the way to its mouth and discharges into Camas Creek, but during the remainder of the year the creek is generally dry below a point about 3 miles south of Dubois.

Two gaging stations were maintained on this stream, and the detailed records are published in water-supply papers of the United States Geological Survey on the Snake River Basin. The upper station is in sec. 21, T. 10 N., R. 36 E., half a mile north of Dubois. The drainage area above this point is 220 square miles. The lower station is at Camas, in sec. 21, T. 8 N., R. 36 E., three-eighths of a mile above the mouth of the stream.

In 1920 the water master reported that about 3,000 acres was being irrigated above Dubois, largely by water diverted from Beaver Creek above the upper gaging station but in part by water from small tributaries of Beaver Creek. Below Dubois about 1,500 acres was irrigated by water diverted below the upper gaging station. This acreage has been greatly reduced in late years because of the inadequate water supply.

The losses between the two gaging stations are shown on page 74, and the contributions to the water table on page 75. The following miscellaneous measurements were made to determine the losses in the 14-mile section of Beaver Creek between Spencer and Dubois, where the creek flows in a basalt channel. These losses constitute a contribution to the ground-water supply.

Losses in Beaver Creek, Spencer to Dubois, Idaho, 1922–24

[Distance by channel, 14 miles; time interval, 7 hours; difference in altitude (Spencer, 5,880 feet; Dubois, 5,150 feet), 730 feet. No diversions now in use]

Date	Made by—	Rattlesnake Creek near Spencer	Beaver Creek at Spencer	Dry Creek at Spencer	Total inflow	Beaver Creek at Dubois	Loss	
							Second-feet	Per-cent
1922								
May 31	L. L. Bryan	60.2	194	18.3	272	219	53.0	19.5
July 10	do	.73	45.4	0	46.1	42.8	3.3	7.2
August 29	do	0	21.8	0	21.8	16.5	5.3	24.3
1923								
June 9	A. G. Fiedler	7.72	127	10.6	145	136	9.0	6.2
September 6	Berkeley Johnson	0	14.9	0	14.9	13.9	1.0	6.7
1924								
May 13	do	4.29	27.9	0	32.2	32.6	9.6	29.8
May 31	Johnson and Veatch	0	13.8	0	13.8	11.6	2.2	15.9
July 3	F. M. Veatch	0	2.54	0	2.54	.58	1.96	77.2

Figures for Beaver Creek at Dubois for May 31 and July 10, 1921, are derived from computed records; all others from discharge measurements.

MEDICINE LODGE CREEK

Medicine Lodge Creek rises in the high mountains and receives a considerable part of its flow from springs. Several small perennial streams enter from each side of the creek as it flows in a southeasterly course. None, however, enter below the gaging station, which is at the mouth of the canyon, in sec. 25, T. 11 N., R. 34 E. This station was installed April 19, 1921, and was operated until November 30, 1923.

The discharge at the gaging station was 51,500 acre-feet in the year ending March 31, 1922, and 50,200 acre-feet in the year ending March 31, 1923. Between 5,000 and 6,000 acres is irrigated below the gaging station, and after the flood season the entire flow is diverted. A very small amount of water is diverted for irrigation in the narrow valleys above the canyon. The creek begins to lose water through its permeable channel below the gaging station and sinks entirely, even in the flood season, about 6 miles northwest of the Jefferson Reservoir. If it is assumed that in each of the 2 years for which records are given 1.7 acre-feet of water was lost by evaporation and transpiration, exclusive of precipitation, from each of 6,000 acres of irrigated land, a total of 10,200 acre-feet was thus lost each year. On this assumption the quantities lost by percolation and contributed to the ground-water supply from water that passed the gaging station were 41,300 acre-feet in 1921–22 and 40,000 acre-feet in 1922–23. The ground water derived from Medicine Lodge Creek does not enter Mud Lake or the other lakes in the vicinity but moves westward in the area farther north. Like Camas and Beaver Creeks, Medicine Lodge Creek has contributed less during recent years because of the low run-off.

BIRCH CREEK

Birch Creek has its origin in a series of springs a few miles upstream from the ranch of the Wood Livestock Co. The flow of the stream is practically constant throughout the year. In the summer the entire flow is diverted for irrigation, but during the rest of the year the stream flows in a southeasterly direction and gradually loses its water through its porous channel until at a point about 20 miles from its source the water completely disappears in the Birch Creek sinks.

A gaging station on this stream was in operation from September 5, 1910, to June 30, 1912, and from April 1, 1921, to January 27, 1923. It was located in sec. 13, T. 10 N., R. 29 E., about 4 miles south of Reno, above practically all diversions.

The records, which have been published in the water-supply papers on the Snake River Basin, show that the flow at the station was 61,500 acre-feet during the year ending September 30, 1922, 65,100 acre-feet during the year ending September 30, 1911, and 52,100 acre-feet during the period October 1, 1911, to June 30, 1912. The records show that this creek has a relatively constant flow.

About 1,200 acres is being irrigated from this creek. Filings have been made on a reservoir site in the canyon a short distance above the gaging station, where the Birch Creek irrigation district proposes to store about 40,000 acre-feet to irrigate land at the lower end of the valley.

The ground-water contours, as shown on plate 12, demonstrate conclusively that no water from Birch Creek or from the Big Lost or Little Lost Rivers contributes to the ground-water supply in the vicinity of Mud Lake.

HENRYS FORK OF SNAKE RIVER

Henrys Fork of the Snake River rises in Henrys Lake, in Idaho, not far from the west boundary of Yellowstone National Park, and flows southward through the Island Park Basin. After emerging from its lava canyon below its confluence with the Warm River it flows southwestward over a lava plain for a distance of about 36 miles and empties into the Snake River. About 5 miles below the mouth of Henrys Fork the Snake River makes an abrupt turn to the south and flows past the towns of Roberts and Idaho Falls. Henrys Fork is fed by numerous springs, and consequently it seldom freezes over. It has two beautiful waterfalls in the Island Park country, northeast of Ashton. The Upper Falls, sometimes called Mesa Falls, are formed by a vertical cliff of silicic lava 90 feet high.

The principal tributaries of Henrys Fork from its source to its mouth are Big Springs, the Buffalo River, the Warm River, Robinson Creek, the Fall River, and the Teton River. These tributaries all enter Henrys Fork from the east side. There is no perennial tributary entering from the west side from Shotgun Creek, near its source, to its mouth, a distance of about 60 miles. This is due chiefly to the porous condition of the rocks on the west side and the absence of high mountains.

Five gaging stations are maintained on Henrys Fork by the United States Geological Survey. The flow past these stations is given in the published water-supply papers on the Snake River Basin.

INTERMITTENT STREAMS

Of the many small intermittent streams that have their sources in the Centennial Mountains north of Mud Lake the principal ones are Dry, Rattlesnake, Patelzick, Thunder, Cottonwood, Blue, Warm, and Crooked Creeks. Each of these streams has a comparatively large flood run-off of short duration, but all of them lose water rapidly after leaving the foothills. They doubtless all contribute to the ground-water supply, but a study of the form of the water table indicates that the ground water contributed by Blue, Warm, and Crooked Creeks does not reach the vicinity of Mud Lake. A measurement obtained on Dry Creek May 9, 1921, indicated a flow of 91 second-feet at a point about 6 miles northeast of Kilgore. At that time it was noted that the entire flow disappeared in lava beds about 4 miles below the point of measurement. A number of large springs, however, were noticed about a mile west of this sink, in the eastern edge of the Camas Meadows, where a large portion of the water lost probably reappears and flows into Camas Creek. The entire normal flow and about half of the flood flow of Dry Creek is diverted into the reservoir of the Wood Livestock Co. on Sheridan Creek, which flows into Shotgun Creek, a tributary of Henrys Fork. The point of diversion in Dry Creek is about 2 miles above the point where the measurement was made on May 9, 1921. Rattlesnake, Patelzick, and Thunder Creeks are used to irrigate small tracts of land near the edge of the plains.

MUD LAKE

The Mud Lake gage is in the SW¼ sec. 13, T. 6 N., R. 34 E., in the intake canal of the First Owsley Canal Co., which pumps water for irrigation from Mud Lake. The gage is 500 feet north of the pump house, 1 mile east of Terreton. During the irrigation season of 1921–22, when the water surface at the gage was affected by the draw-down from pumping, an auxiliary staff at the same datum across the lake, on the north shore at Beckner's ranch, was used. From 1923 to 1928 a gage in the NW¼ sec. 3, T. 6 N., R. 35 E., at Magill's ranch, 6 miles northeast of the gage in the First Owsley intake and set to practically the same datum, was used to supplement the gage at the First Owsley intake canal.

Records are available from April 4, 1921, to September 30, 1929. The zero of the vertical staff gage is 4,775.33 feet above mean sea level. Ice at the gage renders observation difficult at times. Considerable water is diverted from the lake and its tributaries, both by pumping and by gravity, but since 1925 very few gravity diversions have been possible because of the low stage of the lake. Records of daily lake contents are published in the United States Geological Survey water-supply papers on the Snake River Basin. The maximum content of Mud Lake each spring since records have been obtained is shown by the following table:

Maximum quantity of water stored in Mud Lake each year, 1921–1932

	Acre-feet		Acre-feet
June 8, 1921	55, 040	April 14, 1927	35, 200
May 30, 1922	59, 410	April 6, 1928	34, 800
May 4, 1923	61, 660	May 12, 1929	32, 500
May 4, 1924	60, 000	April 26, 1930	26, 400
May 18, 1925	47, 700	May 3, 1931	28, 800
April 27, 1926	57, 700	May 12, 1932	28, 500

WATER TABLES

METHODS OF INVESTIGATION

The water table, or upper surface of the zone of saturation, is almost nowhere a level surface but has irregularities that can be shown on a map by means of contour lines, just as the irregularities of land surfaces are shown on topographic maps. A contour map of the water table of a region generally throws much light on the source, movement, and disposal of the ground water and may also give important information as to the quantity of ground water and the influence of geologic structure upon its occurrence. The water table is generally highest in areas of intake and lowest in areas of discharge of ground water and fluctuates with the amount of inflow and outflow. As ground water, like surface water, tends to move down grade, it generally moves in the direction that the water table slopes, at right angles to the water-table contours.

As the water supply of the Mud Lake Basin was known to be derived largely from ground water, it was evident that the investigation must include the preparation of an accurate contour map of the water table (pl. 12). In order to prepare such a map records were obtained of about 600 wells, including nearly all the wells in the region. Measurements were made of the depth to the water level in practically all the open wells, but for the depth to water in most of the drilled wells it was necessary to take the owners' statements, many of which were verified by the drillers. All measurements were made from definite bench marks, which were installed in order that continued observations could be referred to the same datum plane. The altitudes of most of the wells were tied in by levels in order that the measurements to the water table in the different wells could be referred to the same datum. All sloughs and other outcrops of the water table were mapped.

In order to ascertain the fluctuations of the water table, monthly measurements were made in nearly all the open wells. The reported rise of the water table near Mud Lake in the period from 1900 to 1922 was verified by mapping the areas of dead sagebrush. Areas of greasewood were also mapped, because greasewood is known to depend upon the ground water for existence, and the invasion of a new area by this brush would indicate that the water table had risen. In June 1922 a well was drilled in sec. 16, T. 7 N., R. 38 E., to ascertain the exact depth to water and the fluctuation of the water table between the Egin Bench and Hamer.

As the structure of the basalt varies widely from place to place and as the basalt is intricately related to interbedded and overlying layers of impervious clay, the water table was found to be very capricious and to have peculiar features not commonly found in other regions.

PERCHED CONDITION OF MUD LAKE AND CONTIGUOUS GROUND WATER

One of the most striking and significant facts disclosed by this investigation is that Mud Lake and the water found in the shallow wells in the vicinity of the lake form a perched body of water that lies a few hundred feet above the water table of a deeper body of ground water. The shallow wells on all sides of Mud Lake have water levels that are more or less concordant with the water level of the lake, but deep wells drilled south of the lake pass through the deposit of clay and find water in the basalt, generally 250 to 275 feet below the lake level. The deep water does not rise perceptibly in the wells. It forms a true water table that is far below the lake level and that extends beneath the lake, as shown on plate 12. From all indications, Mud Lake lies upon thick clay strata, which are mainly the cause of its perched position. The perched water table in the clay beds southwest of Mud Lake is due in part to irrigation and in part to water seeping away from Mud Lake. Since 1925 a shortage of water in

Mud Lake has caused a shrinkage of the area of this perched body of water. The lower water table south of Mud Lake is continuous with the main water table of the Snake River Plain and has a general slope to the southwest, as shown on plate 12.

The hydrographs shown in figure 2 represent conditions in the perched-water area on the south side of Mud Lake for the period May 1921 to November 1922. During the time of observation the high stage of these wells was reached in the summer or early fall, and the low stage in the winter or spring. There is a direct relation between the time of the high stage and the distance of the wells from the lake, the wells near the lake rising earlier than those farther away. The effect of the lake on these wells cannot be entirely differentiated from

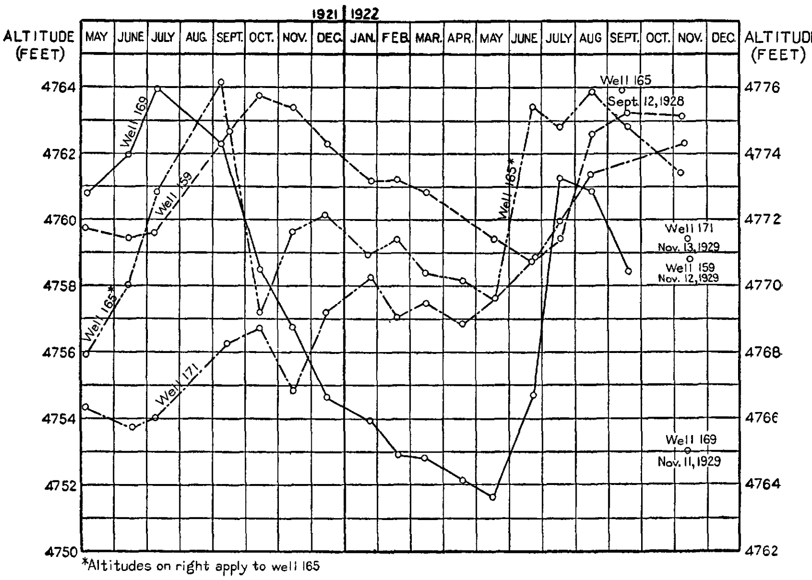


Figure 2.—Hydrographs of wells in the perched-water area on the south side of Mud Lake.

the effect produced by irrigation, although the abrupt rise of the water table in May or June, soon after the beginning of the irrigation season, and the sharp decline in the fall indicate that percolation from the adjacent irrigated land or canals is the chief cause of the high stage. The rise occurs during the dry months and the low stage during the relatively wet months—a fact which eliminates precipitation as the cause.

On figure 2 are shown also measurements of the wells in 1928 or 1929. The measurement of well 165 in 1928 shows that there has been no noticeable change in the water level in this well in 6 years. It is close to Mud Lake, in an irrigated field; hence this lack of change is not surprising. During the intervening period Mud Lake has receded considerably, so that this measurement seems to indicate that the water level of the well is not dependent upon the seepage away from the lake. Measurements of the other three wells in November 1929 show a decline of several feet as compared with November 1922. This was to be expected, in view of the shrinkage of the area of lands irrigated near these wells and the lack of sufficient water to irrigate adequately most of these lands in recent years.

The hydrograph of well 167 (fig. 6), only a quarter of a mile south of the 1921 shore line of Mud Lake, differs from those shown in figure 2 in that it reaches its high stage in the spring and its low stage in the fall, coincident with the high and low stages of the lake. The low stage of 1925 also reflects the decline of Mud Lake during this low-water year. In the Snake River drainage basin there was a shortage of water in 1924, but because this lake is largely fed by ground water it did not reflect this shortage until 1925.

AREA NORTH OF MUD LAKE

There is a rapid drop in the water table in the lava plains at the foot of the mountains and also south of the Camas Meadows. Farther south the water table has a gentle gradient in general toward the southwest, but in the vicinity of Mud Lake and in the areas northwest and southeast of the lake it either comes to an end or descends abruptly. To this water table percolates the water that is lost from Camas, Beaver, and Medicine Lodge Creeks and a few smaller streams and also an undetermined part of the water that falls as rain or snow in the Mud Lake Basin but does not reach these streams.

The flatness of the water table north and east of Hamer indicates that the ground water in that area is in permeable lava. The hydrographs of four wells in the vicinity of Hamer for the period June 1921 to November 1922 are shown in figure 3. These wells show a fluctuation of less than 1 foot during this entire period, which is less than that of any other wells in the Mud Lake region. Wells in this area all end in very permeable basalt, as is shown by the large specific yields of the Hamer wells and of the Raumaker well, which yields when pumped about 1 second-foot of water with only a few inches of draw-down. It seems logical to believe that the slight fluctuation of the water level in the wells in the vicinity of Hamer is due to the permeability of the rocks. Thus water percolating downward from irrigated fields escapes readily. The hydrographs, although covering only a short period, indicate that the slight fluctuation that does occur is caused largely by irrigation. Measurements in 1928 and 1929 in this area show that the position of the water table relative to that of 1921 was practically unchanged, but reports from residents in 1930 indicate that the water table had then fallen about 6 inches.

Although wells have not been drilled in the large lava field north of Mud Lake there is no doubt that the main water table extends across it. Most of the lava is doubtless permeable enough to allow water to percolate through it. The volcanic feeders below the craters may be impermeable but are probably so small as to be negligible. It seems unlikely that there are two distinct water tables north of Mud Lake, as there are south of it. There may, however, be sufficient leaks in the formations to allow water to escape to the deep water table south of the lake and to cause funnel-shaped depressions in the water table

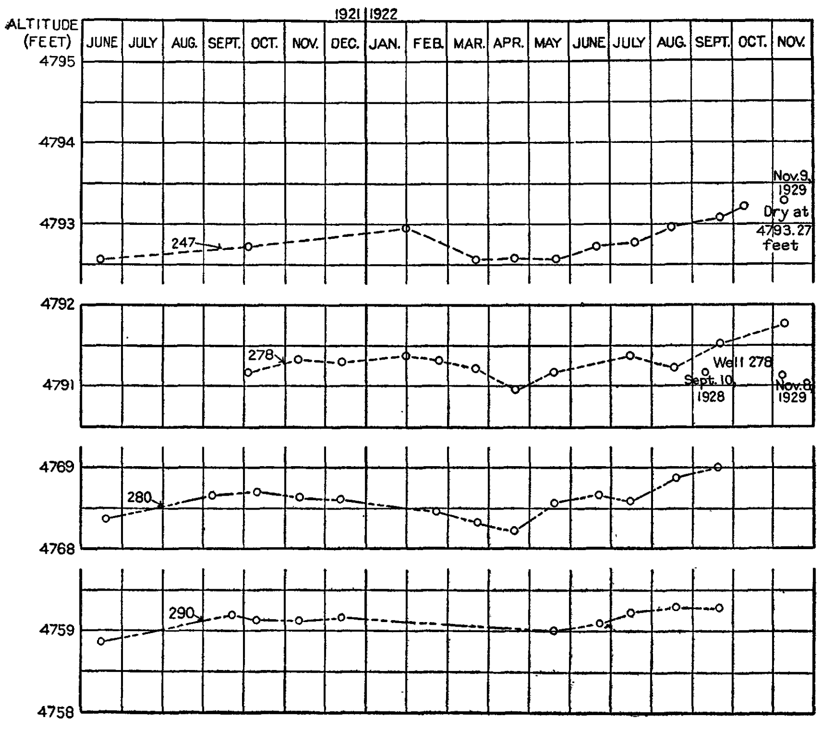


FIGURE 3.—Hydrographs of wells near Hamer.

in the lava field north of the lake. The craters north of Mud Lake are younger than most of the water-bearing lake beds near Terreton and the deeper formations nearby.

The water-table contours indicate that part of the water lost from Camas and Beaver Creeks, which passed under Mud Lake before irrigation on Egin Bench increased the ground-water supply, now reappears, for the most part, as ground water in the swampy area northeast of Mud Lake, where it is disposed of mainly by evaporation and transpiration or by percolating to the surface and draining into Mud Lake. A part of the ground water derived from these creeks also percolates westward into the lava that lies north of Mud Lake, whence it passes farther west to the wet areas in the vicinity of the Jefferson Reservoir and Spring Lake or north of them, or escapes from the basin by percolating southward in the vicinity of Hamar, where the water table drops off rapidly toward the south.

The hydrographs of four wells northeast of Mud Lake in the vicinity of Camas are shown in figure 4. Although these wells are several miles apart, there is a difference of only 2 feet in the altitude of the water levels in them. The flatness of the water table in this area is also shown by the ground-water contours on plate 12 and indicates very permeable water-bearing formations. The slight fluctuation of the water levels in these wells is further indication of the great permeability of the formations. The high stage, in general, occurs during the winter, and as this is too late to be an effect of irrigation and occurs before the snow cover melts or before Camas Creek is in flood, it seems in all probability to be caused by the arrival at this place of ground water from outside areas. As Camas and Beaver Creeks lose heavily each spring in crossing the lava plains near the mountains, and as the slope of the water table is such that this lost water moves underground toward these wells, it is not unlikely that the rise of the water table in December and January occurs in response to losses in these creeks during the previous spring. A secondary rise that occurs during the spring in some of the wells appears to be due to the high stages of Camas Creek at this time, perhaps aided by direct recharge from percolating precipitation. The water table is so close to the surface that direct recharge must occur.

The water lost by Medicine Lodge Creek sinks to this water table and doubtless furnishes a portion of the supply encountered by numerous wells near Winsper, Old Monteview, and Monteview. Some of the water from this creek may reach Spring Lake and the wet tracts farther south, but the map shows that the water table in this part of the basin slopes steeply toward the west, proving that most of the supply from this creek, except that lost in the upper part of the fan, percolates westward to great depths and is lost to the Mud Lake Basin. The only means of recovering most of this water before it escapes from the Mud Lake Basin is by pumping it from wells.

In the vicinity of Spring Lake and the Jefferson Reservoir there is a large tract of swampy land that is chiefly supplied by seepage from the lava that lies to the east. This swampy tract has been produced largely by a rise in the water table similar to that farther east. Apparently this rise has had a tendency to elevate the water table farther north, below the fan of Medicine Lodge Creek. A part of the water that comes to the surface in the vicinity of Spring Lake and the Jefferson Reservoir is used for irrigation, and a part is lost by evaporation and transpiration. A part also doubtless percolates westward

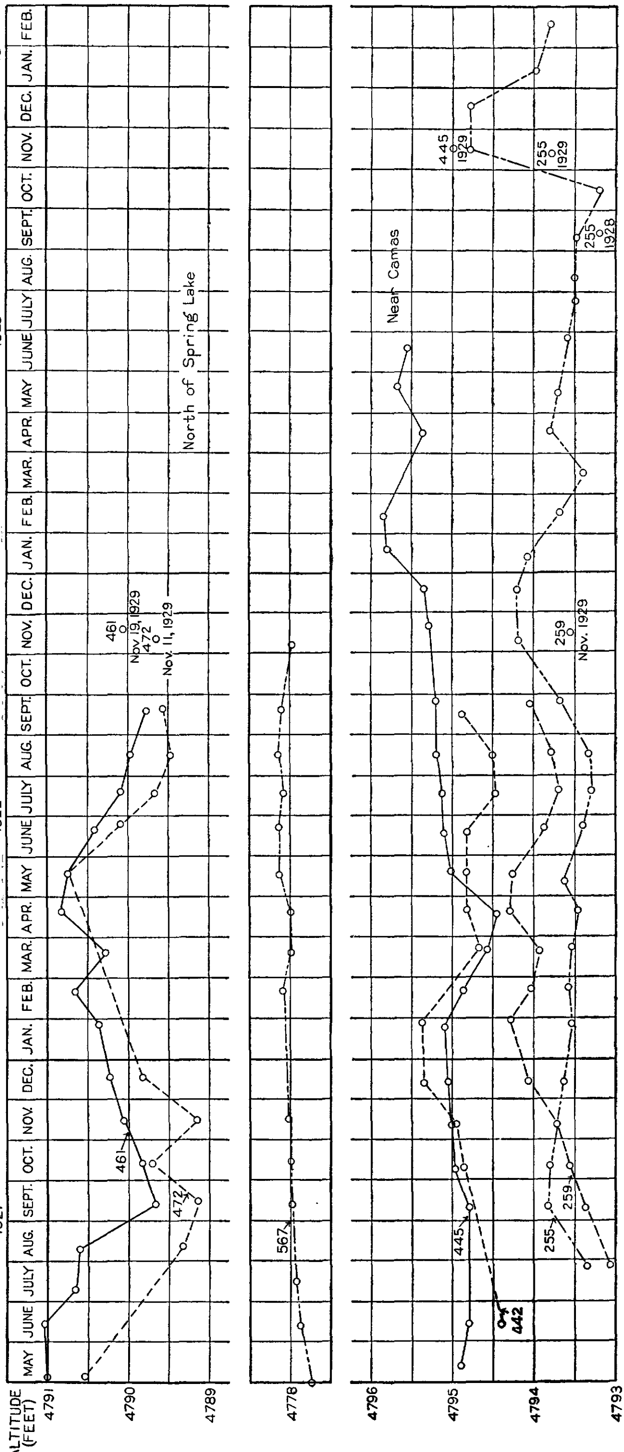


FIGURE 4.—Hydrographs of wells near Camas and north of Spring Lake.

and is lost to the Mud Lake Basin except as it is pumped from wells in the belt to the west, where the depth to water is only moderate.

Hydrographs of five wells northwest of Mud Lake appear in figure 5. The lack of similarity in the fluctuation of these wells is due to the fact that different conditions of recharge affect them. Well 310

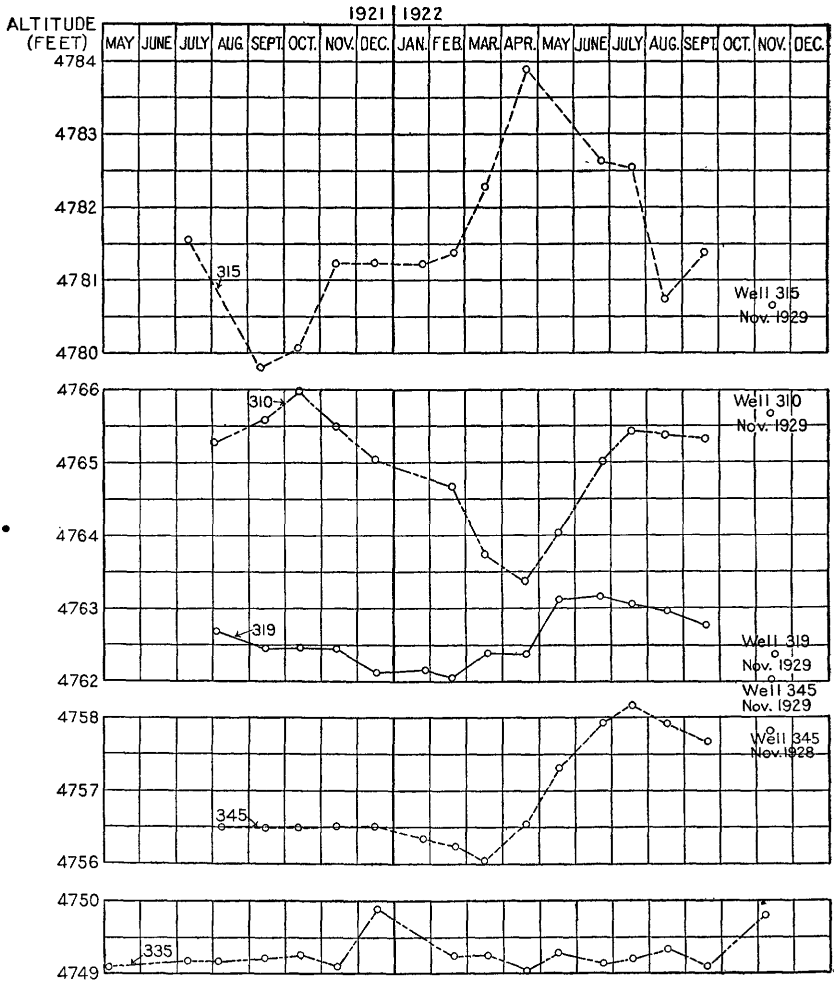


FIGURE 5.—Hydrographs of wells northwest of Mud Lake.

was affected by irrigation and hence behaved like those in figure 2. Well 315 reached its high level in the spring. Well 319 reached its peak a little later than well 315 because of its greater distance from Spring Lake. Well 345 reached its highest stage in July because of the irrigation of land under the McKevitt Ditch, a few hundred feet to the east. The lack of a definite peak in this well in 1921 may have been due to the lack of irrigation of these lands. The high stage of well 335, coming in November or December, is not easily accounted for except as a lag in response to the high stage of the water table in the vicinity of Spring Lake. This well is about 4 miles west of the lake and penetrates fairly fine-grained sediments, in which the rate of ground-water movement must be slow.

In figure 4 are hydrographs of wells 461 and 472, which are 2 and 3 miles, respectively, north of Spring Lake. They reach their peak stage in April or May, at the same time as the lakes. The hydrograph of well 567, in figure 4, is significant because it shows a fluctuation of less than 1 foot and does not follow the trend of the graphs of wells 461 and 472. This well is about 7 miles north of Spring Lake, on the bank of Medicine Lodge Creek. The waters of this creek did not reach this point in 1921 or 1922; hence a response to local recharge from the creek is not to be expected. However, the lack of fluctuation may be interpreted either as indicating a high permeability of the water bearer or as due to the lack of appreciable recharge from Medicine Lodge Creek during this time. The second inference seems the more likely, because wells in coarse gravel on the Medicine Lodge alluvial fan show an increasingly larger fluctuation as the mountains are approached.

The similarity of the time of high and low stages of all the wells in the vicinity of Spring Lake to that of the wells near Camas points rather conclusively to similar conditions of recharge—namely, from losses in Camas and Beaver Creeks rather than from Medicine Lodge Creek. This fact further supports the belief that ground water is percolating westward through the lavas north of Mud Lake, and that the great underground reservoir north of Mud Lake is overflowing to the west to supply Jefferson and Spring Lakes, and the surplus is feeding the water table, which extends westward toward Birch Creek.

Cooperation by Alec Mitchell in measuring his well 305 monthly has made it possible to prepare the graph of this well from November 1921 to September 1929. This well which is about three-quarters of a mile west of the Jefferson Reservoir, is about 10 feet deep and ends in sand. The land around the well is irrigated with water from Spring Lake. In this graph, shown in figure 6, the high stage is annually reached in May or June, and the low stage usually in September or January. The close agreement of the high stage in this well with that in well 167 near Mud Lake, is brought out forcibly in figure 6 and shows the common source of underground supply, although one is about 6 miles northwest of the other.

CAMAS MEADOWS

A perched water table above beds of clay was revealed by test drilling for the proposed Camas Meadows Reservoir. Well 588, in sec. 6, T. 11 N., R. 39 E., encountered 10 feet of gravel resting on 12

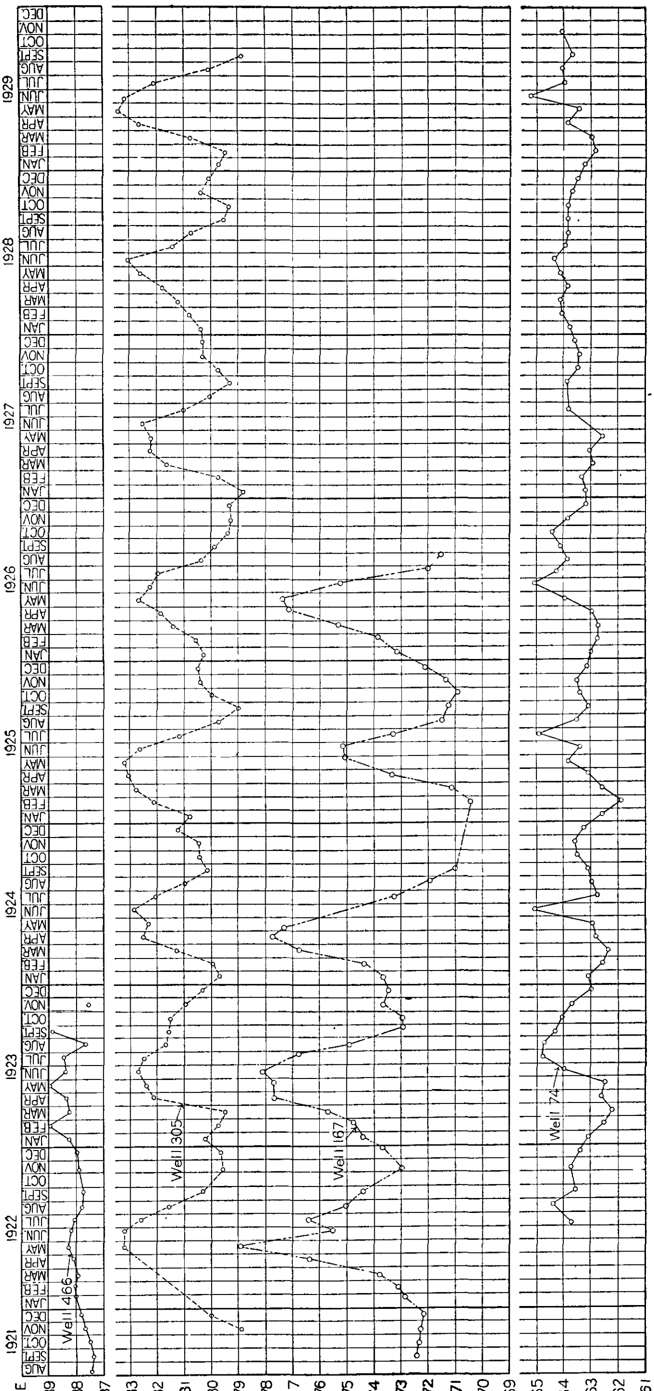


FIGURE 6.—Hydrographs of wells in the vicinity of Mud Lake.

feet of puttylike clay, which in turn rests upon basalt. Ten holes were drilled at this site, and all encountered the clay. The water stands only 3 feet below the land surface in this well. Abundant supplies of water are found a few feet below the surface in the Camas Meadows in clean gravel and sand. Whether this perched water table, which is over 150 feet above the main water table at the south end of the Camas Meadows, extends to the foot of the mountains to the north is unknown, but it is not improbable that the impervious clay beds in the lower end of the meadows grade into sand and gravel to the north and allow water to sink to deeper levels to supply the main water table farther south.

ISLAND PARK BASIN

In a general way the water table of the Island Park Basin slopes gently toward Henrys Fork of the Snake River between the Buffalo River and Osborn Bridge, in sec. 36, T. 12 N., R. 42 E. Southward from this bridge it passes beneath the river and slopes to the southeast. Too few wells have been drilled to determine its exact shape, but no water was found in the well 101 feet deep that penetrated rhyolite (or rhyolitic tuff) beneath basalt and cinders in the bottom of Henrys Fork at the Island Park dam site, in the SE¼SE¼ sec. 14, T. 11 N., R. 42 E. Furthermore, water allowed to run into the well from the river drained away through the well underground. The deep canyon of Henrys Fork between the dam site and Mesa Falls probably drains the ground water of the basin, in large part at least, as measurements on September 9, 1931, show a ground-water gain of 100 second-feet on the 12-mile stretch of channel above Mesa Falls but no loss or gain between Mesa Falls and the Warm River. Some of the ground water of the basin below Osborn Bridge may be tributary to the Warm River rather than to Henrys Fork. This can be explained by the fact that Henrys Fork has been moved to the west side of the basin by the extrusion of basalt and into a new position from a point near Bear Gulch to the mouth of the Warm River during the Buffalo glacial stage. Any ground-water losses from the Henrys Fork drainage basin into the Warm River must be small, however, as during the 4 years from 1927 to 1930 Henrys Fork above the mouth of the Warm River had an average annual run-off of 1,120 acre-feet per square mile of drainage area, compared to 860 acre-feet per square mile of drainage area during the same period on the Warm River.

MARKET LAKE BASIN

During 1922 an investigation was made of the Market Lake Basin in order to determine its relation, if any, to Mud Lake. It was found to be independent of Mud Lake but to have a somewhat similar hydrologic and geologic history.

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According to Sam Hart, who arrived at Market Lake in March 1884, the Utah & Northern Railway, which ran across the bottoms in the same location as the present Oregon Short Line, had three bridges north and two south of Roberts. These bridges allowed flood water of the Snake River to pass under the railroad and fill up the Market Lake depression. During some years this flood water would be entirely dissipated by evaporation, transpiration, and deep percolation, but during a few years it did not entirely dry up. It was then a favorite duck-hunting ground and received its name because so many market hunters came there for game birds.

As early as 1882 John Balmer dug a well in the NW¼ sec. 30, T. 5 N., R. 37 E., and found water 16 feet below the surface; hence a shallow water table existed here, like that near Mud Lake. About 1888 the Utah & Northern Railway was standardized, and the fill made at that time covered up the previous culverts and completely shut out the flood water of the Snake River from Market Lake, allowing it to dry up except in the spring, when snow and rain water collected in it. In 1886, according to L. V. Ledvina, there was about 40 acres of water east of the railroad at the springs near the old stone house, but west of the tracks it was always dry after the middle of August. However, about 1900, 5 years after irrigation began on the Egin Bench, water began to appear west of the railroad tracks, and in a few years the present Market Lake was formed. This lake is smaller than the older one but has never gone dry. (See pl. 3.)

Cooperation by Mrs. Y. A. Roberts, of the village of Roberts, in making readings and keeping records during the period from July 1923 to November 1929 has made it possible to construct a graph (see fig. 6) showing the fluctuation of well 74 from July 1922 to November 1929. This well is too far south of Market Lake to show any effect from it. Instead, the well has a high stage in June or July, as a result of irrigation of land adjacent to it from water diverted from the Snake River.

EGIN BENCH

Before irrigation began on the Egin Bench in 1895 the water table stood more than 100 feet below the surface near Parker, where it now stands within a few feet of the surface during the irrigation season. The shape of the water table is shown by contours on plate 12. The alluvium of this bench is so permeable that the usual surface irrigation methods are not used. Instead, the water table is artificially built up nearly to the surface each spring by leakage from the canals. Instead of furrow or check irrigation, a field is irrigated by running water down laterals until the water table is raised to the desired height by percolation from these laterals. As a result of this method, 10 to 12 acre-feet of water to the acre is diverted annually, as compared with 3 to 5 acre-feet in many other irrigated areas. As shown on plate 12, the water table is essentially a flat-topped ridge following the axis of the bench, with the crest of the ridge under the canals. It has a gradient of about 10 feet to the mile, or the same as the land surface. The ground-water ridge slopes gently toward Henrys Fork on the south side, where ground water slowly percolates back to the river. On the north side of the ridge the contours indicate a virtual cascade of the ground water as it sinks into the permeable lavas to the north. The bench lands lie higher than Henrys Fork but much lower than the lava plains north of them. The ground-water contours indicate that a part of the water going north from the bench moves to the north of the Juniper Buttes and reappears in the vicinity of Camas. Prior to the irrigation of the Egin Bench, H. Steward dug to a depth of 100 feet in the vicinity of Camas to get water, but now it is only about 20 feet to water.

However, not all the Egin Bench water escapes northward to reach the Mud Lake Basin or southward to reappear in Henrys Fork as return flow. A considerable part of it moves southwestward toward Roberts and feeds Market Lake and the water table between Market and Mud Lakes. In 1922 a level line was run from the water level in a well near the end of the Egin Bench to the water level in a well near Hamer, across a stretch of lava and sand where the depth to water was unknown. A uniform gradient of the water table was assumed between these two points, which are about 15 miles apart. Then a test well was drilled at a low point on the surface along this level line, and the depth to water in this well was found to be within 3 feet of the assumed depth. This well (no. 434) was drilled in June 1922, in sec. 16, T. 7 N., R. 38 E., and water was found 52 feet below the surface. The water level in this well reaches its high stage in September and its low stage in April, showing that the well responds to irrigation on the Egin Bench.

The hydrographs of five wells on the Egin Bench are given in figure 7. Well 231, which is in the middle of the bench, has a water-level record extending over a period of nearly 4 years. According to the owner, the depth to water in this well was 48 feet on November 15, 1898. During the period of measurements the water level only once fell to 24 feet below the surface. The annual fluctuation of this well, however, is as much as 20 feet. The water level reaches its high stage in June and its low stage in April. The abrupt rise in April corresponds to the turning of water into the canal on the Egin Bench, and the fairly rapid decline after August of each year is caused by the quick draining away of the ground water when irrigation ceases. Wells near the upper end of the bench show relatively less fluctuation, perhaps because of water being in the upper end of the canals in the

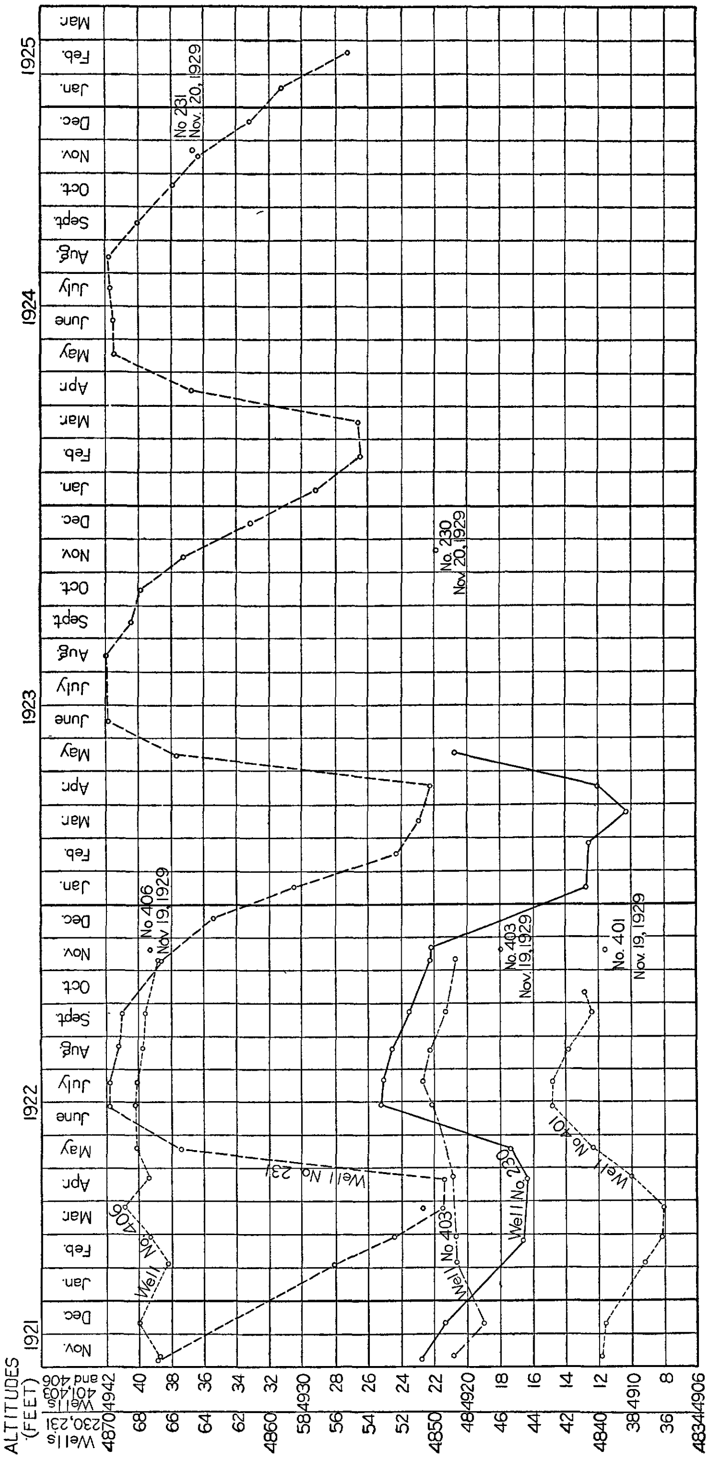

FIGURE 7.—Hydrographs of wells on Egin Bench.

winter but more probably because of the lower permeability of the alluvium and the fact that the lower end of the bench must drain out first.

GROUND-WATER DISCHARGE

PROCESSES AND AREA

Unlike the closed basins so common in the semiarid portions of the West, where all the ground water is discharged by evaporation and transpiration in a swampy tract in the lowest part of the valley, the Mud Lake Basin, although losing heavily by these processes, has an underground outlet. Although topographically it is a closed basin, the rocks forming the south rim are permeable and allow water to escape underground through them. In recent years, as a result of seepage from the Egin Bench, as explained on pages 79–84, ground water appears at the surface and flows into Mud Lake or is dissipated by evaporation and transpiration. If in earlier periods no water stood at the surface a quantity of water equal to at least the average seepage losses of Camas and Beaver Creeks must have escaped from the basin through underground outlets. A similar amount of water is doubtless now escaping from the basin plus an indeterminable amount contributed from the Egin Bench. Some leakage out of the basin is believed to take place between a point 2 miles east of Hamer and West Hamer Bridge. Leakage may also occur between West Hamer Bridge and Spring Lake by water descending into low-lying lava beds and passing under Mud Lake. Additional leakage occurs for several miles northwest of Mud Lake and Spring Lake, as is shown by the contours of the water table near Monteview.

SPRINGS

CHARACTER AND DISTRIBUTION

In the high parts of the Beaverhead and Centennial Mountains, north and northeast of Mud Lake, small springs are fairly abundant, but in the more barren foothills, in the Juniper Buttes, and in large parts of the lava plains, springs are absent or very scarce. Some of the perennial water holes in the lava plains occur in caves in the lava and are fed by the slowly melting ice accumulated during the winter. Most of the mountain springs except those in the Island Park Basin are fed by water that percolates near the surface, and they occur where barriers of impervious rock permit the water to escape from the ground. They do not, of course, discharge any of the water stored in the lava plains but rather feed the streams that contribute to the water in the lava beds.

The springs of the lava plains, on the other hand, are found in depressions where the water table is practically at the surface. These springs discharge the surplus of the underground reservoir, which, constantly receiving new supplies, overflows because the underground conduits are filled to capacity.

Some of the springs in the Island Park Basin discharge very large quantities of water and are among the largest springs in the United States. These springs are the outlets of extensive former stream channels that are now filled and buried by lava rock containing fissures and other large irregular openings through which water flows freely.

ISLAND PARK SPRINGS

Big Springs.—The Big Springs issue from spherulitic obsidian and rhyolite in the NW¼ sec. 34, T. 14 N., R. 44 E. The spring water issues into a pond at the foot of a high cliff that forms the western edge of an extensive timber-covered lava plateau with little run-off. The temperature of the spring water on July 22, 1921, was 53° F. On June 25, 1922, the discharge of the springs was 190 second-feet, and on August 22, 1922, the discharge at a point 400 feet below the highway bridge near the springs was 184 second-feet.[30] The spring branch flows westward about 2 miles to its junction with Henrys Fork. Locally the springs are considered the source of Henrys Fork, the small stream above the confluence being termed "Lake Fork."

Buffalo River Springs.[31]—The Buffalo River heads about 4 miles south of the Big Springs, in sec. 21, T. 13 N., R. 44 E. Innumerable small springs issue along its bank from the railroad bridge to its head. Waldron and Cabin Springs are the only large ones. The former discharges about 5 second-feet and the latter about 10 second-feet. The temperature of the springs on June 11, 1930, was 52° F. The springs issue from jointed, even-bedded, nearly horizontal rhyolitic agglomerate. For the upper 5 miles the river is bordered by steep walls of agglomerate about 50 feet high. The entire flow of the river comes from springs, for there are no indications at the head of it that even an ephemeral stream drains into it. The stream of remarkably clear water from these springs flows westward about 8 miles and discharges into Henrys Fork. The flow of the Buffalo River near its mouth on September 9, 1903,[32] was 183 second-feet, all of which was doubtless spring water.

Warm River Springs.—The Warm River Springs are classed by Meinzer,[33] like the two groups described above, as springs of the first magnitude, or among the 65 largest springs in the United States. They are, however, more scattered than those of the two other groups.

[30] Meinzer, O. E., Large springs in the United States: U. S. Geol. Survey Water-Supply Paper 557, p. 53, 1927.

[31] Idem, p. 53.

[32] U. S. Geol. Survey Water-Supply Paper 100, p. 461, 1904.

[33] Meinzer, O. E., op. cit., pp. 3, 53.

The Warm River has its source in a small spring in sec. 11, T. 12 N., R. 44 E., and flows southward to Henrys Fork. At Eccles siding, about 5 miles below its source, it is only a small stream of about 5 second-feet during the summer, but at its confluence with Henrys Fork, about 16 miles farther south, it has an average low-water discharge of about 250 second-feet. Warm River Springs, in sec. 10, T. 10 N., R. 44 E., are the principal source of water supply of the stream. The chief spring rises in a small cove about 30 feet above the east bank of the river, and when visited in October 1934 it was discharging about 70 second-feet. At the same time the river above this spring was flowing only about 15 second-feet. Most of the water issues from joint cracks in a granular siliceous porphyry, but some water issues in the river bed where the formation is obscure. The rock is divided into horizintal layers suggestive of welded tuff, but it may be a thick lava flow. It forms a cliff about 125 feet high at this place. Several large holes in the rock at the head of the spring cove were dry in 1934. They were discharging water in 1931.

Osborn Springs.—The Osborn Springs, of which there are five different groups, issue from basalt in secs. 5 and 6, T. 11 N., R. 43 E. Their total discharge amounts to about 6 second-feet, which flows into Osborn Pond, a depression a few feet deep without a surface outlet. Here the water disappears by percolation to the water table below, presumably finding its way to the Warm River. On August 29, 1923, these springs had a temperature of 44° F.

Ripleys Ford Springs.—Five springs issue from the foot of a basalt terrace in secs. 8 and 9, T. 12 N., R. 43 E., at Ripleys Ford. On October 20, 1923, it was estimated that nearly 5 second-feet was discharged into Henrys Fork from these springs. The temperature on that date was 42° F.

MOOSE SPRINGS

The Moose Springs rise in sec. 30, T. 13 N., R. 42 E., in Shotgun Valley. They issue from the edge of a basalt flow and from the adjacent alluvium, and in a distance of slightly less than 2 miles the spring branch joins Sheridan Creek to form Shotgun Creek, a tributary of Henrys Fork. On June 12, 1930, the discharge of these springs where they first emerge was estimated at 25 second-feet, and their temperature was 44° F. Grizzly Spring, one of the largest of the springs and at a distance from the rest, discharges about 5 second-feet, and the water boils out of cracks in the basalt under considerable pressure. These springs are the outlet of the underground drainage from the mountains to the north. The basalt rests on the rhyolite and is overlain in places by Quaternary gravel. On September 7, 1932, the Moose Springs channel where it joins Sheridan Creek was discharging 85 second-feet, all of which was spring water, and Sheridan Creek above the Moose Springs channel was discharging 19 second-feet.

SPRINGS IN CAMAS MEADOWS

In Camas Meadows there are numerous springs which discharge from a few gallons a minute to as much as 1 second-foot. A few of these springs rise from the edge of the basalt on the east side of the meadows and feed Spring Creek. Several sloughs rise in the meadows and empty into Camas Creek. The springs feeding these sloughs are mostly small seeps. The water table is close to the surface under most of the Camas Meadows, and nearly all the springs are of the depressional type and owe their origin to the fact that the land surface extends below the water table.

WARM SPRINGS AT HEAD OF MEDICINE LODGE VALLEY

A group of warm springs issue from a white calcareous rock in secs. 5 and 6, T. 13 N., R. 32 E., near the Continental Divide, at the head of Warm Creek, which drains into Medicine Lodge Creek. The total flow is several second-feet, and the water is slightly warm.

WARM SPRINGS CREEK

Warm Springs Creek rises in springs in sec. 24, T. 11 N., R. 32 E. The springs are reported to issue from limestone. The total flow near the ranger station October 14, 1922, was estimated at 10 second-feet. The spring water never freezes but has about the mean temperature of the region and from this fact the creek receives its name. The entire summer flow of the springs is used for irrigation in Warm Springs Valley, and when not in use it sinks in the alluvium at the mouth of the valley.

LIDY HOT SPRINGS

Lidy Hot Springs are near the mouth of Warm Springs Valley, in sec. 35, T. 10 N., R. 33 E., and sec. 2, T. 9 N., R. 33 E. On July 15, 1921, the temperature of one of the springs near the source was 124° F. Their flow is relatively uniform and the total yield was reported to be about 0.6 second-foot. Besides being used for a natatorium the water is used to irrigate about 60 acres of land. An analysis of this water is given on page 105.

SPRINGS IN THE VICINITY OF MUD LAKE

In the marshy area tributary to Mud Lake thousands of seeps and springs issue from basalt and the overlying gravel and sand. The aggregate flow of this entire group of springs averaged about 75 second-feet during 1923, after being heavily depleted by evaporation and transpiration. The discharge of these springs for the years ending September 30, 1922 to 1929, is given in the table below:

Discharge of springs tributary to Mud Lake, 1922–29

	Acre-feet		Acre-fee
1922	40, 800	1927	38, 400
1923	54, 500	1928 (partly estimated)	33, 000
1924	59, 300	1929 (partly estimated)	31, 000
1925	38, 400		
1926	45, 300	Average	42, 600

Only a few of the spring vents are visible, although in many places ponds without any surface inflow discharge 1 or 2 second-feet. A large spring boils up in the bottom of Sand Hole Lake, according to the reports of numerous fishermen. While soundings of Mud Lake were being made through the ice in January 1922 two distinct springs in the center of the lake were noticed discharging water under some pressure. It would not be surprising to find that these springs have ceased to flow in late years, in view of the change in hydrologic conditions. W. G. Sloan, an engineer, looked for them during the low stage of the lake in the summer of 1928 but failed to find them.

Besides the springs that supply Mud Lake there are springs that feed North Lake, Jefferson Lake, Spring Lake, and the innumerable sloughs northwest of Mud Lake. During each of the two years 1922 and 1923 these springs discharged about 25,000 acre-feet. In late years the springs in this area have declined, like those tributary to Mud Lake.

SPRINGS IN THE VICINITY OF MARKET LAKE

The entire water supply of Market Lake is derived from springs except that obtained from precipitation on its surface. Much of the water rises in the bottom in small seeps, although near the stone house on the east side of the railroad a definite spring occurs. In the springtime considerable water can be seen percolating from the margin of the lava flow into the north side of the lake. Most of this water appears to come from melting snow on the adjacent lava beds. The lake beds north of Roberts extend northward under the lava and conduct the water laterally toward Market Lake after it has sunk through the lava that rests on these lake beds. The main supply, however, appears to be derived from the Egin Bench and the area to the south of the bench. The total annual loss by evaporation and transpiration from Market Lake is estimated at 15,750 acre-feet. Deducting a precipitation of 12 inches leaves about 11,250 acre-feet as the annual discharge of the Market Lake springs plus whatever may be lost by ground-water percolation from the lake to the west.

DISCHARGE FROM SOIL AND PLANTS

In addition to the ground water that finds its way to the surface through spring channels, a large amount is annually discharged through the soil and plants. The character, distribution, and condition of the plants in an area generally constitute the best available evidence as to the operation of these processes.[34]

In the Mud Lake region sagebrush (*Artemisia tridentata*)[35] covers practically all the plains area and most of the foothills. Its distribution and root system indicate that it depends on precipitation rather than ground water. Near Mud Lake, especially in the vicinity of Spring Lake, there were considerable areas in 1921 where the sagebrush was dead, and in places it was either submerged or coated with alkali. The sagebrush was killed by the rise of the water table; hence it is evident that this brush cannot thrive with its roots permanently immersed in ground water. In its place heavy stands of greasewood (*Sarcobatus vermiculatus*) have sprung up. This plant is a phreatophyte (one lifting water from the zone of saturation)[36] and is generally found here in alkali soil. In the more sandy areas of shallow ground water rabbitbrush (*Chrysothamnus pumilus*) thrives. It does not appear to grow well in the alkali soils, and in many places it grows among the sagebrush, where it must depend wholly upon precipitation. Where the water table stands within a few inches of the surface wild rye (*Elymus condensatus*), squirreltail (*Hordeum jubatum*), and salt grass predominate. In places where the water is at the surface part or all of the year and is never more than 2 or 3 feet below the surface there are growths of rushes, sedges, and cattails. Areas cleared of sagebrush and not cultivated soon become covered with Russian thistle (*Salsola pestifer*). Northwest of Monteview white sage (*Eurotia lunata*) thrives. The two last-named plants are not phreatophytes.

Areas of discharge of ground water are indicated by the distribution of the above-mentioned water-loving plants, but wild rye and squirreltail thrive well in borrow pits of canals and in other places where irrigation water is available.

Except in the canyons in the mountains, the shallow-water tracts where ground water is being dissipated by transpiration from phreatophytes and by evaporation from soil are confined to the Mud Lake Basin, the Market Lake bottoms, and the Camas Meadows. The Camas Meadows are chiefly covered with wild grass that depends upon

[34] Meinzer, O. E., Plants as indicators of ground water: U. S. Geol. Survey Water-Supply Paper 577, 1927; Geology and water resources of Big Smoky, Clayton, and Alkali Spring Valleys, Nev.: U. S. Geol. Survey Water-Supply Paper 423, pp. 92–94, 1917.

[35] The plant species here mentioned were identified by Frederick V. Coville, botanist, of the U. S. Department of Agriculture, but he is not responsible for the field interpretations.

[36] Meinzer, O. E., Plants as indicators of ground water: U. S. Geol. Survey Water-Supply Paper 577, p. 37, 1927.

ground water. Along the banks of the several channels of Camas Creek in these meadows dense thickets of willows thrive. They depend upon either ground water or surface water.

In the Mud Lake Basin there are many thousands of acres where ground water is within 10 feet of the surface. Here there is a definite zoning of the vegetation. Tules grow luxuriantly in the shallow ponds and along their borders. Beyond the tules there is usually a narrow belt of saltgrass or squirreltail. Then come the greasewood and rabbitbrush. On the sand dunes or knolls sagebrush or rabbitbrush thrives. A similar zone of phreatophytes borders Market Lake, where about 4,500 acres is underlain by water close to the surface. The rate of discharge from these shallow-water areas is discussed under Inventory of Water Supply on pages 90–104.

ARTESIAN WELLS [37]

Prior to 1922 seven flowing wells had been obtained in the vicinity of Hamer. Six of these wells (nos. 267 to 272) belong to the Hamer Canal Co., and one (no. 274), in sec. 20, T. 7 N., R. 36 E., belongs to Robert Clinton. All are 8 inches in diameter except wells 121 and 122, which are 6 inches in diameter, and well 272, which is 10 inches in diameter. These wells penetrate the upper clay bed, which ranges in thickness from 17 to 70 feet, and end in vesicular, water-bearing lava rock erupted from one of the adjacent cones, where they obtain large quantities of water. The water in the lava is here confined under sufficient head (1922) to cause it to rise to an altitude of 4,792 feet above sea level, or slightly above the surface. The water from the wells of the Hamer Canal Co. is raised 17 feet by pumps to the main canal.

The following data were obtained in 1921 regarding the flowing wells of the Hamer Canal Co.:

Records of flowing wells of the Hamer Canal Co., obtained in 1921

Well no.	Depth (feet)	Yield: Second feet	Yield: Gallons a minute	Head [1] (feet)	Specific capacity (gallons a minute for each foot of draw-down)
267	96	1.11	498		
268	120	1.11	498		
269	100	.95	427	[2] 2.75	155
270	60	1.35	605	1.18	512
271	60	1.24	556	1.25	445
272	100	2.23	[3] 1,003		

[1] Based on difference between water level in extension casing and water level in canal when well is flowing.
[2] Reported.
[3] Casing has since been cut lower so that flow is larger.

[37] For description of conditions producing artesian flows, see pp. 37 and 43.

The table shows that the specific capacities of the wells are very large, especially those of wells 270 and 271. Because of their large specific capacities, wells 267 and 268, which are in the sump, could be made to yield more water by cutting off several feet of the casing. This would increase their flow when the water level in the sump is low during the irrigation season. If the head of any of these wells decreases only slightly, they will cease flowing, but they can still be made to yield large supplies by pumping.

Since 1922 the Hamer Canal Co. has drilled seven additional wells and the New York-Idaho Land Co. has drilled two on the edge of the Hamer Slough near well 270. Of the seven wells of the Hamer Canal Co., four were drilled in 1928 by R. N. Wade, of Hamer. They are 10 inches in diameter and extend in a line 60 feet long north from well 267. The deepest well is 120 feet deep. The same log is reported for all of them—namely, 6 feet of sand, 6 feet of lava rock, 45 feet of clay and sand, and then lava to the bottom. All yield copiously. One well is only 27 feet deep and on September 11, 1928, was discharging more than 1 second-foot of water. In 1928 wells 268, 270, and 272 were clogged with sand and turf that had fallen into them. One well was drilled to a depth of 105 feet, and according to the driller it flowed copiously when completed. Another well is only 71½ feet deep, and at 42 feet it struck water in vesicular lava rock which overflowed at the surface.

The 15 wells near Hamer Lake, some only 3 feet apart, did not greatly interfere with one another. This groups of wells, when all the wells were flowing, discharged about 20 second-feet, or about 1,200 acre-feet monthly.

About 1926 R. P. Cope drilled seven wells in a trench on the east side of the Jefferson Reservoir, in the SE¼ sec. 10, T. 7 N., R. 34 E. Only four of them flowed. On September 12, 1928, these wells were discharging about 2 second-feet. One well about 100 feet northwest of the trench was discharging about 50 gallons a minute on this date. On May 12, 1930, Walter Cope finished an 8-inch well 48 feet deep about midway between the trench and this well. When visited the following day its discharge was estimated at 1 second-foot. The temperature of the water was 52° F. The log as reported by the driller was mud and sand, 28 feet; lava, 19 feet; then about 10 inches of loose cinders, and beneath the cinders a compact clay free of grit. The main flow came from the cinders, some of which floated up in the water.

Thomas Wagner is reported to have had a well drilled on the edge of Spring Lake that flowed for a while but later filled up with sand and ceased flowing.

In the early spring of 1930 the First Owsley Canal Co. obtained shallow flowing wells in the swampy tract between Mud and North Lakes. The water in two wells stood at the surface but did not overflow. The log of one of these wells, as determined from samples, is given below.

Log of well of First Owsley Canal Co. near North Lake, Jefferson County, Idaho

[Drilled by R. P. Cope, March 1930]

Sample at 10 feet cuttings of fairly dense blue olivine basalt and considerable wind-blown quartz sand.
Samples at 12 and 18 feet similar to one at 10 feet but contain less sand.
Samples at 20, 22, 24, and 26 feet contain some wind-blown sand, but basalt cuttings indicate that rock is denser.
Samples at 28, 30, 32, and 34 feet dense olivine basalt with practically no sand.
Samples at 36, 38, and 40 feet dense olivine basalt with slight amounts of wind-blown sand.
Sample at 42 feet gray olivine basalt. Cuttings are much coarser.
Sample at 46 feet a mixture of basalt cuttings and fine clay indicating lava flow was drilled through and lake beds penetrated.
Remarks: Driller reports sand and clay to 10 feet, where lava was encountered. Sand in samples below this depth probably sifted into hole or into cracks in the basalt. Samples indicate one lava flow only 35 feet thick resting on lake-bed clays.

A full description of these wells is given in the table of well records.

Mr. Cope states that he drilled a well for the late Mr. Hutchinson on the east side of a small lava cone at the edge of a little slough in the NE¼SE¼ sec. 26, T. 7 N., R. 35 E., and encountered 15 feet of loose lava, 16 feet of solid lava, and then clay. A trench was made connecting it to the adjacent slough and it flowed about 10 miner's inches (about 90 gallons a minute). On May 13, 1930, this well was not flowing, but whether it was clogged with debris could not be ascertained.

Mr. Cope reports that he prospected for artesian water on the southwest side of the same butte, in the SW¼ sec. 25, T. 7 N., R. 35 E., for the Holly Water Users Irrigation Co. In the well nearest the butte the drill encountered 15 feet of soil and 45 feet of lava and did not penetrate the clay.

Other wells were drilled, and in December 1930 the Holly group of wells were connected by means of a drain to Camas Creek. In the fall of 1932 five 8-inch wells were in operation and three others had been abandoned. The wells were uncased and were reported to be from 40 to 86 feet in depth. Observations of their combined average daily discharge, furnished by D. I. Gardner, watermaster, are as follows:

Average daily discharge of Holly Water Users wells, April 1931 to September 1932, in second-feet

1931:		1932:	
April	15	January	13.0
May	16.1	February	11.0
June	16.4	March	10.0
July	14.7	April	10.0
August	15.3	May	9.5
September	16.0	June	9.4
October	16.0	July	11.4
November	16.0	August	13.6
December	15.0	September	14.4

The Jackett flowing wells, consisting of four wells north of Mud Lake, are reported to have been drilled in 1931 to a depth of about 30 feet. They discharge from 4 to 6 second-feet into the outlet channel from Dead Line Lake and thence into Mud Lake.

The Owsley Canal Co.'s flowing wells, which discharge into Camas Creek just above West Hamer Bridge, first delivered water in December 1931. In December 1932 they consisted of a group of 10 wells averaging about 46 feet deep and most of them 10 inches in diameter, of which 8 were in operation. The following observations of their discharge are reported by the Mud Lake water master.

Average daily discharge of Owsley Canal Co.'s wells, December 1931 to September 1932, in second-feet

1931:		1932:	
December 13–31	23	May	34
1932:		June	35
January	23	July	36
February	18	August	35
March	12	September	37
April	13		

The low discharge from February to April 1932 was due to the wells being partly shut off by means of a brush dam in the outlet channel leading away from the group of wells.

Two wells (nos. 69 and 67) were drilled about 1919 near the shore of Market Lake for drainage, and both of them encountered artesian water. The log of well 69 is given on page 110. The artesian head in this well fluctuates from only a few inches to a foot above the land surface. Well 67 is 197 feet deep, and the artesian water was struck at 123 feet. According to Dr. E. D. Jones, the present owner, when the well was last used the water rose in a pipe high enough to flow into a water wagon. These wells are essentially like those at Hamer, with the artesian water apparently confined in a lava flow beneath clay beds.

GROUND-WATER RECHARGE

RECHARGE FROM PRECIPITATION

The relatively impervious basement rocks in the Mud Lake region are overlain to a large extent by lava rocks, associated volcanic products, and deposits of gravel and sand, most of which are so permeable that they receive water freely by percolation from the rain and melted snow and from the streams. Much of the water from the rain and snow that is absorbed by the soil is later returned to the atmosphere by capillary rise and evaporation or is consumed by the vegetation, but the water that penetrates below the capillary and root zones reaches the water table. A study of the Snake River Plain as a whole indicates that on lava fields similar to those in the Mud Lake region only about 10 percent of the precipitation reaches the zone of saturation.

RECHARGE FROM STREAMS IN THE MUD LAKE BASIN

All the streams that flow from the Centennial and Beaverhead Mountains lose water as soon as they reach the plains. Only a small part of the loss can be attributed to evaporation from the streams and wet ground bordering the streams or to transpiration from the plants. Some of the streams are diverted for irrigation and stock watering, but much of the water so diverted is lost by seepage and is added to the ground-water supply. Near the foothills, where only a little irrigation is practiced, the evaporation and transpiration losses were computed for each stream on the basis of the number of acres irrigated and the estimated consumptive use.

A comparison of the losses of Camas and Beaver Creeks between Dubois and Camas is shown in the following tables. No records were obtained at the Dubois station on Camas Creek during 1928 and 1929, but the depletion in these years was estimated from a curve expressing the relation in prior years between discharge at Camas and depletion between Dubois and Camas. Owing to the abandonment of the Lone Tree Reservoir since 1930, as described on page 78, and the lack of complete records of stream flow above that reservoir thereafter, it is not possible to compute the losses since 1929.

Decrease, in acre-feet, in flow of Camas Creek between Dubois and Camas gaging stations, 1921–29

Period	Run-off near Dubois	Run-off near Camas	Decrease between stations
October 1920 to March 1921	[1] 8,000	[1] 4,000	4,000
April to September 1921	81,300	28,380	52,920
Year ending September 30, 1921	89,300	32,380	56,920
October 1921 to March 1922	13,480	6,960	6,520
April to September 1922	65,920	22,540	43,380
Year ending September 30, 1922	79,400	29,500	49,900
October 1922 to April 1923	[1] 14,160	7,720	[1] 6,440
May to September 1923	47,900	15,340	32,560
Year ending September 30, 1923	62,060	23,060	39,000
October 1923 to March 1924	[1] 13,240	7,660	[1] 5,580
April to September 1924	13,100	6,280	6,820
Year ending September 30, 1924	26,340	13,940	12,400
October 1924 to March 1925	[1] 7,130	3,560	[1] 3,570
April to September 1925	61,000	18,970	42,030
Year ending September 30, 1925	68,130	22,530	45,600
October 1925 to March 1926	[1] 14,600	[1] 9,200	[1] 5,400
April to September 1926	22,500	[2] 7,120	15,380
Year ending September 30, 1926:			
New station	37,100	16,320	20,780
Estimate for old station			18,000
October 1926 to March 1927	[1] 8,500	3,450	[1] 5,050
April to September 1927	55,700	[2] 15,140	40,560
Year ending September 30, 1927:			
New station	64,200	18,590	45,610
Estimate for old station			40,600
Year ending September 30, 1928:			
New station		[2] 14,040	
Estimate for old station			13,000
Year ending September 30, 1929:			
New station		[2] 9,190	
Estimate for old station			8,000

[1] Estimated.
[2] New station on Camas Creek 5 miles below old station. From May to September 1925 decrease in flow between the two stations was 3,520 acre-feet, including irrigation diversions.

Decrease, in acre-feet, in flow of Beaver Creek between Dubois and Camas gaging stations, 1921–29

Year	Run-off at Dubois station	Run-off at Camas station	Decrease between stations
October 1920 to Mar. 31, 1921	[1] 1,000	0	1,000
April to Sept. 30, 1921	41,500	11,360	30,140
Year ending Sept. 30, 1921	42,500	11,360	31,140
Year ending Sept. 30, 1922	38,400	10,020	28,380
Year ending Sept. 30, 1923	31,800	6,230	25,570
Year ending Sept. 30, 1924	14,200	1,520	12,680
Oct. 1, 1924, to Mar. 16, 1925	[1] 2,000	0	[1] 2,000
Mar. 17 to Sept. 30, 1925	34,000	10,000	24,000
Year ending Sept. 30, 1925	36,000	10,000	26,000
Oct. 1, 1925, to Feb. 28, 1926	[1] 3,500	0	[1] 3,500
Mar. 1 to Sept. 30, 1926	13,300	4,720	8,580
Year ending Sept. 30, 1926	16,800	4,720	12,080
Oct. 1, 1926, to Mar. 22, 1927	[1] 900	0	[1] 900
Mar. 23 to Sept. 30, 1927	17,900	3,520	14,380
Year ending Sept. 30, 1927	18,800	3,520	15,280
Dec. 5, 1927, to Mar. 19, 1928	[1] 2,300	0	[1] 2,300
Oct. 1 to Dec. 4, 1927; Mar. 20 to Sept. 30, 1928	5,860	633	5,227
Year ending Sept. 30, 1928	8,160	633	7,527
Year ending Sept. 30, 1929	5,020	[1] 500	4,520

[1] Estimated.

The decrease between stations as given above includes diversions for irrigation. The net amount of water consumed annually by the crops has been estimated from reports made by the water master on these streams as to the irrigated acreage and number of irrigations. These estimates were prepared on the basis of an annual consumptive use of 1.7 acre-feet of water to the acre, exclusive of precipitation, for three full irrigations, reduced proportionally in years when a smaller supply was available. The condensed results of the 9 years of observations of losses in the two creeks are tabulated below.

Contributions, in acre-feet, to ground-water tributary to Mud Lake from losses in Beaver and Camas Creeks between Dubois and Camas gaging stations, 1921–29

Year ending Sept. 30	Decrease in run-off of Camas Creek between Dubois and old Camas stations	Decrease in run-off of Beaver Creek between Dubois and Camas stations	Total decrease	Consumed by crops	Net contribution to ground water
1921	56,920	31,140	88,060	3,000	85,060
1922	49,900	28,380	78,280	3,000	75,280
1923	39,000	25,570	64,570	3,000	61,570
1924	12,400	12,680	25,080	2,500	22,580
1925	45,600	26,000	71,600	3,000	68,600
1926	18,000	12,080	30,080	2,500	27,580
1927	40,600	15,280	55,880	2,800	53,080
1928	13,000	7,527	20,527	1,800	18,727
1929	8,000	4,520	12,520	1,000	11,520
Average	31,490	18,130	49,620	2,510	47,110

The annual contribution to the water table from losses in these two creeks averaged about 80,000 acre-feet in 1921 and 1922, compared to only about 15,000 acre-feet in 1928 and 1929. This decrease in the source of Mud Lake ground-water supply is no doubt a major cause for the decline in lake levels since 1923.

The following table shows the estimated quantities of water contributed from perennial streams to the ground-water supply in the Mud Lake Basin for the years ending March 31, 1922 and 1923:

Estimated contributions, in acre-feet, from perennial streams to the ground-water supply in the Mud Lake Basin, Idaho, 1921–22 and 1922–23

Stream	Year ending Mar. 31—	
	1922	1923
Medicine Lodge Creek	33,500	32,000
Beaver Creek	[1] 40,500	[1] 31,000
Camas Creek	[2] 51,500	[2] 43,500
Total	125,500	106,500

[1] Based on percolation loss between Dubois and Camas stations after deducting losses due to irrigation, a loss of 21 percent in the channel between Spencer and Dubois during April, May, and June, and a loss of 7 percent in the same stretch during the remainder of each year. Includes estimate of 2,500 acre-feet of flow past upper station Apr. 1-15, 1921.

[2] Contributed between the upper and lower gaging stations, exclusive of all the water diverted. Some water is contributed to the ground-water supply above and below these stations.

RECHARGE FROM LONE TREE RESERVOIR

Miscellaneous measurements made in 1923 and 1924 and stream-flow records obtained in 1930 indicate that a considerable part of the water lost from Camas Creek sinks through the floor of the Lone Tree Reservoir of the Wood Livestock Co. This reservoir is about 2 miles below the former site of the upper gaging station, in T. 11 N., R. 38 E., and has a maximum capacity of 3,000 acre-feet. The west abutment of the dam is tied to a spatter cone, and the east abutment is not far from a cinder cone. The floor of the reservoir consists of loess-covered basalt, in which in 1922 were observed a number of sink holes similar in origin to those which caused the abandonment of the Jerome Reservoir, near Jerome, Idaho. Attempts have been made to puddle the holes, but without success. Mr. Hoopes, for several years water master of Camas Creek, reports that on one occasion he saw the entire flow of Camas Creek disappearing into a sink hole about 100 feet above the dam. He estimated that the hole was draining about 300 miner's inches (6 second-feet).

The daily discharge and list of measurements from April 10 to May 11, 1930, for Camas Creek above and below the reservoir and the gage heights of the reservoir are given below. The diversions between the stations during this period amounted to 258 acre-feet.

Losses in Camas Creek from gaging station 2 miles above Lone Tree Reservoir to Jacoby ranch, about 6 miles below the reservoir, 1923–24

Date	Measurements (second-feet)								Total flow (second-feet)		Loss	
	Made by—	1	2	3	4	5	6	7	In	Out	Second-feet	Percent
May 20, 1923	A. G. Fiedler	423	0.0	7.36	----	----	----	108	----	115	308	72.8
June 8, 1923	do	297	[1] 3.0	3.76	----	----	----	98.1	----	105	192	64.6
July 5, 1923	do	88.2	.0	.00	----	----	----	[2] 93.0	----	[2] 93.0	----	----
Sept. 5, 1923	B. Johnson	43.5	.0	.00	----	----	----	39.8	----	39.8	3.7	8.5
May 30, 1924	F. M. Veatch and B. Johnson	13.6	[1] .35	1.58	[1] 0.40	1.04	----	7.31	13.6	10.7	2.9	21.3
July 4, 1924	F. M. Veatch	13.0	.0	.00	[1] .40	1.86	----	5.74	13.0	8.0	5.0	38.5
Sept. 7, 1924	do	18.1	.0	.00	[1] .40	3.33	[1] 0.20	8.56	18.3	12.3	6.0	32.8

[1] Estimated.
[2] The fact that stored water was being released from Lone Tree Reservoir at the time these measurements were made accounts for the gain as shown.

1. Camas Creek near Dubois, 2 miles above Lone Tree Reservoir, in sec. 13, T. 11 N., R. 38 E.
2. Wood Livestock Co.'s ditch 1, about sec. 30, T. 11 N., R. 39 E. (diverts water half a mile above Lone Tree Reservoir).
3. Woodie Ditch 2, sec. 26, T. 11 N., R. 38 E. (diverts water from Camas Creek just above Lone Tree Reservoir).
4. Hoop Ditch, about sec. 10, T. 10 N., R. 38 E. (diverts water about 3½ miles below Lone Tree Reservoir).
5. Jacoby Ditch, sec. 17, T. 10 N., R. 38 E. (diverts water 6 miles below Lone Tree Reservoir).
6. Return flow from Jacoby Ditch.
7. Camas Creek at Jacoby ranch, sec. 20, T. 10 N., R. 38 E., 6 miles below reservoir.

Between April 10 and May 11, 1930, the loss in the reservoir and the short stretch of channel between these two stations amounted to 42 percent of the stream flow. The diversions between the two stations were approximately equal to the amount of water released from storage in the reservoir and hence need not be taken into account.

Measurements of Camas Creek at Jacoby ranch, 4 miles below Lone Tree Reservoir, near Dubois, 1930

Date	Made by—	Discharge (second-feet)
Apr. 12	F. M. Veatch	130
Apr. 24	W. V. Iorns	45.6
Apr. 25	do	40.5
Apr. 26	do	43.7
May 11	do	47.7

Daily gage height of Lone Tree Reservoir, near Dubois, 1930

	Feet		Feet		Feet
Apr. 10	31.94	Apr. 25	9.76	May 2	13.20
Apr. 11	32.76	Apr. 26	11.33	May 3	11.80
Apr. 12	30.90	Apr. 27	12.94	May 4	9.90
Apr. 13	28.45	Apr. 28	13.56	May 7	12.06
Apr. 15	23.45	Apr. 29	14.20	May 8	13.90
Apr. 16	21.60	Apr. 30	15.96	May 10	13.55
Apr. 20	13.28	May 1	14.40	May 11	10.54
Apr. 24	9.91				

Daily discharge, in second-feet, of Camas Creek above Lone Tree Reservoir, near Dubois, for the year ending Sept. 30, 1930

Day	April	May	Day	April	May	Day	April	May
1		52	11	377	41	21	60	
2		36	12	261		22	59	
3		39	13	160		23	59	
4		49	14	139		24	54	
5		55	15	139		25	66	
6		77	16	94		26	95	
7		116	17	79		27	82	
8		98	18	60		28	79	
9		74	19	58		29	88	
10	632	52	20	57		30	69	

Daily discharge, in second-feet, of Camas Creek just below Lone Tree Reservoir, near Dubois, for the year ending Sept. 30, 1930

Day	April	May	Day	April	May	Day	April	May
1		36	11	130	56	21	63	
2		33	12	128		22	41	
3		28	13	124		23	38	
4		23	14	117		24	36	
5		22	15	112		25	37	
6		22	16	107		26	43	
7		30	17	101		27	43	
8		36	18	97		28	34	
9		38	19	88		29	36	
10	120	37	20	78		30	37	

NOTE.—On Apr. 11, 1930, about 30 second-feet, as estimated by F. M. Veatch, associate engineer, United States Geological Survey, was flowing over the spillway of Lone Tree Reservoir, which entered Camas Creek below the gaging station. This flow of about 30 second-feet is therefore not included in the record of the discharge for Apr. 11 listed here. On all other days of record the water in Lone Tree Reservoir was below its spillway crest. Therefore except for Apr. 11 the discharge records shown represent the total flow from the reservoir.

The water-table contours on plate 12 indicate that water seeping away from the Lone Tree Reservoir percolates downward through the lava to the main water table, whence it moves southwestward toward Mud Lake. The gradient of the water table from a point a few miles south of the reservoir to Mud Lake is only about 1 foot to the mile. The hydrographs of wells near Camas shown on figure 4 indicate that water lost in the reservoir during one spring does not affect the water level in these wells until the following winter. The use of this reservoir has been abandoned since 1930, and the losses have thus been reduced to those occurring in the natural channel through the reservoir bed.

The water lost from the reservoir travels underground and reappears in the sloughs and suffers similar losses to those in the surface flow of Camas Creek, but undoubtedly to a larger extent, as it reaches the surface over a larger area. A part may also go to supply North Lake and the lakes northwest of Mud Lake, where it is permanently lost for use by the Mud Lake projects. Therefore the reservoir has been a detriment during the years of deficient water supply since 1924, especially insofar as the Mud Lake supply is concerned, but it was beneficial during the preceding 3 years, because it furnished underground storage when there was a surplus of water in Mud Lake.

RECHARGE FROM HENRYS FORK AND ITS TRIBUTARIES

Henrys Fork of the Snake River with its tributaries drains an area east of the Mud Lake Basin. Very little is known regarding the flow of Henrys Fork between the Buffalo and Warm Rivers, a distance of about 32 miles. In the first 8 miles of its course below the Buffalo River it receives less than 25 second-feet of water from tributaries, all of which have their sources in springs. In the remainder of its course to the mouth of the Warm River it flows in a lava-walled canyon without perennial surface tributaries.

The springs feeding Henrys Fork in the first 8 miles of its course below the mouth of the Buffalo River show that ground water is being contributed to it. Moreover, wells in this part of the Island Park Basin show a shallow water table extending 1 to 3 miles from the river banks. At 12 miles below the mouth of the Buffalo River, at the Island Park dam site, a test hole was drilled in the channel of Henrys Fork through basaltic cinders and was completed at a depth of 101 feet in impervious rhyolite or rhyolitic tuff. After the river water was cased out and the hole was dry to the bottom, water poured into it disappeared. Hence Henrys Fork at this place is perched above porous basaltic cinders.

The results from other test holes indicate that the ground water of the upper part of the Island Park Basin flows southward or southeastward and probably in large part discharges as spring inflow into Henrys

Fork in the 12 miles above Mesa Falls, where the stream is known to gain 100 second-feet. During glacial time Henrys Fork was diverted from its canyon near Bear Gulch, in sec. 6, T. 9 N., R. 44 E., and cut a new canyon through the Big Bend Ridge, which it now occupies. The Warm River now flows in the abandoned canyon of Henrys Fork below Bear Gulch. Between Mesa Falls, which is above Bear Bulch, and the mouth of Warm River, below Bear Gulch, Henrys Fork shows neither loss nor gain, according to various measurements made at low stages during 1931 and 1932.

The Warm River derives a considerable part of its flow from a large spring about 8 miles above its mouth, which enters from the east bank of the stream. This spring may derive its water from the Yellowstone Plateau. During low stages the average flow of the Warm River above the mouth of Robinson Creek, 1 mile upstream from Warm River station, is about 250 second-feet, and all the water comes from springs supplied principally from the adjacent areas of porous lava, although possibly to some extent from losses in Island Park.

Henrys Fork, which drains an area east of the Mud Lake Basin, emerges from its canyon a short distance below its confluence with the Warm River and thence flows southwestward toward Ashton. An analysis of the stream-flow records for the section of the stream between the Warm River and Ashton gaging stations shows that there is no percolation loss from this part of the river. Similarly the stream-flow records for the stretch of channel between Ashton and St. Anthony for the periods from June 1 to September 30, 1921, and from June 1 to September 30, 1922, when complete records of inflow and diversions were available, show that there was no appreciable loss by percolation from this section or river. Considerable water, however, enters the ground from canals diverting water between Ashton and St. Anthony, as described on page 83.

Between St. Anthony and its mouth Henrys Fork receives a ground-water inflow that averages about 400 second-feet. It is reported by early residents of this section that prior to the beginning of irrigation, in the early 1890's, the ground-water levels were lower than the water level in Henrys Fork but that in later years continued irrigation raised the ground-water high enough so that it drained into the river. The ground-water map of this area shows that the ground-water flow from the Henrys Fork Valley between St. Anthony and the mouth of the fork is to the west, toward Market Lake and the territory between Market and Mud Lakes. Henrys Fork in this stretch of its course acts as an intercepting drain, skimming off the top of the ground-water flow.

RECHARGE ON THE EGIN BENCH

The great and progressive increase in the visible supply of water in the Mud Lake Basin during the period 1900 to 1922 attracted wide attention. This increase had long been attributed by the inhabitants of the region to percolation of water used in irrigation on the Egin Bench. In this investigation an effort was made to determine conclusively whether water percolates from the Egin Bench to the Mud Lake Basin, and, if so, in what quantities.

The problem could be approached in two different ways—(1) by establishing the fact that there has been an increase in water supply and then determining whether other possible causes can be eliminated, or (2) by determining the geologic structure, the slope of the water table, and the movement of ground water between the Egin Bench and the swampy tracts in the Mud Lake Basin. Both these methods of investigation were pursued so far as was feasible.

That there was a large increase in the size of Mud Lake and a substantial rise in the water table in the period from 1900 to 1922 has been definitely proved by the testimony of many trustworthy persons and by abundant physical evidence, such as the existence of dead sagebrush in the western areas and of partly submerged houses and wells.

As there are no great differences in the amounts of water that escape underground from the Egin Bench annually, except in occasional dry years like 1919 and 1931 the variations in the ground-water inflow to Mud Lake must be dependent upon other causes. Evidently the water derived from the Egin Bench tends to maintain the water table at the surface near Mud Lake, and the annual supply of the lake is now chiefly dependent upon the water furnished by Camas and Beaver Creeks. As shown on page 75, the losses from these streams are dependent upon the amount of run-off from the mountainous part of the drainage basin. Mud Lake is therefore essentially a skimming basin whose lip is at a critical level where a slight change in position of the adjacent water table determines the amount of the inflow.

The large diversions from Mud Lake since 1921 make the variation in supply more noticeable, because of the lack of hold-over storage from year to year, as in previous years. Market Lake is almost entirely dependent on the Egin Bench for its supply, and because its water is not utilized, it has shown practically no variation in size since it reached an approximate equilibrium sometime prior to 1921.

Precipitation records in the Mud Lake region do not cover a sufficient length of time to determine whether the precipitation during this period was abnormally heavy. There are no records of precipitation at the high altitudes that supply the streams with most of their water, and there are no continuous stream-flow records on Beaver or Camas Creeks prior to 1921. The oldest stream-flow record in southern Idaho is that on the Snake River at Neeley, shown in figure 8. It will be observed from this diagram that during the 12 years from 1907 to 1918 the run-off was above normal in every year except 1915, whereas beginning in 1919 the average annual run-off has been distinctly

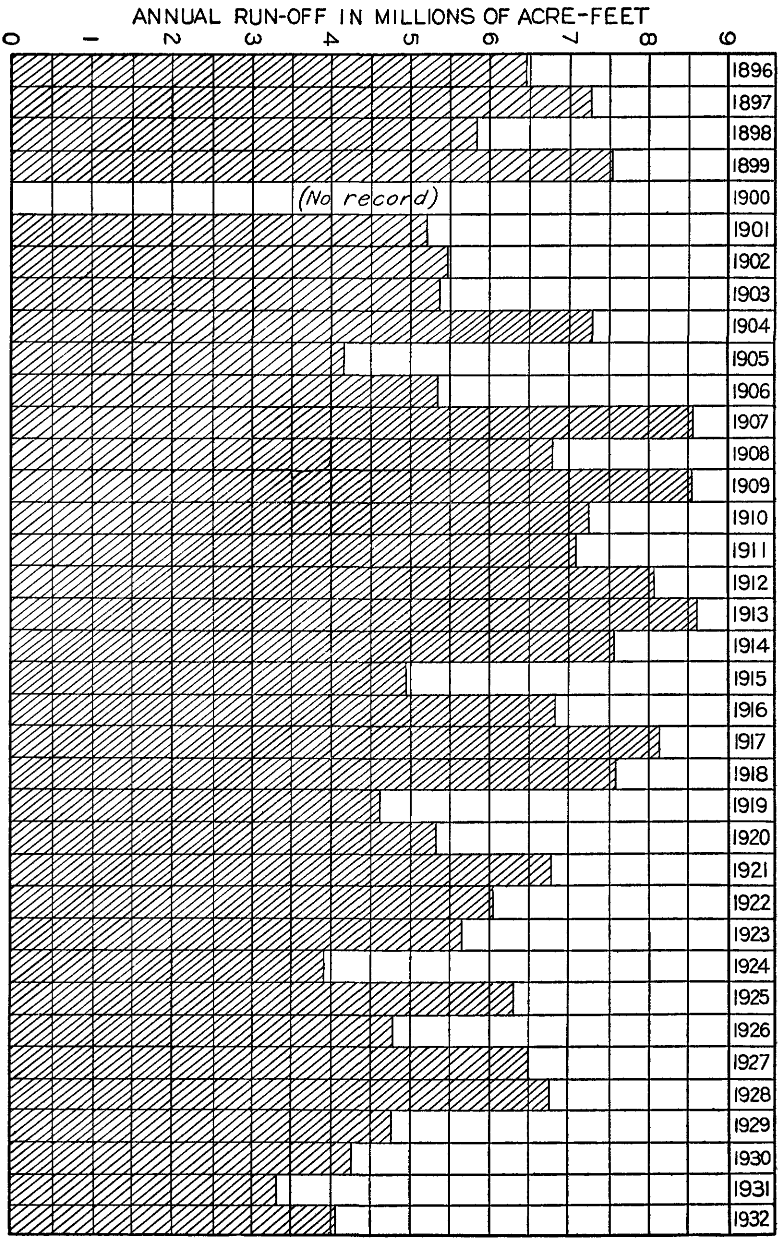

FIGURE 8.—Annual run-off of Snake River at Neeley, 1896–1932

below normal. It is also a matter of general knowledge that a great area of dry-farm wheat land was developed and farmed on the Snake River Plain during the decade ending in 1918, and that deficient precipitation since that date has resulted in the abandonment of practically all these dry farms. It is thus probable that both the surface flow of Camas Creek into Mud Lake and the contributions to the water table from precipitation and stream-channel losses were greater during the 12 years ending in 1918 than they had previously been. Mud Lake, however, continued to rise until 1923, when it reached its maximum stage, and the ground-water inflow to the lake was a year later in attaining its maximum annual amount. It seems reasonable to assume, therefore, that although the favorable climatic conditions from 1907 to 1918 may have been a factor in the gradual upbuilding of the water table adjacent to Mud Lake the continued increase in the Mud Lake water supply for some years thereafter was to a large extent due to some peculiar conditions that affected only this basin.

A natural change may have taken place, such as the closing of channels in the lava through which water may have been escaping or the opening of new channels for ground-water inflow by earthquake or other agency. Such a natural change is very improbable, though its occurrence cannot well be either proved or disproved.

A careful study was made of the areas adjacent to the Mud Lake Basin in order to discover any artificial change that should be taken into account. None was found except the irrigation development on the Egin Bench. Hence, though this method of approaching the problem does not lead to any positive conclusion, it strongly supports the theory that the increase in the water supply of the Mud Lake Basin was due to irrigation on the Egin Bench.

It has been assumed by some persons that the water from the Egin Bench percolates to the swampy tracts of the Mud Lake Basin through intervening surface deposits of sand. This investigation has shown, however, that the sand deposits lie largely above the water table and that any water that percolates from the Egin Bench to the swampy tracts of the Mud Lake Basin must pass through lava or through deposits of sand or gravel interbedded with lava.

In June 1922 a test well was drilled by the Geological Survey in the NE¼ sec. 16, T. 7 N., R. 38 E., to explore the water table. Later in the year several other wells were drilled by local people between Hamer and the test well. The form of the water table as determined by these wells indicates that the ground water moves largely in a southwesterly direction toward the deep-water region south of Hamer. It is therefore improbable that Mud Lake receives any large supplies of ground water from the lower part of the Egin Bench by way of Hamer.

During the later part of 1922 a survey was made of all the deep wells north of the Egin Bench. The water-table map (pl. 12) constructed from the data obtained indicates that on the north side of the Egin Bench there is a ground-water cascade which permits large quantities of the water used for irrigation on the bench to flow northward. The map also indicates that after the ground water has moved northward some distance it turns westward and later rises in the bed of Camas

Creek and adjacent depressions south of the town of Camas, eventually finding its way into Mud Lake. The fact that the rise of the water table was first observed in the wells near Camas also supports this evidence.

Owing to the method of subirrigating on the Egin Bench, large quantities of water are used. During the winter the water table sinks to levels 10 to 25 feet below the surface, but in the spring it is built up by seepage from the canals, and during the summer it is usually held up by the same method within 3 to 5 feet of the surface. The water is diverted from Henrys Fork through six large canals—the Dewey, Last Chance, St. Anthony Union, Egin, St. Anthony Union Feeder, and Independent.

Records of the water diverted during the irrigation seasons of 1919 to 1932 are given below:

Diversions, in acre-feet, by Egin Bench canals, 1919–32

Year	May	June	July	August	September	Total
1919	71, 400	66, 400	51, 400	45, 300	31, 700	266, 000
1920	82, 400	78, 900	62, 000	47, 900	26, 800	298, 000
1921	71, 200	63, 600	63, 000	48, 300	27, 000	273, 000
1922	72, 400	81, 800	61, 600	48, 600	32, 100	296, 000
1923	82, 800	64, 700	62, 600	50, 300	38, 100	298, 000
1924	85, 700	64, 300	59, 800	55, 200	32, 900	298, 000
1925	77, 200	64, 900	62, 600	48, 700	29, 100	282, 000
1926	84, 000	61, 000	59, 600	48, 700	36, 500	290, 000
1927	69, 100	65, 500	66, 900	54, 000	31, 200	287, 000
1928	81, 500	59, 500	66, 200	54, 600	33, 700	296, 000
1929	76, 700	72, 100	65, 400	57, 900	32, 300	304, 000
1930	76, 600	67, 100	61, 600	45, 400	33, 600	284, 000
1931	72, 300	58, 900	48, 400	35, 900	36, 000	252, 000
1932	83, 000	72, 000	63, 000	56, 500	35, 600	310, 000
Mean	77, 600	67, 200	61, 000	49, 800	32, 600	288, 000

During the nonirrigation season from October 1921 to April 1922 these canals diverted 88,300 acre-feet. Such records are not available for other years, but if this figure is assumed to represent the normal diversion each year outside of the irrigation season, the average annual diversion to the Egin Bench from 1919 to 1932 amounted to about 376,000 acre-feet.

The 30,000 acres in cultivation on the Egin Bench would probably consume by evaporation and transpiration, exclusive of amounts supplied directly by precipitation, about 50,000 acre-feet of water annually, leaving 326,000 acre-feet contributed each year to the water table under the Egin Bench. A part of this annual contribution moves northward from the Egin Bench, as previously described, and eventually reappears in Mud Lake.

Other areas irrigated with water from Henrys Fork also lose large quantities of water by seepage. During the years from 1920 to 1927 the average annual inflow into the Henrys Fork Valley from Henrys Fork, the Warm River, Robinson Creek, the Fall River, the Teton

River, and Moody Creek was 2,222,000 acre-feet. During the same years the average annual discharge of Henrys Fork 6 miles above its mouth was 1,340,000 acre-feet. The amounts consumed by the crops on 115,000 acres of land irrigated in the valley, estimated at 1.6 acre-feet to the acre, exclusive of precipitation, amounted to 184,000 acre-feet, leaving an indicated annual loss underground from the Henrys Fork Valley of 698,000 acre-feet. Some of this lost water finds its way into the Mud Lake Basin and is in part the cause of the present perennial character of Mud Lake.

Prior to irrigation on the Egin Bench the water table was 100 feet below the surface at Camas and about 20 feet at Sandhole Lake. The flood waters of Camas and Beaver Creeks entered Mud Lake each year but were dissipated by evaporation and percolation. Ample testimony is available to prove that none of the springs in the vicinity of Mud Lake then existed, except possibly the one in Sandhole Lake; hence the underground outlets must have had sufficient capacity to carry away beneath the surface all the ground water moving toward the lake. The water arriving from the Egin Bench was sufficient to raise the water table to the surface in the vicinity of Mud Lake, indicating that the underground outlets prior to that time were charged nearly to capacity. The presence near Terreton of lake beds of low permeability helps to check underground discharge and raise the water table. At an assumed effective porosity of 10 percent a rise of the water table of about 20 feet under the area of 100,000 acres of land near Mud Lake required only about 200,000 acre-feet of additional water. A somewhat larger amount would have been necessary to build up the water table under the lands between the Egin Bench and Mud Lake and between the Egin Bench and Roberts. No data are at hand on the amount of water diverted on the Egin Bench during the first few years after irrigation was started, but at that time nearly all the flow of the Henrys Fork was available. As it is known that about 326,000 acre-feet is now contributed annually to the zone of saturation under the Egin Bench, it may well be that at least 200,000 acre-feet of water went into ground storage beyond the borders of the Egin Bench. Nearly 5 years was required for the water from the Egin Bench to have any visible effect on the Mud Lake Basin, and about 23 years more for it to produce the maximum effect.

INVENTORY OF WATER SUPPLY

UNITS OF STORAGE

The units of storage in the Mud Lake Basin may be regarded as Hamer Lake, Mud Lake (including Rays and Sandhole Lakes), the Jefferson Reservoir, the Jefferson Reservoir addition, Spring Lake, and North Lake. (See pl. 3.) In this discussion Rays Lake, Sandhole Lake, and all other ponds and sloughs that are directly tributary to

Mud Lake and were affected by backwater of the lake during the high stage in June 1921 are considered a part of Mud Lake, and all conclusions are based on this definition of area. Hamer Lake, the Jefferson Reservoir, the Jefferson Reservoir addition, Spring Lake, and North Lake are not included except their overflow (p. 90). North Lake was not tributary to Mud Lake in 1921, but during the spring of 1922 it spilled over into Mud Lake. Its area, capacity, and supply are for convenience considered separately.

MUD LAKE

AREA AND CAPACITY

Plane-table surveys were made in 1921 outlining the areas covered by the high and low stages of Mud Lake during that year. (See pl. 3.) From these surveys and from soundings obtained through the ice cover in January 1922, area and capacity curves were constructed. With the reduction of the area of the lake since 1923 new capacity and area curves have been prepared. (See fig. 9.)

OUTLINE OF WATER SUPPLY

The water supply for Mud Lake is derived from (1) surface water from Camas and Beaver Creeks that passes the gaging stations at Camas; (2) ground-water inflow to Camas Creek between Camas and West Hamer Bridge; (3) ground-water inflow from the north directly into the lake or into Camas Creek below West Hamer Bridge or through spring-fed streams that discharge into the lake; and (4) precipitation on the lake. This water is disposed of by diversion for irrigation, by evaporation from the lake and tributary water bodies and transpiration from tules and other vegetation in the lake and adjacent swampy areas, and by percolation out from the lake.

Measurements of these several items of source and disposal of the water supply were started in April 1921 and were continued in detail until 1924. Since 1924 the records are less complete, but most of the essential data are available up to 1932 and are tabulated below. Beginning in 1931 the waters of Mud Lake have been administered according to court decree, and records for 1931–32 have been supplied by D. I. Gardiner, water master.

SURFACE FLOW INTO MUD LAKE

The following table gives the available records of the surface flow of water into Mud Lake. The discharge of Camas and Beaver Creeks is taken from records at the United States Geological Survey gaging stations maintained on those streams. After October 1, 1925, the Camas Creek records were obtained at a new station about 5 miles below the old one. From May to September 1925 the decrease in flow between the old and new stations on Camas Creek, including diversions, was 3,520 acre-feet. In years of low run-off the decrease would doubtless be less.

The gain from the combined flow of Beaver and Camas Creeks at Camas to the flow of Camas Creek at West Hamer Bridge was computed from miscellaneous measurements made at West Hamer Bridge

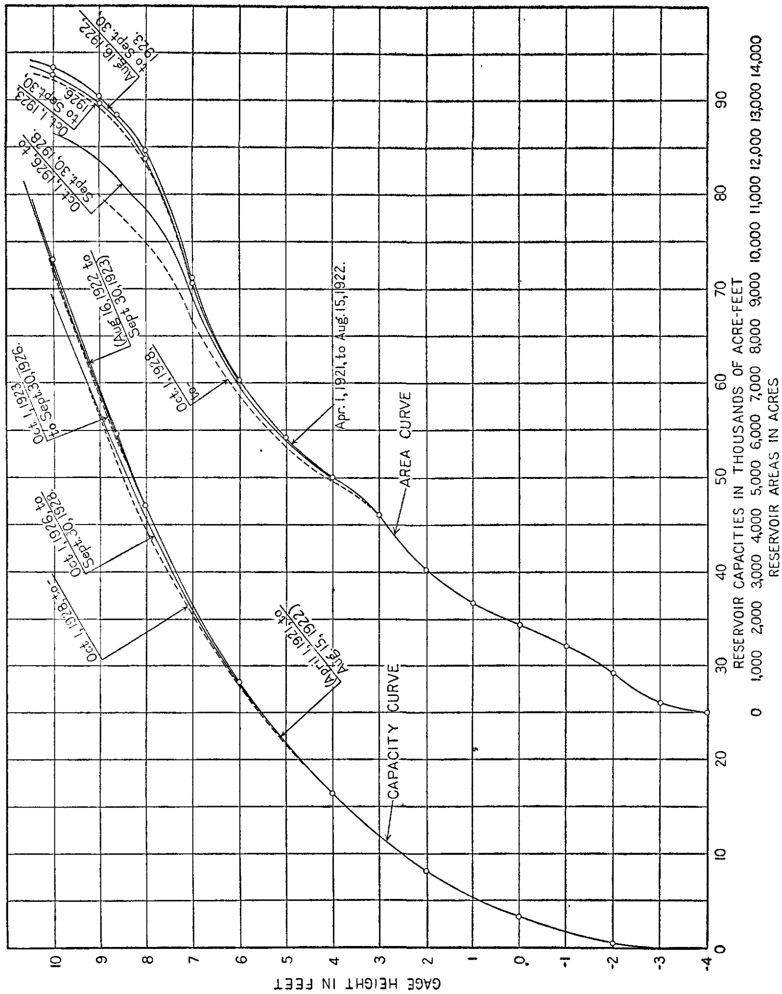

FIGURE 9.—Area and capacity curves for Mud Lake, 1921-29.

whenever current-meter measurements were made at the stations near Camas. Except during flood-water periods this gain is derived from ground-water inflow and does not change much from day to day. Records of other observed ground-water inflow are based on occasional current-meter measurements of all the spring-fed streams entering the lake. Prior to 1932 the largest average contribution to the water supply of the lake was the ground-water inflow to Camas

Creek between Camas and West Hamer Bridge. However, the development of water by wells and by drainage from North Lake and Jefferson Lake, which increased the ground-water inflow below West Hamer Bridge in 1931 and 1932, resulted during 1932 in a pronounced decrease in the gain between Camas and West Hamer Bridge from that previously existing.

The fluctuations of ground-water inflow to Camas Creek lag about a year behind the fluctuations in the flow of the surface streams. This lag indicates considerable underground storage. The water supply for the Egin Bench has been well sustained, and it appears that the deficiency in the supply for Mud Lake since 1924 is due principally to a decrease in the supply from the drainage basins of Camas and Beaver Creeks.

Surface flow into Mud Lake, in acre-feet, 1921–32

Month	Camas Creek at Camas	Beaver Creek at Camas	Ground-water gain or loss between Camas and West Hamer Bridge	Other observed ground-water inflow	Total observed inflow
1921					
April	4,310	1,815	−595	1,010	6,540
May	14,100	6,330	−4,230	984	17,184
June	6,370	3,220	−2,030	893	8,453
July	1,430	0	+140	861	2,431
August	1,200	0	+1,040	861	3,101
September	970	0	+2,120	952	4,042
The period	28,380	11,365	−3,555	5,561	41,751
1921–22					
October	467	0	+3,613	1,090	5,170
November	1,050	0	+3,590	1,130	5,770
December	1,720	0	+3,690	1,230	6,640
January	1,430	0	+4,290	1,230	6,950
February	1,070	0	+3,600	1,060	5,730
March	1,220	0	+2,780	1,110	5,110
April	2,240	601	+1,209	1,010	5,060
May	12,900	6,700	−3,700	984	16,884
June	2,980	2,720	+3,820	893	10,413
July	1,570	0	+2,480	861	4,911
August	1,560	0	+1,370	885	3,815
September	1,280	0	+1,670	910	3,860
The year	29,487	10,021	+28,412	12,393	80,313
1922–23					
October	1,190	0	+3,890	1,060	6,140
November	1,210	0	+5,390	1,070	7,670
December	959	0	+5,931	1,170	8,060
January	953	0	+5,087	1,230	7,270
February	728	0	+4,152	1,060	5,940
March	590	0	+5,160	1,110	6,860
April	2,090	1,140	+2,630	1,010	6,870
May	5,440	3,600	−1,780	984	8,244
June	4,220	1,490	+2,260	893	8,863
July	2,600	0	+2,550	922	6,072
August	1,700	0	+3,020	953	5,673
September	1,380	0	+3,710	1,040	6,130
The year	23,060	6,230	+42,000	12,502	83,792
1923–24					
October	1,920	0	+4,540	1,180	7,640
November	1,900	0	+4,820	1,190	7,910
December	1,290	0	+5,530	1,290	8,110
January	947	0	+5,263	1,290	7,500
February	863	0	+4,467	1,270	6,600
March	738	0	+4,862	1,430	7,030
April	3,450	1,510	+3,790	1,430	10,180

Surface flow into Mud Lake, in acre-feet, 1921–32—Continued

Month	Camas Creek at Camas	Beaver Creek at Camas	Ground-water gain or loss between Camas and West Hamer Bridge	Other observed ground-water inflow	Total observed inflow
1923–24					
May	1,220	8	+4,722	1,200	7,150
June	237	0	+2,013	851	3,101
July	600	0	+1,460	713	2,773
August	436	0	+2,074	799	3,309
September	339	0	+2,251	833	3,423
The year	13,940	1,518	+45,792	13,476	74,726
1924–25					
October	621	0	+2,509	935	4,065
November	625	0	+3,575	970	5,170
December	406	0	+4,514	1,050	5,970
January	430	0	+4,290	1,050	5,770
February	555	0	+3,575	944	5,074
March	922	0	+3,608	1,050	5,580
April	4,170	4,340	+1,690	780	10,980
May	5,450	4,020	−860	738	9,348
June	3,990	1,640	+680	430	6,740
July	2,240	0	+560	550	3,350
August	1,530	0	+1,580	676	3,786
September	1,590	0	+2,710	839	5,139
The year	22,529	10,000	+28,431	10,012	70,972
1925–26					
October	1,800	0	+4,410	984	7,194
November	[1] 1,800	0	+3,470	893	6,163
December	[1] 1,250	0	+3,660	922	5,832
January	[1] 950	0	+3,820	861	5,631
February	[1] 800	0	+3,480	833	5,113
March	2,600	3,040	+3,460	1,210	10,310
April	4,550	1,680	+2,640	1,080	9,950
May	1,240	0	+2,700	885	4,825
June	278	0	+1,852	732	2,862
July	479	0	+1,781	610	2,870
August	371	0	+1,789	580	2,740
Setpember	203	0	+1,957	696	2,856
The year	16,321	4,720	+35,019	10,286	66,346
1926–27					
October	526	0	+2,144	861	3,531
November	762	0	+2,908	952	4,622
December	615	0	+4,085	1,110	5,810
January	490	0	+4,250	1,110	5,850
February	440	0	+3,710	1,000	5,150
March	615	0	+3,935	1,110	5,660
April	1,240	660	+3,160	910	5,970
May	5,840	1,180	+480	830	8,330
June	4,820	1,680	+520	655	7,675
July	1,380	0	+320	553	2,253
August	1,070	0	+510	615	2,195
September	791	0	+2,039	655	3,485
The year	18,589	3,520	+28,061	10,361	60,531
1927–28					
October	1,550	0			
November	2,520	0			
December	1,540	0			
January	1,230	0			
February	1,150	0			
March	1,760	615			
April	1,210	18			
May	1,340	0			
June	226	0			
July	563	0			
August	403	0			
September	543	0			
The year	14,035	633	[2] 25,000	[2] 8,000	47,668
1928–29					
October	571	0			
November	815	0			
December	553	0			

[1] Estimated. [2] Yearly total estimated. Data insufficient to make monthly estimates.

Surface flow into Mud Lake, in acre-feet, 1921–32—Continued

Month	Camas Creek at Camas	Beaver Creek at Camas	Ground-water gain or loss between Camas and West Hamer Bridge	Other observed ground-water inflow	Total observed inflow
1928–29					
January	430	0			
Feburary	333	0			
March	615	0			
April	1,610	[1] 200			
May	3,140	[1] 300			
June	508	0			
July	255	0			
August	184	0			
September	177	0			
The year	9,191	500	[2] +24,000	[2] 7,000	40,691
1929–30					
October	246	0			
November	268	0			
December	307	0			
January	246	0			
February	278	0			
March	437	0			
April	2,360	1,730			
May	491	0			
June	160	0			
July	146	0			
August	109	0			
September	162	0			
The year	5,210	1,730	[2] +24,000	[2] 8,000	38,940
1930–31					
October	237	0	+2,700	500	3,437
November	306	0	+2,800	1,100	4,206
December	123	0	+3,300	1,550	4,973
January	123	0	+3,500	2,150	5,773
February	111	0	+3,600	2,200	5,911
March	148	0	+4,000	1,950	6,098
April	1,930	0	+1,060	2,193	5,183
May	140	0	+1,975	2,302	4,417
June	6	0	+643	1,434	2,083
July	9	0	+323	1,304	1,636
August	0	0	+307	1,331	1,638
September	0	0	+708	1,352	2,060
The year	3,133	0	+24,916	19,366	47,415
1931–32					
October	0	0	+1,316	1,584	2,900
November	0	0	+1,267	2,202	3,469
December	0	0	+1,506	3,093	4,599
January	0	0	+1,660	3,724	5,384
February	0	0	+1,283	3,283	4,566
March	0	0	+1,962	2,672	4,634
April	1,020	0	+1,479	3,240	5,739
May	11,000	0	−5,370	4,104	9,734
June	3,890	0	−153	3,634	7,371
July	586	0	+78	3,348	4,012
August	178	0	−129	3,262	3,311
September	167	0	+154	3,357	3,678
The year	16,841	0	+5,053	37,503	59,397

[1] Estimated.
[2] Yearly total estimated. Data insufficient to make monthly estimates.

Owing to changed conditions in 1931 and 1932 after the development of flowing wells in the vicinity of West Hamer Bridge, the ground-water inflow below that point has been tabulated in detail for those 2 years. The wells of the Owsley Canal Co. discharge into Camas Creek just above the West Hamer Bridge, but since the operation of these wells the records at the bridge have been computed to show the Camas Creek discharge just above the inflow from the Owsley wells. Records of the discharge of these flowing wells since April 1931 have been supplied by D. I. Gardner, Mud Lake water master. Prior to that date they have been estimated.

Mud Lake inflow below West Hamer Bridge, in acre-feet, 1930–32

	Holley Water Users Association wells	Owsley Canal Co. wells	Jackett wells and Dead Line Lake	North Lake Outlet	Jefferson Lake Outlet	Other visible inflow	Total
1930–31							
October	0		300	0	0	200	500
November	0		300	0	600	200	1, 100
December	400		300	0	600	250	1, 550
January	900		300	50	600	300	2, 150
February	900		300	120	580	300	2, 200
March	900		350	400	0	300	1, 950
April	893		400	600	0	300	2, 193
May	990		436	676	0	200	2, 302
June	976		179	179	0	100	1, 434
July	904		370	30	0	0	1, 304
August	941		390	0	0	0	1, 331
September	952		400	0	0	0	1, 352
The year							19, 366
1931–32							
October	984	0	400	0	0	200	1, 584
November	952	0	450	0	600	200	2, 202
December	922	821	500	0	600	250	3, 093
January	799	1, 414	550	61	600	300	3, 724
February	633	1, 035	600	115	600	300	3, 283
March	615	738	650	369	0	300	2, 672
April	595	774	678	893	0	300	3, 240
May	584	2, 078	650	492	0	300	4, 104
June	559	2, 094	433	298	0	250	3, 634
July	701	2, 189	308	0	0	150	3, 348
August	836	2, 177	249	0	0	0	3, 262
September	857	2, 220	280	0	0	0	3, 357
The year							37, 503

PRECIPITATION ON AND EVAPORATION FROM THE LAKE AND TRIBUTARY WATER BODIES

The following table gives the precipitation on the lake and tributary water surfaces and the evaporation, including transpiration, from these areas. The monthly figures of evaporation shown in the table represent 65 percent of the monthly evaporation at the land pan near Terreton. Transpiration is tabulated only from June to September, which are the months of appreciable growth of tules, and then only when the lake covers more than 6,000 acres. In recent years the water surface has generally had an area of less than 6,000 acres, and the great beds of tules have practically disappeared. In computing total monthly evaporation losses the rate of evaporation from open water surfaces was first applied to the entire surface of Mud Lake and the tributary water surfaces, and to the quantity thus obtained was added a quantity derived by assuming that the water surface in excess of 6,000 acres contained tules and then applying to this excess area the excess in rate of loss as determined from the records of the tule tank.[38] The average monthly areas of water surface were ob-

[38] See Stearns, H. T., and Bryan, L. L., op. cit. (Water-Supply Paper 560), p. 117.

tained from the daily gage heights of the lake and the area curve given in figure 9. Variations in area during the different years are due to sections of the lake being diked off. For the 4 years, 1927–30 climatic data obtained at Mud Lake were limited to observations of precipitation and temperature, and the calculated evaporation each month during these years was based on the average rate occurring during the earlier years when evaporation records were kept.

The evaporation, including transpiration, reached a maximum of about 43,000 acre-feet in 1922, but owing to the decreased lake area it dwindled to only about 10,000 acre-feet in 1930 and has been only a little greater in 1931 and 1932.

Monthly and annual precipitation on and evaporation from Mud Lake and tributary water bodies, 1921–32

[Climatic data from Terreton station except as otherwise noted]

Month	Mean temperature (°F.)	Average area of water surface (acres)	Precipitation on the water surface		Evaporation from the total water surface, computed at rate of evaporation from open water		Additional loss due to transpiration from tule areas (acre-feet)	Total (acre-feet)
			Feet	Acre-feet	Feet	Acre-feet		
1921								
April	37	11,600	[1]0.074	860	0.24	2,790		2,790
May	54	12,200	.187	2,280	.43	5,240		5,240
June	64	12,300	.030	370	.57	7,000	2,400	9,400
July	68	9,000	.052	470	.68	6,120	3,000	9,120
August	66	5,800	.020	120	.53	3,070		3,070
September	51	5,000	.035	180	.38	1,900		1,900
The period			.398	4,280	2.83	26,120	5,400	31,520
1921–22								
October	47	5,250	.013	70	.22	1,150		1,150
November	34	6,000	.007	40	.10	600		600
December	21	6,900	.162	1,120	[2].08	550		550
January	3	8,500	.066	560	[2].05	420		420
February	11	10,300	.032	330	[2].05	510		510
March	20	11,600	.083	960	[2].10	1,160		1,160
April	38	12,180	.057	690	.217	2,640		2,640
May	52	12,680	.098	1,240	.513	6,500		6,500
June	64	12,450	.052	650	.568	7,090	2,450	9,540
July	68	11,150	.052	580	.563	6,480	5,750	12,230
August	63	7,220	.168	1,210	.486	3,500	1,200	4,700
September	62	6,280	0	0	.414	2,600	500	3,100
The year			.790	7,450	3.361	33,200	9,900	43,100
1922–23								
October	49	6,490	.029	190	[2].22	1,420		1,420
November	28	7,410	.046	340	[2].10	740		740
December	19	8,720	.062	550	[2].08	700		700
January	18	10,400	.068	710	[2].05	520		520
February	14	11,570	.038	450	[2].05	580		580
March	18	12,240	.012	150	[2].10	1,220		1,220
April	43	12,850	.079	1,030	.162	2,110		2,110
May	53	13,580	.132	1,740	.387	5,090		5,090
June	57	12,670	.150	1,900	.413	5,260	3,200	8,460
July	70	11,170	.117	1,320	.619	6,900	5,500	12,400
August	65	7,710	.088	670	.497	4,010	1,600	5,610
September	58	6,350	.042	270	.392	2,530		2,530
The year			.863	9,320	3.070	31,080	10,300	41,380

See footnotes at end of table.

Monthly and annual precipitation on and evaporation from Mud Lake and tributary water bodies, 1921–32—Continued

[Climatic data from Terreton station except as otherwise noted]

Month	Mean temperature (°F.)	Average area of water surface (acres)	Precipitation on the water surface		Evaporation from the total water surface, computed at rate of evaporation from open water		Additional loss due to transpiration from tule areas (acre-feet)	Total (acre-feet)
			Feet	Acre-feet	Feet	Acre-feet		
1923–24								
October	42	6,490	.117	760	[2].22	1,060		1,060
November	32	7,700	0	0	[2].10	820		820
December	17	9,110	0	0	[2].08	720		720
January	9	10,730	.015	160	[2].05	530		530
February	28	11,630	.042	490	[2].05	580		580
March	28	12,290	.038	470	[2].10	1,230		1,230
April	41	12,780	.009	120	[3].20	2,550		2,550
May	57	12,450	.014	170	[3].44	5,500		5,500
June	60	9,600	.008	80	[3].52	5,000	1,500	6,500
July	67	6,430	.009	60	[3].62	4,000	400	4,400
August	65	5,100	0	0	[3].50	2,550		2,550
September	55	4,840	.051	250	[3].40	1,930		1,930
The year			.303	2,560	3.28	26,470	1,900	28,370
1924–25								
October	46	5,000	.065	320	[2].22	1,100		1,100
November	28	5,540	.016	90	[2].10	550		550
December	[4]12	6,350	.060	380	[2].08	510		510
January	[4]17	7,100	.084	600	[2].05	350		350
February	29	8,100	.062	500	[2].05	400		400
March	35	9,550	.105	1,000	[2].10	960		960
April	42	11,300	[5].104	1,180	[3].20	2,260		2,260
May	58	11,800	[5].090	1,060	[3].44	5,200		5,200
June	59	10,800	[5].125	1,350	[3].52	5,600	2,070	7,670
July	69	7,400	[5].068	500	[3].62	4,600	1,480	6,080
August	65	5,300	[5].082	430	[3].50	2,650		2,650
September	[4]56	5,000	[5].092	460	[3].38	1,900		1,900
The year			.953	7,870	3.26	26,080	3,550	29,630
1925–26								
October	[4]42	5,200	[5].157	820	[2].22	1,140		1,140
November	31	6,750	[5].023	160	[2].10	680		680
December	27	8,100	[5].062	500	[2].08	650		650
January	17	10,100	[5].040	400	[2].05	510		510
February	32	11,000	[5].025	280	[2].05	550		550
March	39	12,000	[5].013	160	[2].10	1,200		1,200
April	50	12,650	[5].042	530	[1].35	4,430		4,430
May	57	12,100	[5].028	340	.53	6,410		6,410
June	65	7,400	[5].032	240	.58	4,300	520	4,820
July	69	5,300	[5].096	510	.61	3,230		3,230
August	65	4,000	[5].024	100	.55	3,030		3,030
September	50	3,300	[5].007	20	.40	1,320		1,320
The year			.549	4,060	3.62	27,450	520	27,970
1926–27								
October	45	3,600	[5].006	20	[2].22	790		790
November	34	4,800	[5].032	150	[2].10	480		480
December	18	5,600	[5].048	270	[2].08	450		450
January	16	6,400	[4].025	160	[2].05	320		320
February	27	7,200	.018	130	[2].05	360		360
March	[4]37	7,900	[4].025	200	[2].10	790		790
April	43	8,400	.020	170	[5].35	2,940		2,940
May	50	8,150	.162	1,320	[1].47	3,830		3,830
June	62	6,800	.016	110	.58	3,950	300	4,250
July	68	4,750	.001	0	.62	2,950		2,950
August	62	2,900	.064	190	.48	1,390		1,390
September	55	2,800	.110	310	.38	1,060		1,060
The year			.527	3,030	3.48	19,310	300	19,610
1927–28								
October	[4]47	3,300	[4].075	250	[2].22	730		730
November	37	4,350	.033	140	[2].10	440		440
December	[4]18	5,100	0	0	[2].08	410		410
January	[4]23	6,000	[4].042	250	[2].05	300		300
February	[4]24	6,900	[4].017	120	[2].05	340		340

See footnotes at end of table.

Monthly and annual precipitation on and evaporation from Mud Lake and tributary water bodies, 1921–32—Continued

[Climatic data from Terreton station except as otherwise noted]

Month	Mean temperature (°F.)	Average area of water surface (acres)	Precipitation on the water surface		Evaporation from the total water surface, computed at rate of evaporation from open water		Additional loss due to transpiration from tule areas (acre-feet)	Total (acre-feet)
			Feet	Acre-feet	Feet	Acre-feet		
1927-28								
March	35	7,700	.011	80	[2] .10	770		770
April	[4] 43	8,300	[4] .017	140	[3] .20	1,660		1,660
May	[4] 58	7,250	[4] .050	360	[3] .44	3,190		3,190
June	57	4,800	.136	650	[3] .52	2,500		2,500
July	[4] 68	2,900	[4] .024	70	[3] .62	1,800		1,800
August	[4] 64	2,100	[4] .021	40	[3] .50	1,050		1,050
September	58	2,000	[4] .012	20	[3] .32	760		760
The year			.438	2,120	3.26	13,950		13,950
1928–29								
October	43	2,200	.016	40	[2] .22	480		480
November	36	2,800	.113	320	[2] .10	280		280
December	13	3,750	.084	320	[2] .08	300		300
January	6	4,800	.022	110	[2] .05	240		240
February	11	5,350	.030	160	[2] .05	270		270
March	30	6,200	.046	290	[2] .10	620		620
April	39	7,150	.078	560	[3] .20	1,430		1,430
May	49	7,330	.013	100	[3] .44	3,220		3,220
June	58	5,700	.028	160	[3] .52	2,960		2,960
July	68	2,900	.020	60	[3] .62	1,800		1,800
August	68	1,950	.025	50	[3] .50	980		980
September	[4] 53	1,850	[4] .030	60	[3] .38	700		700
The year			.505	2,230	3.26	13,280		13,280
1929–30								
October	45	2,000	.053	110	[2] .22	440		440
November	25	2,070	.0	0	[2] .10	210		210
December	26	2,600	.022	60	[2] .08	210		210
January	4	3,800	.032	120	[2] .05	190		190
February	27	4,700	.053	250	[2] .05	240		240
March	37	5,400	[4] .030	160	[2] .10	540		540
April	51	6,300	[4] .036	230	[3] .20	1,260		1,260
May	52	5,800	[4] .050	290	[3] .44	2,550		2,550
June	56	3,800	.048	180	[3] .52	1,980		1,980
July	69	1,630	.002	0	[3] .62	1,010		1,010
August	67	1,620	.258	420	[3] .50	810		810
September	56	1,780	.092	160	[3] .38	680		680
The year			.676	1,980	3.26	10,120		10,120
1930–31								
October	41	2,000	.050	100	[2] .22	440		440
November	28	2,350	[4] .040	90	[2] .10	240		240
December	6	3,400	[4] .040	140	[2] .08	270		270
January	13	4,700	.038	180	[2] .05	240		240
February	17	5,250	.032	170	[2] .05	260		260
March	27	5,960	.029	170	[2] .10	600		600
April	43	6,750	.012	80	[3] .20	1,350		1,350
May	52	6,200	.069	430	[3] .44	2,730		2,730
June	63	4,500	.030	140	.596	2,680		2,680
July	68	2,000	.027	50	.679	1,360		1,360
August	65	1,450	.058	80	.540	780		780
September	55	1,270	.070	90	[3] .38	480		480
The year			.495	1,720	3.435	11,430		11,430
1931–32								
October	45	1,550	.012	20	[2] .22	340		340
November	26	1,920	.030	60	[2] .10	190		190
December	14	2,650	.170	450	[2] .08	210		210
January	[4] 12	4,100	.065	270	[2] .05	210		210
February	8	4,900	.018	90	[2] .05	250		250
March	20	5,350	.01	50	[2] .10	540		540
April	43	6,260	.10	630	[3] .20	1,250		1,250
May	52	6,700	.082	550	.425	2,850		2,850
June	59	5,950	.240	1,430	.407	2,430		2,430
July	65	4,560	.150	680	.552	2,510		2,510
August	63	2,300	.056	130	.490	1,130		1,130
September	55	1,980	.00	0	[3] .38	750		750
The year			.933	4,360	3.054	12,660		12,660

[1] Partly estimated. [2] Estimated from records at other Idaho stations. [3] No records. Used average of other similar years. [4] Estimated from adjacent stations. [5] Monteview record.

DIVERSIONS FOR IRRIGATION

The area irrigated from Mud Lake has been determined from records supplied by the canal companies and water users as follows:

Area irrigated from Mud Lake, 1921–29

	Acres		Acres		Acres
1921	11,000	1924	12,500	1927	12,300
1922	11,200	1925	11,300	1928	12,800
1923	12,400	1926	12,200	1929	11,800

The area irrigated since 1929 is believed to have remained about the same.

The available records of monthly and annual diversions for irrigation are given in the table on page 96. During the years 1925–30 records of diversions from Mud Lake were lacking with the exception of those for the First Owsley project. Estimates of the amounts diverted by the other canals during these years were made by obtaining from the water users the acreage irrigated and the number of irrigations and then applying to such figures the use of water shown by the several canals during prior years when the diversions were measured.

INVISIBLE LOSS OR GAIN

The invisible loss or gain of Mud Lake was computed by difference, which includes all the errors that may have entered into the calculations of the other items as well as any addition from spring water rising in the lake bottom and losses by seepage away from it. During the irrigation season the results of calculations of the invisible loss or gain are especially erratic, probably because of errors in the computed amounts diverted and evaporation losses. That there is invisible loss from the lake is indicated by the records for the winter, when the factors of evaporation and diversion are practically eliminated.

From December to March the average invisible loss was computed to be about 1,000 acre-feet monthly. There is probably some ground-water leakage from the lake to the south and west, but it is likely that part of this invisible loss is accounted for by ground storage. Owing to the broad, flat shape of the basin, considerable areas of soil are saturated as water accumulates in the lake and the lake is enlarged. Later in the season, as stored water is withdrawn, a substantial portion of this water is held by the soil against gravity, and is dissipated by evaporation from the moist ground surface that is exposed when the lake level recedes. Any error in the assumed coefficient of 0.65 used to reduce observed evaporation-pan records to lake evaporation would also be reflected by corresponding errors in the calculated invisible loss. The table shows that large losses are involved in the utilization of Mud Lake. Indeed, in some years the losses by evaporation and transpiration together with the invisible loss are practically equal to the amounts diverted from the lake.

SUMMARY

Prior to 1908 Mud Lake was supplied exclusively from the flood waters of Beaver and Camas Creeks, which remained in the lake until dissipated by evaporation and percolation. Owing to the relatively impermeable character of the lake bed some water generally remained there throughout the year. Beginning about 1908 the lake started to rise as the result of ground-water inflow from the northeast, which was caused by ground-water contributions of substantial amount from the Egin Bench percolating northwestward and joining the ground-water flow of Camas Valley. This additional contribution from the Egin Bench was augmented during a series of 12 years, from 1907 to 1918, in which the flow of Beaver and Camas Creeks was above normal. Mud Lake continued to rise until 1923, when it reached its maximum content of 61,660 acre-feet. After 1924 it declined, until in 1930 its maximum content was only 26,400 acre-feet. Since 1930 there has been an increase of about 2,000 acre-feet in maximum content. Mud Lake is like a saucer, of which the northeasterly lip skims off the upper part of the ground-water inflow and the southwesterly lip is perched far above the deep water table. A slight variation in ground-water levels on the northeast or inflow side of the lake results in considerable variation in the volume of inflow.

The decline in the lake since 1923 is most readily accounted for by the decrease in contributions from Camas and Beaver Creeks. The decreased flow of these creeks where they emerge from the mountains resulted in greatly decreased contributions to the water table feeding Mud Lake. In 1921 and 1922 the contribution to the ground water from channel losses in these streams averaged about 80,000 acre-feet annually, but in 1928 and 1929 the average annual contribution had dropped to about 15,000 acre-feet. In 1921 and 1922 Camas Creek discharged each year into Mud Lake about 40,000 acre-feet, but in 1929 and 1930 its annual discharge into Mud Lake had dropped to 8,000 acre-feet—a decrease in surface inflow to Mud Lake of 32,000 acre-feet annually. Except for the continuance of contributions from the Egin Bench, Mud Lake would no doubt have gone entirely dry during recent years of deficient run-off from the drainage areas of Beaver and Camas Creeks.

Inflow, use, and losses from Mud Lake, in acre-feet, 1921–32

Month	Surface inflow	Precipitation on lake	Evaporation, including transpiration	Lake contents at beginning of month	Diversions	Invisible loss or gain	
						Loss	Gain
1921							
April	6,540	860	2,790	43,000	200	510	
May	17,184	2,280	5,240	46,900	1,960	5,774	
June	8,453	370	9,400	53,390	12,240		2,137
July	2,431	470	9,120	42,710	12,600		2,539
August	3,101	120	3,070	26,430	9,470	181	
September	4,042	180	1,900	16,930	4,180		1,148
The period	41,751	4,280	31,520		40,650	641	
1921–22							
October	5,170	70	1,150	16,220	60		200
November	5,770	40	600	20,450	0	410	
December	6,640	1,120	550	25,250	0	970	
January	6,950	560	420	31,490	0	1,220	
February	5,730	330	510	37,360	0	840	
March	5,110	960	1,160	42,070	0		400
April	5,060	690	2,640	47,380	0		3,530
May	16,884	1,240	6,500	54,020	3,530	4,514	
June	10,413	650	9,540	57,600	11,980	703	
July	4,911	580	12,230	46,440	9,920		3,259
August	3,815	1,210	4,700	33,040	7,620		155
September	3,860	0	3,100	25,900	3,770		420
The year	80,313	7,450	43,100		36,880	693	
1922–23							
October	6,140	190	1,420	23,310	430	740	
November	7,670	340	740	27,050	170	1,520	
December	8,060	550	700	32,630	0	2,590	
January	7,270	710	520	37,950	0	2,160	
February	5,940	450	580	43,250	0		70
March	6,860	150	1,220	49,130	0	790	
April	6,870	1,030	2,110	54,130	250		1,470
May	8,244	1,740	5,090	61,140	6,650	764	
June	8,863	1,900	8,460	58,620	10,700		187
July	6,072	1,320	12,400	50,410	11,300		2,388
August	5,673	670	5,610	36,490	9,730	233	
September	6,130	270	2,530	27,260	5,450	2,580	
The year	83,792	9,320	41,380		44,680	7,262	
1923–24							
October	7,640	760	1,060	23,100	1,660	480	
November	7,910	0	820	28,300	1,040		350
December	8,110	0	720	34,700	0	2,790	
January	7,500	160	530	39,300	0	2,230	
February	6,600	490	580	44,200	0	1,310	
March	7,030	470	1,230	49,400	0	270	
April	10,180	120	2,550	55,400	110	3,740	
May	7,150	170	5,500	59,300	11,850	4,370	
June	3,101	80	6,500	44,900	11,600		119
July	2,773	60	4,400	30,100	9,170		1,537
August	3,309	0	2,550	20,900	2,890	4,369	
September	3,423	250	1,930	14,400	1,890		647
The year	74,726	2,560	28,370		40,210	16,906	
1924–25							
October	4,065	320	1,100	14,900	1,040		115
November	5,170	90	550	18,300	0	210	
December	5,970	380	510	22,800	0	1,740	
January	5,770	600	350	26,900	0	1,420	
February	5,074	500	400	31,500	0	774	
March	5,580	1,000	960	35,900	0		280
April	10,980	1,180	2,260	41,800			
May	9,348	1,060	5,200	47,400			
June	6,740	1,350	7,670	47,400			
July	3,350	500	6,080	35,800			
August	3,786	430	2,650	23,600			
September	5,139	460	1,900	14,700			
The year	70,972	7,870	29,630		[1] 37,870	[1] 10,542	

[1] Yearly totals only. Data insufficient to warrant monthly figures during irrigation months.

Inflow, use, and losses from Mud Lake, in acre-feet, 1921–32—Continued

Month	Surface inflow	Precipitation on lake	Evaporation, including transpiration	Lake contents at beginning of month	Diversions	Invisible loss or gain	
						Loss	Gain
1925–26							
October	7,194	820	1,140	15,700			
November	6,163	160	680	23,400			
December	5,832	500	650	30,400	0		318
January	5,631	400	510	36,400	0	921	
February	5,113	280	550	41,000	0	643	
March	10,310	160	1,200	45,200	0	870	
April	9,950	530	4,430	53,600			
May	4,825	340	6,410	57,000			
June	2,862	240	4,820	40,000			
July	2,870	510	3,230	23,300			
August	2,740	100	3,030	13,700			
September	2,856	20	1,320	9,580			
The year	66,346	4,060	27,970		[1] 40,086	[1] 9,390	
1926–27							
October	3,531	20	790	8,660			
November	4,622	150	480	11,700			
December	5,810	270	450	18,000	0	630	
January	5,850	160	320	23,000	0	890	
February	5,150	130	360	27,800	0	1,920	
March	5,660	200	790	30,800	0	1,370	
April	5,970	170	2,940	34,500			
May	8,330	1,320	3,830	34,400			
June	7,675	110	4,250	32,400			
July	2,253	0	2,950	21,800			
August	2,195	190	1,390	9,060			
September	3,485	310	1,060	6,940			
The year	60,531	3,030	19,610		[1] 33,486	[1] 11,355	
1927–28							
October		250	730	7,770			
November		140	440	9,940			
December		0	410	15,800			
January		250	300	20,500			
February		120	340	25,500			
March		80	770	30,200			
April		140	1,660	34,400			
May		360	3,190	33,900			
June		650	2,500	22,700			
July		70	1,800	11,400			
August		40	1,050	4,560			
September		20	760	3,760			
The year	[1] 47,668	2,120	13,950		[1] 30,187	[1] 9,431	
1928–29							
October		40	480	3,990			
November		320	280	6,120			
December		320	300	8,560			
January		110	240	12,500			
February		160	270	17,500			
March		290	620	22,000			
April		500	1,430	28,600			
May		100	3,220	31,900			
June		160	2,960	29,300			
July		60	1,800	15,200			
August		50	980	4,680			
September		60	700	2,890			
The year	[1] 40,691	2,230	13,280		[1] 25,000	[1] 4,981	
1929–30							
October		110	440	3,650			
November		0	210	3,970			
December		60	210	4,710			
January		120	190	8,890			
February		250	240	12,300			
March		160	540	17,100			
April		230	1,260	23,300			
May		290	2,550	26,000			
June		180	1,980	16,700			
July		0	1,010	4,430			
August		420	810	1,550			
September		160	680	2,700			
The year	38,940	1,980	10,120		[1] 25,000	6,130	

[1] Yearly totals only. Data insufficient to warrent monthly figures during irrigation months.

Inflow, use, and losses from Mud Lake, in acre-feet, 1921–32—Continued

Month	Surface inflow	Precipitation on lake	Evaporation, including transpiration	Lake contents at beginning of month	Diversions	Invisible loss or gain	
						Loss	Gain
1930–31							
October	3,437	100	440	3,320	950	1,017	-------
November	4,206	90	240	4,450	450	1,066	-------
December	4,973	140	270	6,990	0	233	-------
January	5,773	180	240	11,600	0	413	-------
February	5,911	170	260	16,900	0	1,421	-------
March	6,098	170	600	21,300	0	168	-------
April	5,183	80	1,350	26,800	0	1,913	-------
May	4,417	430	2,730	28,800	8,973	3,244	-------
June	2,083	140	2,680	18,700	8,609	3,224	-------
July	1,636	50	1,360	6,410	2,870	1,356	-------
August	1,638	80	780	2,510	1,085	1,133	-------
September	2,060	90	480	1,230	900	420	-------
The year	47,415	1,720	11,430	----------	23,837	15,608	-------
1931–32							
October	2,900	20	340	1,580	900	560	-------
November	3,469	60	190	2,700	400	1,119	-------
December	4,599	450	210	4,520	0	----------	81
January	5,384	270	210	9,440	0	584	-------
February	4,566	90	250	14,300	0	906	-------
March	4,634	50	540	17,800	0	----------	256
April	5,739	630	1,250	22,200	0	619	-------
May	9,734	550	2,850	26,700	7,741	1,693	-------
June	7,371	1,430	2,430	24,700	9,691	3,180	-------
July	4,012	680	2,510	18,200	8,613	3,279	-------
August	3,311	130	1,130	8,490	5,786	1,135	-------
September	3,678	0	750	3,880	3,200	----------	42
The year	59,397	4,360	12,660	----------	36,331	12,696	-------

Summary of water supply and use of water, in acre-feet, of Mud Lake, 1921–32

Year ending Sept. 30—	Supply							Use and loss				
	Camas Creek at Camas	Beaver Creek at Camas	Ground-water gain from Camas to West Hamer Bridge	Other observed ground-water inflow	Precipitation on lake	Decrease in lake storage during year	Total supply	Diversions	Transpiration and evaporation	Increase in storage during year	Invisible loss	Total
1921 [1]	28,380	11,365	[2] −3,555	5,561	4,280	26,780	72,811	40,650	31,520	0	641	72,811
1922	29,487	10,021	28,412	12,393	7,450	0	87,763	36,880	43,100	7,090	693	87,763
1923	23,060	6,230	42,000	12,502	9,320	210	93,322	44,680	41,380	0	7,262	93,322
1924	13,940	1,518	45,792	13,476	2,560	8,200	85,486	40,210	28,370	0	16,906	85,486
1925	22,529	10,000	28,431	10,012	7,870	0	78,842	37,870	29,630	800	10,542	78,842
1926	16,321	4,720	35,019	10,286	4,060	7,040	77,446	40,086	27,970	0	9,390	77,446
1927	18,589	3,520	28,061	10,361	3,030	890	64,451	33,486	19,610	0	11,355	64,451
1928	14,035	633	[3] 25,000	[3] 8,000	2,120	3,780	53,568	30,187	13,950	0	9,431	53,568
1929	9,191	500	[3] 24,000	[3] 7,000	2,230	340	43,261	25,000	13,280	0	4,981	43,261
1930	5,210	1,730	[3] 24,000	[3] 8,000	1,980	330	41,250	25,000	10,120	0	6,130	41,250
1931	3,133	0	24,916	[4] 19,366	1,720	1,740	50,875	23,837	11,430	0	15,608	50,875
1932	16,841	0	5,053	[4] 37,503	4,360	0	63,757	36,331	12,660	2,070	12,696	63,757

[1] April to September only.
[2] Loss.
[3] Estimated.
[4] Includes developed water from drains and wells.

MINOR LAKES

HAMER LAKE

Hamer Lake is a natural reservoir supplied by seepage of ground water supplemented by the flow of artesian wells. During the irrigation season of 1921 it received a flow of about 6 second-feet from six artesian wells of the Hamer Canal Co. Since 1921 the number of wells has been increased. A ditch dug from Hamer Lake northwestward through several ponds and sloughs drains water from these ponds and sloughs into the lake during the irrigation season, when the lake is low. A plane-table survey of Hamer Lake made at a high stage about June 1, 1921, showed the lake to have an area of 184 acres, an average depth of about 3 feet, and a content of about 550 acre-feet. Early in July 1921 the lake was practically pumped dry by the pumps of the Hamer Canal Co. The artesian wells were then uncapped and used to supplement the seepage from the shores and bed of the lake.

Records of pumping operations by the Hamer Canal Co. during 1921 show that 2,370 acre-feet was diverted and used to irrigate between 450 and 500 acres. The total loss by evaporation from the lake during the year was about 590 acre-feet, as calculated from an estimated loss of 3.2 feet over an area of 184 acres. In addition some water flowed from this lake into Mud Lake and has been reckoned with the supply of Mud Lake. On June 16, 1921, the gage in Hamer Lake read 2.16 feet; on March 10, 1922, it read 2.90 feet. In 1923, 2,480 acre-feet was pumped from the lake; in 1924, 4,120 acre-feet. After 1924 records of the diversions were not kept until 1931, when the diversions were 5,640 acre-feet, and 1932, when they were 3,920 acre-feet. As shown by the water-table contours on plate 12, the ground water in this vicinity moves southwestward and escapes from the basin.

NORTH LAKE

As North Lake has no surface inlet, it receives its entire supply from ground water. It had no surface outlet in 1921, but in 1922 it spilled over into Mud Lake for a few weeks. In 1929 it was connected to Mud Lake by a drain that is described on page 114. During 1932 the flow in this drain started in January, gradually increasing thereafter until April 7 when it reached a maximum of 19 second-feet, after which it receded until the drain went dry on July 1. The total discharge during the year ended September 30, 1932, was 2,228 acre-feet.

Because North Lake was not tributary to Mud Lake in 1921 it was not considered in the measurements of area or capacity of Mud Lake, and in 1922 its area and capacity were not included because otherwise the calculations for the 2 years would not be comparable. The altitude of the lake on June 20, 1921, was 4,792.35 feet above mean sea level, or 7.35 feet above Mud Lake. The lake fell during the summer and rose again in the fall. A staff gage was installed June 25 on the south side of North Lake, on a fence post on the line between sec. 25, T. 7 N., R. 34 E., and sec. 30, T. 7 N., R. 35 E. At that time the gage read 6.92 feet, and on October 10 it read 4.92 feet.

A plane-table survey of the lake, made in June 1921, indicated an area at high stage of 1,180 acres. The evaporation and transpiration from this area during the year ended March 31, 1922, was estimated to be 3.4 feet instead of 3.2 feet, because of the small additional loss by transpiration on the marshy area, making a total of about 4,000 acre-feet. There were no diversions from the lake for irrigation. No soundings were made of the lake, but from observations around the shores it was estimated that at high water the depth averaged 3.5 feet. This indicates a maximum content at the high stage in 1921 of 4,100 acre-feet. A survey by O. S. Anderson, of Menan, in April and May 1920, showed the area of the lake to be 1,200 acres and the content 5,000 acre-feet.

JEFFERSON RESERVOIR

The Jefferson Reservoir receives its supply entirely from ground water. Formerly it was a series of springs and ponds that made their appearance about the time that ground water appeared at Hamer Lake and North Lake. The reservoir supply is now supplemented by the flow from several artesian wells, described on page 70. The reservoir is diked on the south and west sides and is used as a storage unit. No accurate data are available, however, to show that the flow from the Jefferson Reservoir formerly entered Mud Lake. Reports of residents in the vicinity of the reservoir are conflicting. From available topographic data and a study of the situation in the field the following tentative deductions were made:

1. Before the present dikes and canals were built, water from the Jefferson Reservoir probably wasted out over the level country to the southwest, as is indicated by the appearance of the soil, dead sagebrush, and relatively recent growth of greasewood. Probably very little water reached Mud Lake before these dikes were constructed. However, if the dikes separating the Jefferson Reservoir from the swamp area due south of it were removed and the remainder of the diking system were unmolested, water would flow from the reservoir toward Mud Lake.

2. During the winter the Jefferson Reservoir fills up, and water either wastes through the canal on the lands of the reservoir project or flows over the spillway into the Jefferson Reservoir addition to the south.

3. The Jefferson Reservoir addition is formed by a dike on its south and west sides, and were it not for the dike on the south, water would flow from it directly into Mud Lake. If the dike on the west were removed also, the prevailing direction of flow might possibly be toward the southwest, as from the Jefferson Reservoir, for Mud Lake at extremely high stages discharges over its dikes in that direction.

The area of the Jefferson Reservoir at the high stage on June 21, 1921, was 1,104 acres. On the same date the altitude, at a gage height of 3.09 feet, was 4,788.80 feet above sea level, or 5.12 feet higher than Mud Lake. No soundings of the reservoir were made. A survey made by O. S. Anderson in March 1920 showed an area of 1,140 acres and a maximum content of 4,560 acre-feet. From observations made during the investigation it is believed that the average depth of the reservoir at the high stage is not more than 3 feet, which gives a maximum content of above 3,310 acre-feet.

Water was diverted for irrigating 862 acres through the main canal of the Jefferson Reservoir Irrigation Co. during the irrigation season of 1921. Daily readings of the depth of water over the two rectangular gates in the diversion dam were made by W. H. Abbott. From occasional discharge measurements of the flow through the canal and daily readings it has been calculated that about 3,930 acre-feet was diverted from April 1 to September 30, 1921.

On the basis of 3.4 feet of evaporation and transpiration over an area of 1,104 acres, a loss of 3,760 acre-feet was sustained during 1921. This is believed to be a conservative estimate of the loss, because about 40 percent of the reservoir consists of tule marsh, in which the loss by transpiration is doubtless high.

The data given above show a total supply throughout 1921, including diversions, evaporation, and transpiration, of about 7,690 acre-feet. This, however, is probably a very moderate estimate, because the reservoir usually fills early in the winter, and considerable water wastes through the canal before irrigation begins. About 3,620 acre-feet was diverted in 1923. Records were not kept after 1923. In 1929 the water master reported 1,970 acres under irrigation; in 1928, 1,570 acres.

JEFFERSON RESERVOIR ADDITION

Between the Jefferson Reservoir and Mud Lake is the Jefferson Reservoir addition. A dike about 200 feet long formerly prevented the flow from the sloughs and any waste water from the Jefferson Reservoir from entering Mud Lake. Since 1930 the water from Jefferson Reservoir and the addition have been permitted to flow freely into Mud Lake from November to February, inclusive, according to the terms of the Mud Lake water decree. The area of the water surface of the addition at the high stage in June 1921 was 250 acres. Two diversions for irrigation were noted—the Hansen Ditch and the Abbott Ditch. Approximately 200 acres was irrigated in 1921 with water diverted through these two ditches. This reservoir is believed to have an average depth of about 1 foot at the high stage. The constant flow from the springs on the east side is not enough to offset losses through evaporation, transpiration, and diversions for irrigation during the summer; hence the reservoir practically dries up before the end of the irrigation season.

An annual evaporation and transpiration loss of 4 feet has been assumed, as about 75 percent of the reservoir contains tules or other marsh vegetation. This factor applied to 250 acres gives a loss of 1,000 acre-feet. On the assumption that diversions during the irrigation season amount to about 500 acre-feet, the total supply in 1921 is estimated at 1,500 acre-feet. Since 1924 the lands under irrigation from this addition have been short of water, because the lowering of the lakes has affected this body of water also.

SPRING LAKE

No gage-height records were obtained on Spring Lake, and no soundings were made. The supply comes from a series of springs in the center and northeastern part of the lake. A rough plane-table survey made in July and October 1921 shows a wetted area of 2,200 acres. Prior to the time that the dikes were constructed on the west and southwest sides of the lake the flow of the springs was used for irrigation, and during the remainder of the year this water wasted over the nearly level country to the southwest. About 700 acres was irrigated from Spring Lake in 1921. The McKevitt, Mitchell, and Wilson Ditches can divert water from the lake, but the Wilson Ditch was not used in 1921. A shortage of water was experienced in July and August of that year. The lands were irrigated in the spring and again in the fall, but on account of the shortage reported it is believed that 2 acre-feet to the acre is a fair estimate of the amount used on the 700 acres. This gives 1,400 acre-feet used for irrigation. The loss by evaporation and transpiration is probably high, as about 60 percent of the lake is marsh. If it was 4 feet over the entire wetted area of 2,200 acres, it amounted to 8,800 acre-feet. The total annual supply is therefore estimated at about 10,000 acre-feet. In addition there were seepage losses toward the west from the lake. At the high stage the lake is estimated to have an average depth of 1.5 feet and a capacity of 3,300 acre-feet. Since 1925 the lands irrigated from this lake have been short of water, like the rest of the lands in the Mud Lake Basin.

GROUND-WATER SUPPLY

A rough analysis of the probable total quantity of ground water that fed the lakes and reservoirs in the Mud Lake Basin or was discharged by evaporation and transpiration on the marshy lands without reaching any of the lakes in 1921 is given below.

The water supplies of the minor lakes (diversions for irrigation plus losses by evaporation and transpiration) as determined during 1921 were about as follows: Hamer Lake, 3,000 acre-feet; North Lake, 4,000 acre-feet; Jefferson Reservoir, 7,700 acre-feet; Jefferson Reservoir addition, 1,500 acre-feet; Spring Lake, 10,000 acre-feet; total, 26,200 acre-feet. Practically all of this water is derived from springs and seepage except that which falls on the lakes as rain or snow. From the total area of the lakes as used in the preceding calculations and the records of precipitation, it appears that the total amount of water that fell on the lake areas as rain or snow was somewhat over 3,000 acre-feet. Therefore the supply derived from ground water during the year ending March 31, 1922, was about 23,000 acre-feet.

The total area covered by lakes, reservoirs, and marshy lands where the water table was not more than 5 feet below the surface was about 27,670 acres, as determined by planimeter measurements on maps that were carefully made in the field with a plane table. The area of Mud Lake used in the preceding calculations is 12,600 acres, and the aggregate area of the minor lakes about 4,920 acres, making a total of about 17,520 acres. Deducting 17,520 acres from 27,670 acres leaves 10,150 acres of area which has not heretofore been taken into consideration but in which the water table was within 5 feet of the surface. Ground water that stands within a few feet of the surface will suffer loss by capillary rise and evaporation and by absorption and transpiration of plants. The exact depth from which ground water is discharged by these processes depends on the character of the soil and the kind of plants. For the present computation the limiting depth was taken to be 5 feet, although there is also some discharge where the water table stands somewhat more than 5 feet below the surface.

About 75 percent of the 10,150 acres is subject to heavy transpiration on account of the prolific growth of marsh vegetation. The evaporation from the open water of Mud Lake during the year was determined to be 3.21 feet, the evaporation and transpiration from the tule pan from June 13 to September 23 was 4.28 feet, and the evaporation and transpiration from a submerged tule-covered area during the year, if computed by the difference method previously described, amounted to 4.62 feet. Therefore a loss of 4 feet was arbitrarily assumed for the area of 10,150 acres, making a total computed loss of about 40,000 acre-feet. Deducting the precipitation upon the area, which amounted to about 7,000 acre-feet, leaves about 33,000 acre-feet which was derived from ground water.

On the basis of the foregoing calculations the quantity of ground water that appeared at the surface in the lakes and marshes of the Mud Lake Basin during the year ending March 31, 1922, was as follows:

Ground-water supply of the Mud Lake Basin during the year ending March 31, 1922, in acre-feet

Discharged through Mud Lake	40, 000
Discharged through five minor lakes	23, 000
Discharged from marshes and other areas of shallow ground water not included with the lakes	33, 000
	96, 000

By the same method of computation the supply for the year ending March 31, 1923, was found to be about 120,000 acre-feet. Since that time the supply has been less, but the records are not adequate to justify estimates of the annual supply.

QUALITY OF WATER

Analyses of 17 samples of water collected in 1921 from the Mud Lake Basin are given in the following table. Samples were taken from a few wells reported to have a high alkali content and from surface sources representing the entire supply of irrigation water diverted from Mud Lake and nearby sloughs. The good quality of the water in the deposits of sand and gravel indicates that the soluble mineral matter is being carried from the region by ground water. The water in the basalt contains comparatively small quantities of dissolved solids and generally is not hard. Spring Lake water proved to be the only irrigation water analyzed that contained enough alkali to be troublesome. Otherwise the irrigation water of the Mud Lake Basin is to be considered good.

Analyses of water from Mud Lake region

[Analyzed by Margaret D. Foster. Samples collected in 1921. Parts per million]

Owner or name	Location	Source	Depth of well (feet)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total dissolved solids at 180° C.	Total hardness as $CaCO_3$ (calculated)	Temperature when collected (° F.)	Material in which the water occurs
O. C. Brown	Northeast corner SE ¼ sec. 14, T. 10 N., R. 35 E.	Drilled well	376	28	0.10	91	40	21	143	54	177	15	520	392	48	Basalt.
Hamer Canal Co.	NE ¼ SW ¼ sec. 14, T. 7 N., R. 36 E.	do	60	44	.08	27	10	13	131	11	6.2	2.2	169	108		Do.
Chas. Rising	NW¼NE¼ sec. 29, T. 8 N., R. 34 E.	do	40	32	.19	31	13	20	158	14	16	1.4	204	131	55	Do.
C. A. Olson	Southeast corner SW ¼ sec. 18, T. 6 N., R. 35 E.	do	262	33	.09	36	12	16	153	12	2.2	3.2	213	139	54	Do.
Luxton Market	1½ miles north of Idaho Falls.	do	190	23	.15	69	19	20	257	45	20	5.9	334	250		Do.
J. R. Raumaker	Northwest corner SW ¼ sec. 5, T. 7 N., R. 37 E.	do	135	43	.08	27	9.4	15	[1] 140	7	6.4	2.9	178	106		Do.
J. Hendrickson	NW¼SE¼ sec. 21, T. 8 N., R. 36 E.	Dug well	22	28	.16	52	11	6.6	206	6.2	4.6	6.7	216	175	54	Gravel.
C. S. Sharp	Northeast corner sec. 22, T. 8 N., R. 36 E.	do	28	25	.32	216	42	82	144	118	431	38	1,032	712	55	Do.
W. Czarvecki	SE¼NE¼ sec. 23, T. 7 N., R. 33 E.	do	34	32	.09	104	32	45	193	55	205	Trace.	633	391	54	Do.
T. D. Scody	NW¼SW¼ sec. 18, T. 7 N., R. 35 E.	do	17	15	.10	233	103	377	247	303	890	27	2,158	1,000	49	Sand.
G. Welchman	SE¼SE¼ sec. 32, T. 7 N., R. 34 E.	do	50	9.2	.65	412	98	134	110	349	821	77	2,029	1,430	58	Do.
Alec Mitchell	Northwest corner NE ¼ sec. 19, T. 7 N., R. 34 E.	Driven well	50	36	.24	49	15	17	162	30	34	1.4	274	184	62	Do.
Lidy Hot Springs	Sec. 2, T. 9 N., R. 33 E.	Hot springs		37	.17	80	17	34	164	176	8.7	Trace.	447	270	115	
North Lake	Sec. 19, T. 7 N., R. 35 E.			22	.37	56	16	68	314	21	49	Trace.	396	206	32.5	
Spring Lake	SE¼ sec. 5, T. 7 N., R. 34 E.			27	.22	71	70	415	[1] 675	356	313	Trace.	1,638	464	36	
Jefferson Lake	T. 7 N., R. 34 E.			24	.13	38	19	70	296	34	35	Trace.	367	173	36.5	
Mud Lake	First Owsley pumping plant.			27	.27	38	14	34	209	15	24	.50	268	152	60	

[1] Includes carbonate radicle less than 10 parts per million.

UTILIZATION OF WATER SUPPLIES

WELL CONSTRUCTION

Most of the dug wells in this region are in localities underlain by alluvium. The wells are sunk into the alluvium and are cased with wood. They have proved satisfactory for domestic purposes, although considerable difficulty has been experienced with burrowing animals falling into them. Where the lava rock is close to the surface and the depth to the water table is not great a few wells have been blasted into the rock and have obtained sufficient water. A well belonging to Charles Holland, at Howe, near the mouth of the Little Lost River and not far west of the Mud Lake region, is 3 feet in diameter and blasted through lava to a depth of 135 feet.

About 1921 several wells, 8 to 10 feet in diameter, were dug in the alluvium in the vicinity of Monteview with an orange-peel steam shovel for the purpose of developing irrigation supplies. A few of the wells were equipped with pumps. Beds of running sand encountered just below the water table gave considerable trouble, and much time was spent in experimenting with different types of casing, in developing methods of shutting out the sand, and in reaching effective depths below the water table. Properly constructed drilled wells would probably give better results in deposits of this kind.[39]

Wells drilled into the lava rocks by the percussion method have been generally successful. Drillers average about 12 feet a day in the basalt when making a 6-inch hole. Thin beds of dune sand interstratified with the lava rocks cause trouble for the drillers. These "pockets of sand" are often not adequately cased out of the hole, and in a few years after a well has been drilled it may become clogged with sand and may have to be cleaned out.

PUMPING FROM WELLS FOR IRRIGATION

The water table is so close to the surface under several thousand acres in the low part of the basin that pumping from wells for irrigation is economically feasible. In the vicinity of Monteview well 459, which is equipped with a 10-horsepower gasoline engine and a horizontal centrifugal pump, is used for irrigation. The owner reports a total lift of about 25 feet. About 1927 Thomas Wagner started a project to pump water from drilled wells in the NW¼ sec. 31, T. 8 N., R. 34 E., on the north side of Spring Lake. The depth to water in the group of wells at this place in September 1928 was only about 3 feet. One line of wells is connected by suction pipes to a large centrifugal pump operated by a Diesel engine.

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[39] Stearns, H. T., and Bryan, L. L., Preliminary report on the geology and water resources of the Mud Lake Basin, Idaho: U. S. Geol. Survey Water-Supply Paper 560, p 130, 1925.

With the present irrigation schedule of the electric power company serving this territory, water can be lifted 20 feet in units as small as 20-horsepower plants at a cost of 1 cent a kilowatt-hour, or only about 50 cents an acre-foot for electric current. With this low rate, pumping is feasible in the Mud Lake region wherever the lift is not great and electricity is available. It may also prove feasible for ranchers outside of irrigated tracts to install deep-well turbine pumps in their domestic wells to pump water for lawns, shade trees, gardens, and small fields of alfalfa.

DEEP-WELL PUMPING

The depth to the water level in some wells on high parts of the lava plains of the Mud Lake region is 300 to 1,000 feet, which necessitates the use of deep-well pumps capable of high lifts. Numerous wells with water levels about 300 feet below the surface yield adequate supplies for domestic use by means of lift pumps and windmills. On ranches with considerable stock the water pumped by windmills is stored in reservoirs to provide a supply for calm days, or else an auxiliary gas engine is installed. The following paragraphs with slight alteration are taken from an article previously published.[40]

The well of the Oregon Short Line at Dubois (no. 581) is 600 feet deep and is cased with oil-well casing that is 10 inches in diameter at the top and 6 inches at the bottom. The well is finished with a sand strainer 16 feet long. It was drilled most of the way through lava rock but ends in a bed of sand. Its original depth was 615 feet, but shortly after it was drilled the sand squeezed up in the casing for 15 feet. The well is equipped with a lift pump having a cylinder 5 feet long. At the time the test was made the depth to the water level in the well was 370 feet. During this test the pump was driven by steam at the rate of 30 strokes a minute for a period of 10 hours and yielded 6,700 gallons an hour. The supply of water was not appreciably affected by this test.

Another well, 450 feet deep, with a water level 432 feet below the surface, is equipped with a lift pump and an 8-horsepower gasoline motor. The pump yields 11 gallons a minute and in ordinary operation delivers 500 gallons an hour. In 1921 the owner sold water at a profit for sheep at half a cent a gallon and to neighbors for domestic purposes at a third of a cent a gallon.

At the United States Sheep Experiment Station there is a 4½-inch well (no. 591) that is 750 feet deep and ends in sandstone. The depth of the water level in this well is 680 feet. The pump is a Fairbanks-Morse no. 4 type H power head, having wooden sucker valves and a single-acting plunger. The pump requires about 6 horsepower to operate it at a maximum capacity. The pump jack has a 16-inch

[40] Stearns, H. T., Deep-well pumping in Idaho: Howell Drillers' News, vol. 4, no. 9, p. 3, September 1925.

short stroke and a 20-inch long stroke, and when operating with the long stroke it should pump 630 gallons an hour. In actual practice, however, it is impossible to get a yield of over 550 gallons an hour from the pump. There is a 2½-inch galvanized pump pipe, at the end of which is a 2¼-inch brass cylinder 3 feet long. Formerly this pump was operated with a Fairbanks-Morse 10-horsepower Z type kerosene engine. During a test made several years ago with this equipment, 32,000 gallons of water was pumped in 65 hours with no appreciable draw-down of the water level. In this test 50 gallons of kerosene was consumed. With kerosene at 20 cents a gallon, the cost of lifting the water from the depth of 680 feet was therefore only 3 cents a hundred gallons. Moreover, according to a recent statement by the superintendent of the experiment station, the cost of pumping has been cut to half this amount by using a 7½-horsepower single-phase electric motor and a high-speed silent chain.

PUBLIC WATER SUPPLIES

All the towns and villages in the region obtain their water supply from wells, except Spencer, which obtains its supply from Canyon Springs. Only Dubois, Roberts, St. Anthony, and Ashton have distribution systems.

In the NW¼SW¼ sec. 21, T. 10 N., R. 36 E., on the east bank of Beaver Creek, is a well drilled by the city of Dubois that is 430 feet deep. The log of this well is given below:

Log of well 582, city of Dubois

Formation	Thickness	Depth
	Feet	*Feet*
Soil and gravel	7	7
Basalt	56	63
Water and clay	15	78
Basalt with five streaks of sand	352	430

The water level in this well as reported by the driller is 345 feet below the surface. Prior to 1921 the water was pumped from this depth to a water tower by a 4-inch lift pump. In drilling the well a small amount of water was reported at 63 feet, but it was cased out because it was considered insufficient to supply the city. In 1921 the city decided to explore this supply of water in order if possible to dispense with the high lift. A well was blasted down through the upper basalt to the bed of clay that is 63 feet below the surface. The basalt was found to be brecciated and scoriaceous where it rests on the clay, and the clay was baked red for about 1 foot. Beneath the zone of baking the clay was yellow. On November 18, 1921, when this well was examined, nearly 200 gallons of water a minute was issuing from the breccia at the contact. During the time of the visit workmen were excavating a tunnel in the bed of clay to hold 34,000 gallons of water, to serve as an underground storage tank to replace the one above the ground. In order to dispose of the water while excavating the underground reservoir the water was allowed to drain into the casing of the drilled hole, which was cut off at this depth. When the water was not draining into the hole it would rise within 48 feet of the surface. When the tunnel was completed the water was pumped directly into the mains, and at that time about 100,000 gallons daily was required to meet the needs of the city.

It was evident at the time that this water was seeping out of Beaver Creek and was perched above the main water table. It was discovered when the creek went dry near the well, however, that the water was coming from seepage from the creek at a considerable distance upstream. Since 1927 Beaver Creek has been dry so much of the year that this perched supply has failed, and water is now obtained by the city from the railroad well.

St. Anthony has two wells, each 238 feet deep, from which the water is pumped to a water tower. The total lift is 155 feet. No records have been kept of the amount of water pumped. Ashton pumps annually about 1,800,000 gallons from a well 365 feet deep, according to data furnished by the city clerk. Roberts pumps about 17,500 gallons daily from a dug well 10 feet deep in the town site. Spencer obtains its water from Canyon Springs, in Beaver Canyon. The Oregon Short Line Railroad has wells at most of the stations in the area. A description of these wells will be found in the table of well records.

DRAINAGE BY MEANS OF WELLS

The presence of both a perched and a main water table in the vicinity of Mud and Market Lakes makes drainage by wells feasible. Although as yet there has been no need of drainage in the vicinity of Mud Lake, the use of wells for this purpose may be of economic value in the future. Well 166, on the shore of Mud Lake, was drilled 237 feet, and the water level in it stands 207 feet below the high-water surface of Mud Lake. The owner reports 125 feet of silt and clay, overlying 13 feet of sand and gravel, beneath which is at least 99 feet of basalt. Although never tried, there is little doubt that water from Mud Lake could be drained into this hole. A pit 96 feet deep and about 6 feet in diameter in the lava on the North Side Minidoka tract, in Minidoka County, drains 26 second-feet continuously.

In the vicinity of Market Lake drainage by wells has been successfully practiced, but because of lack of care most of the wells no longer take in water. Prior to 1922 the Shepherd Investment Co., of Idaho Falls, drilled seven wells for drainage about a mile west of Market Lake. The records of these wells are given below. Wells 69 and 67 turned out to be flowing wells instead of drainage wells. On November 7, 1929, it was estimated that well 22 was draining 1 second-foot of water and that well 80 was draining about a quarter of a second-foot.

Log of well 69, in the southeast corner of the SW¼NW¼ sec. 17, T. 5 N., R. 37 E.

[Altitude 4,760 feet; diameter 5⅝ inches. Drilled by Andrew Kendrick in 1919 but never used because it obtained artesian water. On July 6, 1922, the water stood 0.87 foot above the land surface]

	Thickness	Depth
	Feet	*Feet*
Sand	34	34
Clay	26	60
Sand	13	73
Clay (watertight)	5	78
Coarse sand with water	17	95
Clay	3	98
Hard gravel	37	135
Gravel and clay (caving in places)	7	142
Clay	6	148
Lava (basalt) at bottom		

Log of well 79, in the NW¼NE¼ sec. 1, T. 5 N., R. 36 E.

[Altitude 4,754 feet; diameter 5⅝ inches for 71 feet and 4¼ inches to bottom. Drilled by W. A. Rogers. Cased for 129 feet 8 inches. Used successfully as a drainage well, and on Nov. 8, 1929, a small stream of water was running into it. On that date the water level was 29 feet below the land surface]

	Thickness	Depth
	Feet	*Feet*
Sand and clay	15	15
Sand	55	70
Clay	19	89
Lava (basalt)	36	125
Sand and clay	47	172
Lava (basalt)	9	181

Log of well 79a, in the southwest corner of sec. 36, T. 6 N., R. 36 E.

[Altitude 4,753 feet. Drilled 8 inches in diameter in June 1921 and cased for 40 feet]

	Thickness	Depth
	Feet	*Feet*
Black soil	3	3
Yellow clay	15	18
Sand and clay with a little water	10	28
Clay	10	38
Hard lava (basalt)	10	48
Porous lava (with crevices and water)	10	58
Black hard lava	20	78
Lava pumice and water	10	88
Hard black lava	6	94

Log of well 80, in the northwest corner of the SW¼ sec. 1, T. 5 N., R. 36 E.

[Altitude 4,854 feet; diameter 7⅝ inches. Drilled by Andrew Kendrick. Cased for 28 feet 10 inches]

	Thickness	Depth
	Feet	*Feet*
Soil and clay	20	20
Broken lava	5	25
Lava (basalt); water at 58 feet	51	76

Log of well 82, in the northwest corner of the NW¼ sec. 12, T. 5 N., R. 36 E.

[Altitude 4,753 feet; diameter at top 7⅝ inches, at bottom 5⅝ inches. Drilled by W. A. Rogers. Depth to water Nov. 1, 1929, 27 feet. Cased for 193 feet]

	Thickness	Depth
	Feet	*Feet*
Soil	15	15
Sand	10	25
Broken lava (basalt)	5	30
Lava with several streaks of rotten rock and clay	60	90
Lava (basalt)	36	126
Clay	34	160
Lava basalt; lost water at 172 and 190 feet; struck water at 208 feet	48	208

Log of well 83, in the southwest corner of the NW¼ sec. 12, T. 5 N., R. 36 E.

[Altitude 4,753 feet; diameter at top 7⅝ inches, at bottom 5⅝ inches. Drilled by Andrew Kendrick. Cased for 72 feet]

	Thickness	Depth
	Feet	*Feet*
Clay and soil; water at 12 feet	12	12
Sand	43	55
Clay	15	70
Lava; sand streak at 150 feet	80	150
Lava (basalt)	27	177

The water drains away chiefly through the lava, but it is not known at what horizon the main drainage occurs in the wells. In 1929 a site was selected by the senior author for a drainage well in the north end of the borrow pit on the east side of the new highway across Market Lake. This site was chosen because it is near the lava margin, where the water table was known to be at least 15 feet below the surface and where the borrow pit could be used as a collecting ditch. A 6-inch well drilled at this site to a depth of 151 feet by R. P. Cope in the winter of 1929 drains somewhat more than 1 second-foot of water. The log of the well as reported by Dr. Earl Jones is as follows: Soil, 18 feet; lava, 132 feet; sand, 1 foot. Unfortunately, the well was drilled when the ground was frozen and water could not be obtained to test it, therefore the effective drainage formation was not determined. However, one of the drillers reported that none of the drilling water was lost in the first 36 feet, and that there was no indication of ground-water movement until the depth of 100 feet was reached. The depth to water when the well was completed was about 36 feet. The next well that is drilled should be carefully tested, and if the lava drains effectively at shallow depths, pits blasted to the water table may be more successful than wells. It may also prove more economical to drill wells that are larger than 6 inches in diameter.

In order to lower the water table after the lake has been drained into wells, it may prove economically feasible to excavate an open drain through the lake bottom. The fact that artesian water has been obtained in wells 69 and 67 suggests that the open drains could be made more effective by drilling artesian wells in their bottoms. The water from these wells would help to lower the water table by reducing the head on the seeps now feeding Market Lake.

METHODS FOR OBTAINING MAXIMUM CONSERVATION AND UTILIZATION OF THE WATER SUPPLY

The inventory of the water supply shows that a large part of the water supply of the Mud Lake Basin is lost for irrigation or other use in the basin through evaporation and transpiration and that another large though less definitely known part is lost through percolation to the deep water table. It also shows that there is wide fluctuation in the quantity of water from year to year, which greatly reduces the value of the supply for irrigation. The results of the geologic and hydrologic study show that much of the loss can be prevented and that the yearly supply can to a large extent be equalized by a proper use of the great natural underground reservoir that is formed by the permeable lava rocks in the area lying north and northeast of Mud Lake. In order to make use of the underground reservoir, it is necessary to operate it much as a surface reservoir is operated—that is, to withdraw water from it at the times when the water is needed and thereby to draw down the water level and provide storage at times of heavy run-off. However, the underground reservoir has a great advantage over a surface reservoir, because the water which it stores is protected from loss by evaporation except where its water level is near the land surface. Lowering the head of water in the underground reservoir of the Mud Lake Basin will reduce the loss from the underground reservoir by transpiration and soil evaporation and by deep percolation. Moreover, by maintaining a proper program for withdrawals from the underground reservoir a minimum use can be made of Mud Lake and the other surface reservoirs, and the heavy losses by evaporation from them can be materially reduced. The withdrawals from the underground reservoir must be made chiefly by means of wells. Considerable benefits can be accomplished by means of properly regulated flowing wells, but the maximum beneficial use will probably require at least some low-lift pumping from wells. The lowering of head that will result from the use of wells may affect unfavorably certain lands that are naturally subirrigated. These unfavorable results will doubtless be small in comparison with the benefits that will result from effective regulation of the underground reservoir.

It is essential that the significance of withdrawing water through wells should be understood. In general the sinking of wells in the shallow-water area north and northeast of Mud Lake and the withdrawal of water from them either by artesian flow or by pumping should not be regarded as the discovery of new supplies of water but rather as means for the better utilization of the known supply. Thus the drilling of wells is comparable to the construction of a surface reservoir which is used to conserve water that would otherwise go to waste and to make it available when needed. Obviously an indefinitely large supply of water can be developed temporarily by drilling wells into the underground reservoir, just as an indefinitely large supply can be developed temporarily by installing pumps on any surface reservoir. If, however, future developments in the Mud Lake Basin are made on the basis of the temporary yield of wells instead of on the basis of average annual supply, as determined by this investigation, failure will be inevitable. The chief respect in which excessive pumping from the underground reservoir will differ from excessive pumping from Mud Lake is in the vastly greater storage capacity of the underground reservoir, on account of which the disastrous results will not be so promptly felt.

In the preliminary report on this investigation published in 1925, the following recommendation is made in the concluding paragraph:[41]

> Another promising possibility is to reduce the losses through evaporation and transpiration, and also the losses through percolation, by pumping from wells where the ground water is nearly at the surface and where the water-bearing lavas are very permeable, as at the artesian wells of the Hamer Canal Co. The pumped water could be led into Mud Lake or into the other storage units at their low stages or directly upon land to be irrigated. If the pumped water is used on land lying within certain limits the percolation losses in irrigation will be recovered; if it is used south or west of those limits, the water that percolates beyond the reach of the roots of the irrigated crops will be permanently lost to this region. If it proves feasible to pump water from wells for irrigation in the belt west and northwest of the swampy tract of Spring Lake, where the water table slopes toward the west, the water recovered will be largely or wholly water that would otherwise be lost to the region.

Over 30 flowing wells were brought in between 1922 and 1930 in the shallow-water area north and northeast of Mud Lake, most of them since Water-Supply Paper 560 was published.

One method of increasing the available water supply through use of the underground reservoir would be by draining the sloughs to the north and east by open cuts and by drilling flowing wells that would discharge into these drains. A somewhat detailed plan based on this method was presented in the report that was released in manuscript form in 1930 and is included herewith for consideration:

On plate 13 four proposed drains are shown. The area of Mud Lake as shown on this plate is that covered by the lake in 1921, as surveyed by L. L. Bryan. On October 19, 1929, a part of the proposed drain A was finished by the First Owsley Canal Co., and four wells were drilled adjacent to it near the point where it enters North Lake.

[41] Stearns, H. T., and Bryan, L. L., Preliminary report on the geology and water resources of the Mud Lake Basin, Idaho: U.S. Geol. Survey Water-Supply Paper 560, p. 132, 1925.

Three of these wells discharge by artesian pressure into the drain. The water level of the fourth well stands at the top of the casing, and if the casing were lowered it would also overflow. The part of the drain that has been completed leads from North Lake to a slough in sec. 27, T. 7 N., R. 34 E., but it would be much more effective if it were connected to Mud Lake, as shown in plate 13, and deepened an additional 4 feet. At present it enters North Lake at an altitude of 4,787.75 feet, or only 1.55 feet below the water level in the lake on the date the drain was completed. Measurements of the discharge of this drain are given below.

Discharge, in second-feet, of North Lake drain at outlet, 1929–30

[Measurements by John L. Hutton]

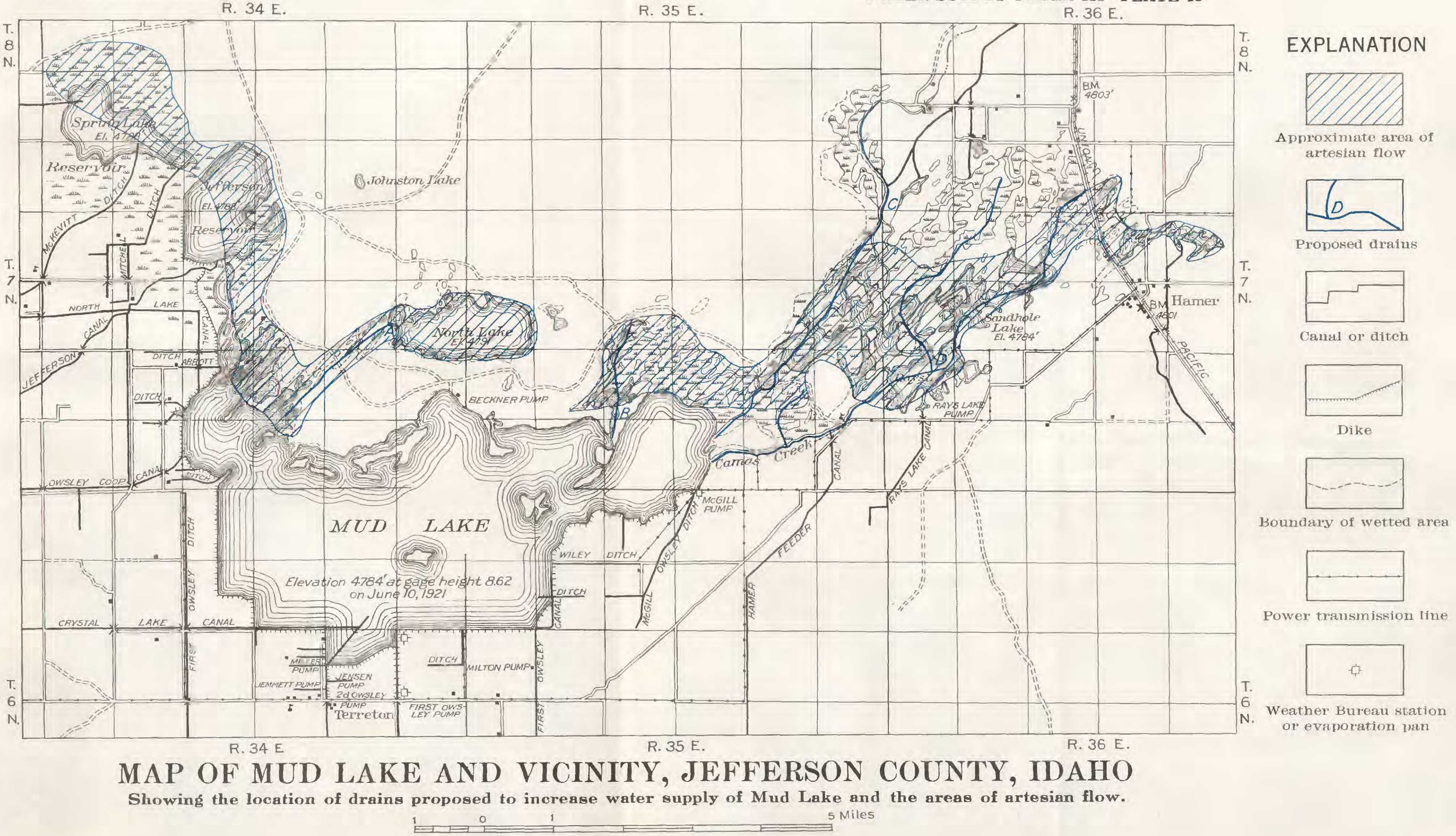
Oct. 21	23.00	Jan. 24	0.96	Apr. 6	20.21
Nov. 1	18.95	Feb. 5	.70	Apr. 14	14.26
Nov. 16	10.34	Feb. 19	11.56	Apr. 27	13.50
Dec. 4	10.42	Feb. 26	12.98	May 13	12.50
Dec. 14	12.31	Mar. 1	3.75	May 23	9.96
Dec. 27	8.37	Mar. 3	2.74	June 9	7.25
Jan. 8	2.65	Mar. 8	20.92		

As shown above, the drain yielded 23 second-feet when completed, but part of this was storage taken from North Lake. However, North Lake is essentially fed by springs, and by removing part of the head their discharge was increased. The low flow in January and February 1930 was caused by subzero weather which froze the ground and the lake, thereby shutting off the flow. The gradual decrease during the winter is apparently due entirely to this condition.

Four 8-inch wells were drilled by Walter Cope, of Terreton, along this ditch in an area of about 50 square feet, in the SE¼ sec. 23, T. 7 N., R. 34 E., during March and April 1930. Mr. Cope reports the log of the first well he drilled there as 9 feet of sand and mud, 4 feet of loose lava, 1 foot of red cinders, 21 feet of lava (basalt), 12 feet of red lava (basalt), and 1 foot of clay. The well was stopped in the clay at a total depth of 48 feet, and hence the thickness of the clay is not known. There is 13 feet of casing in the hole, and the driller reports that some of the flow was shut off between 9 and 13 feet. The well discharged about 70 gallons a minute when completed.

The second well is 15 feet east of the first and is 50 feet deep. Its log is nearly the same as that of the first well. On March 20, 1930, according to the driller, it was discharging about 0.4 second-foot (180 gallons a minute). Cuttings from this well are described on page 71.

The third well is about 15 feet southwest of the second and is 47 feet deep. The driller reports the same log except that there was 2 feet of cinders. The well started flowing at a depth of 13 feet, but the



MAP OF MUD LAKE AND VICINITY, JEFFERSON COUNTY, IDAHO

Showing the location of drains proposed to increase water supply of Mud Lake and the areas of artesian flow.

main flow was struck in the lava just above the clay beds in the bottom. It discharged about 0.8 second-foot (360 gallons a minute) when completed.

The fourth well is 15 feet south of the second and is 46 feet deep. It has the same log as the rest except that no cinders were encountered. The casing projected too high for it to flow.

On May 14, 1930, when the wells were visited, they were discharging an aggregate of nearly 2 second-feet of water that had a temperature of 46° F. The gage on the drain at the bridge below the wells read 7.88 feet, which, according to Mr. Hutton, indicated a discharge of 10 second-feet from North Lake and the wells. At the time of the visit the banks near the mouths of the wells were caving, and the wells were in danger of becoming plugged. Boxes placed over them would protect them from the caving banks and from rocks that might be thrown in by thoughtless visitors. The water from these wells is clear, and, to judge from the taste, it contains much less mineral matter than that in North Lake. As the lake had no surface outlet its waters carry considerable alkali, but from now on it should get fresher. With the success attained by these wells in so small an area it is evident that more can be brought in. Additional wells could be drilled nearer the outlet of the lake and in the lake bottom as soon as it is more completely drained. As well 301 encountered an abundant supply of water in a bed of cinders on the east side of North Lake, wells near it should obtain strong flows if connected to the lake by a trench. The cinders are derived from a small cone nearby (see pl. 3), and hence they will be much thicker on the east side of the lake. They are unconsolidated and make an ideal water bearer.

A fifth well was drilled 2,000 feet down the drain but did not flow. It was only 25 feet deep, and the log reported by Mr. Cope showed 15 feet of sand and clay, 2 feet of loose lava, 2 feet of clay, 6 feet of lava, and then clay. The log of this well indicates that the water-bearing lava thins out toward the southwest.

A test well 60 feet deep was drilled on the edge of the slough in the NE¼SE¼ sec. 25, T. 7 N., R. 34 E., on the north shore of Mud Lake. The well penetrated only sand and clay, and the water barely flowed over the casing. Another test well, 32 feet deep, was drilled on the north line of the NW¼NW¼ sec. 36, T. 7 N., R. 34 E. In this well the water stands in the casing 2½ feet above the adjacent slough and about 4 feet above Mud Lake. A trench connecting it to the lake had not yet been dug; hence the yield of the well is not known. Mr. Hutton reports that beneath a few feet of lava boulders and clay 15 feet of lava was encountered resting on pea gravel. If strong flows can be obtained from wells here, it will be an advantage to develop water at this place instead of at North Lake, because water transmitted from North Lake to Mud Lake is depleted by evaporation.

This well should be drilled deeper, however, as gravel and sand beds also yield water, and there is a chance that several might be encountered.

Three other proposed drains are shown on plate 13. The locations of these drains are subject to modifications, and a detailed survey to find the site where excavation would be cheapest prior to construction. Drain B would be only 1½ miles long, and although it would drain very little surface water, wells in it should tap artesian water. However, before it is constructed, wells should be drilled about half a mile apart along the line of the proposed trench. With the altitude of the water in the wells known and with the results of a pumping test to determine their specific capacities, the feasibility of this drain can be ascertained without any great expenditure.

Drain C would deepen a small spring-fed creek and finally reach Camas Creek after draining a number of large sloughs. If legally feasible, the entire flow of Camas Creek should be conducted to Mud Lake through this drain, thereby shortening its course and preventing it from filling up the numerous sloughs through which it traverses in this area. Even in low-water years a continuous flow of about 10 second-feet reaches Mud Lake through the spring-fed creek that would be deepened by drain C. Near the head of this creek, in sec. 26, T. 7 N., R. 35 E., artesian flows should be obtained.

Drain D would simply require the cleaning out of Camas Creek to Rays Lake. A short lateral drain could be excavated into sec. 26, T. 7 N., R. 35 E., if drain C did not effectively remove all the water in this area. Drain C would deliver the water of Rays and Sandhole Lakes and should recover considerable water that would otherwise be lost by evaporation and transpiration. From the information at hand it seems advisable to have drain D divide into two forks in Rays Lake, one going northeast and draining the sloughs near Hamer and the other north, as shown on plate 13. Drain D should develop considerable ground water in addition to conserving the surface water that will otherwise be dissipated by evaporation and transpiration. It would pass by well 274, which obtained a good flow at 91 feet.

Both of the two last-mentioned drains would interfere with the Hamer Feeder and Rays Lake pumping projects, and the cooperation of those interested in these projects would have to be enlisted to prevent legal entanglements. Drain C would have the advantage of shortening the channel of Camas Creek. Drain D would pass through two large lakes and an explored artesian locality. Furthermore, if the proposed project of bringing water from the Henrys Fork to Mud Lake should be carried out, drain D could be utilized as part of the canal between Henrys Fork and Mud Lake.

The proposed system of drains and artesian wells would have the advantage of delivering the water obtained into Mud Lake by gravity, thereby requiring only the present pumping equipment. However, in wet years, when the water is not needed, the drains would deplete the underground storage unless the wells were capped and check gates were placed at intervals in the drains so that their flow could be arrested. Moreover, the pressure head on the flowing wells is so slight that their yield might diminish greatly with use. The cost of excavating the drains and drilling the wells would be considerable, and it might therefore prove more economical to pump from wells. The water table could be lowered more by pumping from wells than by the use of drains and flowing wells. Hence, to a greater extent, water would be withdrawn only as needed, there would be a minimum of waste, and more underground storage capacity would be made available for the surplus water of wet years. Moreover, a greater amount of the leakage out of the basin would be salvaged. Electric rates for pumping water for irrigation are sufficiently low to make the pumping method appear feasible. If the water were withdrawn from the underground reservoir only as needed and were conducted across Mud Lake by canals to the points of diversion, the loss by evaporation from the lake would largely be prevented.

More or less following out the oral recommendations made by the senior author to various Mud Lake water users from 1928 to 1930, developments by drains and artesian wells progressed considerably during 1931 and 1932. As has already been explained, such developments will result in a decrease in the natural flow of Camas Creek into Mud Lake, and the contribution from the wells and drains will only in part represent an additional water supply. Provision should be made for tight checks in the drain ditches and for capping the artesian wells, so that the diversions from the underground reservoir can be efficiently regulated and, at least in years of plentiful supply, the ground water can be withheld from freely flowing into the lake. Provision might well be made so that in years of abundant run-off water could be held in the Lone Pine Reservoir for percolation into the underground reservoir.

The interrelations between the natural ground-water flow and natural subirrigation that has existed in the past and the inflow of water developed from drains and wells are such that some unification or merging of existing water rights would be desirable in order to prevent possible litigation over the effects of the development by drains and wells.

The maximum yearly diversion from Mud Lake was 44,680 acre-feet, in 1923. Thereafter diversions declined until they were only 23,837 acre-feet in 1931, but they increased again in 1932 to 36,331 acre-feet. Without regulation the available supply for Mud Lake will vary from year to year with the run-off from Beaver and Camas Creeks, and when a series of years of heavy precipitation, such as those from 1907 to 1918, again occurs the conditions in the high-water years of 1921 to 1923 will no doubt recur. If, however, an effective system is installed and wisely operated for utilizing the storage capacity of the underground reservoir and regulating diversions from it, the high-water conditions of peak years will be avoided and the supplies available in dry years will be substantially increased

WELL TABLE

The following table gives a list of the wells, showing number, location, and owner. Records of these wells, identified by location and owner, have been published in Water Supply-Paper 775.

Wells in Mud Lake Basin

[See plate 12]

Well no.	Location: Quarter	Section	Township N.	Range E.	Owner
1	NE¼NW¼	6	5	40	Alexander Erickson.
2	NW¼NW¼	23	5	40	F. W. Webster.
3	NW¼SW¼	26	5	40	Ed. Swenson.
4	SW¼SW¼	29	5	40	W. W. Fyfe.
5	SW¼SW¼	30	5	40	Seth Grover.
6	NE¼SE¼	31	5	40	Cheese Factory.
7	NE¼NW¼	31	5	40	Clifford Grover.
8	NE¼SW¼	31	5	40	Henry Whittaker.
9	NE¼SW¼	32	5	40	R. A. Young.
10	SW¼SW¼	33	5	40	Mrs. Jackson.
11	NW¼NE¼	34	5	40	Will Grover.
12	SW¼NW¼	32	5	41	John Thompson.
13	SW¼NE¼	7	5	39	—— Pelton.
14	SE¼SE¼	8	5	39	—— Birhoff.
15	SW¼SE¼	8	5	39	V. Corey.
16	SE¼SE¼	9	5	39	Bee Hive Well.
17	SW¼NE¼	10	5	39	T. E. Smith.
18	SW¼SE¼	10	5	39	J. Thompson.
19	SW¼NW¼	11	5	39	T. E. Smith.
20	NW¼NW¼	11	5	39	Thomas Smith.
21	SW¼NW¼	12	5	39	C. B. Briggs.
22	NE¼SE¼	12	5	39	—— Peost.
23	NE¼SW¼	13	5	39	—— Fixstead.
24	NW¼SE¼	13	5	39	G. S. Arnold.
25	SE¼NE¼	15	5	39	Thomas Kington.
26	NW¼NW¼	15	5	39	—— Olsen.
27	NW¼SW¼	16	5	39	J. L. Jones.
28	SE¼SE¼	16	5	39	D. A. Spaulding.
29	NE¼NE¼	16	5	39	—— Hansen.
30	NW¼NW¼	17	5	39	—— Jones.
31	NE¼NW¼	21	5	39	Mrs. Clark.
32	NW¼NE¼	22	5	39	A. M. Anderson.
33	NW¼NW¼	23	5	39	—— Thornton Well.
34	SE¼SE¼	23	5	39	John Reed.
35	SE¼NW¼	24	5	39	Frank Sharp.
36	NE¼NW¼	25	5	39	—— Simmons.
37	SE¼NW¼	26	5	39	J. R. Nelson.
38	SE¼SW¼	27	5	39	J. D. Nelson.
39	SW¼SW¼	27	5	39	Ed Hill.
40	SE¼SE¼	27	5	39	Hill & Pettinger.
41	SE¼SW¼	30	5	39	Rufus Cole.
42	NE¼NW¼	32	5	39	John Kearney.
43	SW¼SW¼	32	5	39	J. Blogett.
44	SW¼NE¼	33	5	39	Lorenzo Store.
45	NE¼SE¼	36	5	39	Charles Burns.
46	SE¼SE¼	36	5	39	Robert McIntyre.
47	NE¼NE¼	36	5	39	—— Carlson.
48	NW¼NW¼	36	5	39	Joel Robison.
49	SE¼SE¼	1	5	38	D. Gold.
50	NW¼SE¼	4	5	38	Oscar Nelson.
51	SE¼SE¼	9	5	38	Clarence Hart.
52	NE¼NW¼	15	5	38	Martin Freidell.
53	SE¼SE¼	16	5	38	B. A. Tanner.
54	SW¼SW¼	20	5	38	—— Youngstrum.
55	SW¼SE¼	20	5	38	C. S. Owen
56	SE¼SE¼	20	5	38	E. M. Staker.
57	SE¼SE¼	21	5	38	Railroad Well.
58	SE¼SW¼	25	5	38	S. Olsen.
59	NW¼SW¼	27	5	38	D. A. Casper.
60	SE¼NE¼	31	5	38	J. W. Hart.
61	NW¼SW¼	33	5	38	—— Poole.
62	NE¼SW¼	33	5	38	Menan Cash Store.
63	NE¼NW¼	34	5	38	Roy Wright.
64	NW¼NE¼	35	5	38	—— Hardy.
65	NW¼NW¼	35	5	38	Lucy V. Scott.
66	NE¼SW¼	35	5	38	Mary E. Scott.
67	SW¼SW¼	8	5	37	Dr. E. D. Jones.
68	SE¼SW¼	9	5	37	Verne Crystal.
69	SW¼NW¼	17	5	37	Shepherd Investment Co.
70	NE¼SW¼	20	5	37	L. A. Green.
71	SW¼SW¼	21	5	37	A. F. Tomchak.
72	SW¼SW¼	29	5	37	C. Lapacak.
73	SE¼NW¼	29	5	37	N. Borgraff.
74	SW¼SW¼	30	5	37	Y. A. Roberts.
75	NE¼NE¼	31	5	37	Charles Hooper.
76	SE¼NE¼	32	5	37	Oregon Short Line R. R.
77	NE¼SW¼	32	5	37	Durward Fry.
78	NW¼NW¼	33	5	37	W. Polson.
79	NW¼NE¼	1	5	36	Shepherd Investment Co.
79a	SW¼SW¼	36	6	36	Do.
79b	SW¼SE¼	35	6	36	Do.
80	NW¼SW¼	1	5	36	Do.
81	NE¼SE¼	10	5	36	A. I. Harris.
82	NW¼NW¼	12	5	36	Shepherd Investment Co.
83	SW¼NW¼	12	5	36	Do.
84	NE¼NE¼	12	5	36	
85	SE¼NE¼	14	5	36	R. O. Robinson.
86	NE¼NE¼	22	5	36	Al. Dunsmoor.
87	SE¼SW¼	23	5	36	Do.
88	SW¼NW¼	23	5	36	Do.
89	NW¼NE¼	24	5	36	T. Newnahm.
90	NW¼NE¼	24	5	36	Do.
91	SW¼NW¼	24	5	36	H. E. Dunsmoor.
92	NW¼NE¼	25	5	36	J. T. Doyle.

Wells in Mud Lake Basin—Continued

[See plate 12]

Well no.	Location: Quarter	Section	Township N.	Range E.	Owner
93	NE¼SE¼	25	5	36	G. Gilchrist.
94	SE¼NE¼	26	5	36	Weber & Kienlen.
95	NE¼NW¼	35	5	36	M. Waight.
96	SE¼NE¼	35	5	36	E. Behrens.
97	SE¼NW¼	4	5	35	F. W. Kiefer.
98	NW¼NE¼	2	6	41	Ernest Andrews.
99	NW¼NW¼	5	6	41	J. R. Thompson.
100	SW¼SW¼	7	6	41	G. W. McKinley.
101	SE¼SE¼	9	6	41	H. L. Treman.
102	SE¼NW¼	30	6	41	E. A. Beasley.
103	NE¼SE¼	1	6	40	Fred Hines.
104	SW¼SW¼	1	6	40	John Ricks.
105	SW¼SW¼	3	6	40	Edward Lewis.
106	SW¼SW¼	7	6	40	H. C. Hansen.
107	NE¼NE¼	7	6	40	H. C. Hegsted.
108	NW¼NW¼	9	6	40	—— Roberts?
109	NE¼NW¼	13	6	40	Henry Garn.
110	NE¼SW¼	14	6	40	Do.
111	NE¼NE¼	15	6	40	M. L. Nave.
112	NE¼NE¼	16	6	40	E. L. Evans.
113	SW¼SW¼	16	6	40	Anna Parker.
114	SW¼NW¼	17	6	40	Milton Mangum.
115	SE¼NE¼	17	6	40	R. N. Jeppesen.
116	NE¼NE¼	17	6	40	Don Fram.
117	NE¼NW¼	18	6	40	Mrs. John Long.
118	NW¼NW¼	22	6	40	Leo J. Hoskinson.
119	NE¼NE¼	22	6	40	D. W. Stowe.
120	NE¼SW¼	35	6	40	Harvey Summers.
121	NE¼NE¼	2	6	39	B. J. Lavery.
122	SE¼SW¼	3	6	39	George Mortimer.
123	SE¼SW¼	6	6	39	G. E. Burrell.
124	NW¼NE¼	7	6	39	E. Perrenoud.
125	SE¼NE¼	7	6	39	J. A. White.
126	SE¼SE¼	7	6	39	Lyman Lake.
127	NW¼SW¼	10	6	39	David Rock.
128	NE¼SE¼	11	6	39	William Lutz.
129	NE¼NE¼	12	6	39	Will Hope.
130	SE¼NE¼	15	6	39	J. Hendricks.
131	SE¼	19	6	39	
132	NE¼SE¼	22	6	39	N. Smith.
133	SE¼SW¼	24	6	39	G. Webber.
134	SE¼SE¼	25	6	39	Gottlieb Rufi.
135	SW¼SE¼	26	6	39	Nephi Larson.
136	SE¼SW¼	26	6	39	—— Wynn.
137	NE¼NW¼	28	6	39	Thomas Siepert.
138	NE¼SE¼	36	6	39	John Parmer.
139	NW¼SW¼	3	6	38	Jolly, Hilton & Hanson.
140	SW¼	17	6	38	John Farnes.
141	SW¼	33	6	38	Mrs. A. Gohr.
142	NE¼NE¼	35	6	38	Louise Carter.
143	NE¼NE¼	35	6	38	Do.
144	--------------	21	6	37	S. O. Green.
145	SE¼SE¼	29	6	37	C. A. Randall.
146	SE¼SW¼	12	6	36	Alma Bird.
147	NE¼NW¼	6	6	36	O. E. Peterson.
148	NE¼NE¼	1	6	35	V. P. Peterson.
149	NE¼NW¼	3	6	35	C. O. McGill.
150	NE¼NW¼	9	6	35	E. L. Wiley.
151	SE¼NW¼	9	6	35	M. M. Owsley.
152	SW¼SW¼	10	6	35	W. H. Hutchinson.
153	NE¼SE¼	12	6	35	E. P. Jensen.
154	SW¼NW¼	17	6	35	Charles Onken.
155	SE¼SW¼	18	6	35	C. A. Olsen.
156	NW¼NW¼	23	6	35	J. F. Hart.
157	SE¼NE¼	30	6	35	J. J. Tierney.
158	NW¼NW¼	4	6	34	M. E. Staley.
159	SW¼SE¼	5	6	34	W. A. Schuldberg.
160	SE¼NE¼	7	6	34	Girard & Hutton.
161	NW¼NW¼	8	6	34	R. A. Hansen.
162	NE¼NW¼	8	6	34	V. L. Johnson.
163	NW¼NE¼	8	6	34	J. Keller.

Well no.	Location: Quarter	Section	Township N.	Range E.	Owner
164	SE¼SE¼	8	6	34	L. C. Lily.
165	SW¼SE¼	9	6	34	J. B. Kyte.
166	NE¼NE¼	13	6	34	J. A. Melton.
167	NE¼NE¼	15	6	34	John T. Sykes.
168	SE¼NW¼	15	6	34	A. Miller.
169	SE¼SW¼	15	6	34	Edwin Cutler.
170	SW¼SE¼	16	6	34	Pingree Land.
171	NW¼NE¼	17	6	34	A. E. Bolenger.
172	NW¼SW¼	18	6	34	R. Comstock.
173	SW¼SW¼	25	6	34	John Quale.
174	NE¼NE¼	29	6	34	Spidel & Rickman.
175	NW¼NW¼	35	6	34	John Kurd.
176	NE¼NE¼	3	6	33	W. Yoerty.
177	NW¼NE¼	15	6	33	A. D. Melton.
178	SE¼NE¼	36	6	36	Second Owsley.
179	SE¼	32	6	31	Charles Holland.
180	SW¼	33	6	31	Do.
181	SW¼NW¼	3	7	41	F. M. Hobbs.
182	NE¼SE¼	5	7	41	W. S. Stalker.
183	NW¼NW¼	5	7	41	Thomas Smith.
184	SE¼SW¼	6	7	41	Mrs. F. Murrey.
185	SW¼SW¼	6	7	41	J. F. Butler.
186	SE¼SW¼	8	7	41	S. Swensen.
187	SW¼SE¼	9	7	41	R. W. Hill.
188	NW¼NE¼	14	7	41	J. J. Reynolds.
189	SW¼SW¼	16	7	41	Joe Gould.
190	SW¼SE¼	18	7	41	A. M. Davis.
191	NW¼NE¼	20	7	41	M. P. Nybord.
192	NE¼NE¼	20	7	41	C. W. Daw.
193	SW¼SE¼	22	7	41	P. Butler.
194	NW¼SW¼	30	7	41	Melvin Birch.
195	SE¼SW¼	31	7	41	J. F. Bird.
196	NE¼NE¼	2	7	40	Walter Olsen.
197	NE¼NE¼	8	7	40	H. C. Rice.
198	SW¼SE¼	10	7	40	R. V. Birch.
199	SE¼SE¼	11	7	40	J. T. Birch.
200	SE¼SE¼	12	7	40	Mrs. Ralph Murri.
201	NE¼NE¼	15	7	40	A. C. Jacobs.
202	NE¼NE¼	18	7	40	
203	SE¼SE¼	19	7	40	J. P. Jensen.
204	SW¼NW¼	20	7	40	Alice Roylance.
205	NE¼SE¼	21	7	40	Tom Morfield.
206	NE¼NE¼	22	7	40	Harry Wright.
207	SE¼SE¼	22	7	40	N. C. Blow.
208	NE¼NE¼	26	7	40	E. W. Johnson.
209	SE¼SE¼	26	7	40	Conrad Bower.
210	SE¼SE¼	27	7	40	Mrs. S. A. White.
211	NE¼NW¼	28	7	40	—— Sheldon.
212	SE¼SE¼	29	7	40	C. C. Childs.
213	SW¼SW¼	29	7	40	W. J. Lavley.
214	NE¼SE¼	30	7	40	Schoolhouse.
215	NW¼NW¼	32	7	40	W. J. Lavley.
216	SE¼SE¼	33	7	40	C. Haynes.
217	SE¼SE¼	34	7	40	W. A. Pincock.
218	NE¼NE¼	1	7	39	
219	SE¼SE¼	8	7	39	John Wilcox.
220	SW¼SE¼	12	7	39	Annie Smith.
221	NE¼NE¼	13	7	39	W. M. Ericson.
222	SW¼SW¼	13	7	39	Thomas Ball.
223	NE¼NE¼	16	7	39	J. H. Powell.
224	SW¼NW¼	16	7	39	D. Rydalch.
225	NE¼NE¼	17	7	39	T. Parkinson.
226	SE¼SE¼	18	7	39	E. G. Davis.
227	SW¼SW¼	19	7	39	—— Bowerman.
228	SE¼NE¼	19	7	39	Fred Davis.
229	SE¼SE¼	19	7	39	R. Hilman.
230	SE¼SE¼	20	7	39	S. G. Chandler.
231	NW¼NW¼	22	7	39	C. H. DeCamp.
232	NE¼NE¼	22	7	39	Jos. Johanson.
233	NW¼NW¼	23	7	39	Mrs. E. Blake.
234	NW¼SW¼	27	7	39	John Harmon.
235	NE¼NE¼	31	7	39	N. Robertson.

Wells in Mud Lake Basin—Continued

[See plate 12]

Well no.	Location: Quarter	Location: Section	Location: Township N.	Location: Range E.	Owner
236	SE¼SE¼	31	7	39	Jos. Brown.
237	NE¼NE¼	32	7	39	J. Jackson.
238	NE¼NW¼	33	7	39	Do.
239	NE¼NW¼	16	7	38	U. S. Geological Survey.
240	SE¼SE¼	32	7	38	August Nelson.
241	NW¼SW¼	34	7	38	
242	NE¼NW¼	4	7	37	William Harvey.
243	NW¼SW¼	5	7	37	J. R. Raumaker.
244	SW¼SE¼	7	7	37	M. Gerber.
245	SW¼NW¼	10	7	37	William Tarbut.
246	NW¼SW¼	14	7	37	Raumaker & Hable.
247	NW¼SE¼	18	7	37	L. Wall.
248		22	7	37	William Harvey.
249	SW¼NE¼	24	7	37	G. A. Garner.
250	NE¼NW¼	28	7	37	Fred Gerber.
251	SW¼SW¼	1	7	36	E. Holman.
252	NE¼NE¼	4	7	36	—— Thiessen.
253	NE¼SW¼	4	7	36	John Terry.
254	NW¼SE¼	4	7	36	Guy Powell.
255	SE¼NE¼	5	7	36	Andrew Killion.
256	NW¼SE¼	5	7	36	C. E. Bramwell.
257	NE¼SE¼	6	7	36	S. E. Brown.
258	NW¼NE¼	6	7	36	W. S. Lair.
259	SE¼NW¼	6	7	36	Ray Bohney.
260	NW¼NE¼	8	7	36	Wood Livestock Co.
261	NE¼NW¼	9	7	36	R. E. Hartwell.
262	NE¼NW¼	9	7	36	C. A. Perkins.
263	SE¼SE¼	10	7	36	Ed Blakey.
264	NW¼NE¼	11	7	36	M. Turman.
265	SE¼NE¼	12	7	36	Do.
266	SW¼NE¼	13	7	36	T. Turman.
267	SW¼NW¼	14	7	36	Hamer Canal Co.
268	SW¼NW¼	14	7	36	Do.
269	SW¼NW¼	14	7	36	Do.
270	NE¼SW¼	14	7	36	Do.
271	NW¼SE¼	14	7	36	Do.
272	SW¼NW¼	14	7	36	Do.
273	SW¼SW¼	20	7	36	R. D. Clinton.
274	SW¼SW¼	20	7	36	Do.
275	NE¼NE¼	21	7	36	Turman Co.
276	SW¼NW¼	21	7	36	J. S. Landon.
277	SW¼SW¼	22	7	36	A. Hanny.
278	NE¼NE¼	22	7	36	J. Winchester.
279	NE¼NW¼	22	7	36	William Rush.
280	SE¼SE¼	22	7	36	J. Hyland.
281	NE¼SE¼	22	7	36	J. Milborn.
282	SW¼NE¼	22	7	36	J. Turman.
283	NW¼NE¼	22	7	36	C. H. Turman.
284	NE¼NE¼	23	7	36	Do.
285	NE¼NW¼	14	7	36	H. Long.
286	SW¼NE¼	22	7	36	Town of Hamer.
287	NW¼NW¼	24	7	36	Otto Gross.
288	NW¼NW¼	24	7	36	W. Bashore.
289	SW¼SE¼	26	7	36	E. Jensen.
290	SW¼SE¼	26	7	36	Do.
291	NW¼SW¼	26	7	36	J. W. Polson.
292	SW¼NW¼	26	7	36	L. E. Addell.
293	SE¼NE¼	27	7	36	F. H. Churchill.
294	SW¼SW¼	27	7	36	H. Curtis.
295	NW¼SE¼	29	7	36	H. Ricks, Jr.
296	NE¼NE¼	31	7	36	B. Woodard.
297	NE¼NW¼	35	7	36	C. Churchill.
298	SE¼NE¼	36	7	36	C. A. Randall.
299	NW¼SW¼	18	7	35	T. D. Scody.
300	NE¼NW¼	19	7	35	—— Johnson.
301	SW¼NW¼	20	7	35	
302	SW¼NW¼	17	7	34	P. Kuhaski.
303	NW¼NW¼	19	7	34	T. Wagner.
304	NW¼NE¼	19	7	34	A. Mitchell.
305	NE¼NW¼	20	7	34	Do.
306	NE¼NW¼	20	7	34	Do.
307	NE¼SE¼	29	7	34	J. Hanson.
308	SW¼NE¼	29	7	34	C. Nordstrom.
309	SW¼NW¼	29	7	34	M. F. Munsey.
310	NE¼SW¼	30	7	34	Charles Kelch.
311	SW¼SW¼	31	7	34	M. K. Thompson.
312	NW¼NE¼	32	7	34	L. Ferusi.
313	SE¼NE¼	32	7	34	T. A. Jackson.
314	SE¼SE¼	32	7	34	G. Welchman.
315	NW¼NE¼	1	7	33	S. Leek, Jr.
316	NW¼NE¼	1	7	33	Do.
317	SW¼SW¼	1	7	33	Spring Lake School.
318	SE¼NE¼	2	7	33	William Miller.
319	SE¼SW¼	2	7	33	T. H. Winder.
320	NE¼NE¼	3	7	33	E. C. Griffin.
321	NE¼SE¼	3	7	33	E. Hohle.
322	SE¼SE¼	3	7	33	Do.
323	SE¼SW¼	3	7	33	Fred Correll.
324	NE¼SW¼	10	7	33	Mike Rowen.
325	NE¼SW¼	10	7	33	Luke Rowen.
326	SW¼NW¼	11	7	33	J. Rowen estate.
327	NW¼SW¼	11	7	33	
328	NW¼SW¼	12	7	33	E. T. Miller.
329	NW¼NE¼	12	7	33	Walter Hicks.
330	SE¼SE¼	13	7	33	Wagner School.
331	SE¼SW¼	13	7	33	P. A. King.
332	NW¼SE¼	13	7	33	C. P. Ouldhouse.
333	SE¼NE¼	14	7	33	B. Connell.
334	SE¼SE¼	14	7	33	F. Holtmeyer.
335	SW¼SW¼	14	7	33	H. Schnavley.
336	NW¼SW¼	14	7	33	Guarantee Trust Co.
337	SE¼NW¼	15	7	33	I. Schnavley.
338	NE¼NE¼	21	7	33	—— Levy.
339	NE¼NW¼	21	7	33	E. Watts.
340	NE¼NW¼	22	7	33	N. Konen.
341	NE¼SW¼	22	7	33	C. Rudershausen.
342	NW¼SE¼	22	7	33	O. Swift.
343	SW¼SW¼	23	7	33	G. Winder.
344	SW¼SW¼	23	7	33	Do.
345	SE¼NE¼	23	7	33	W. Czarnecki.
346	SW¼NE¼	24	7	33	P. McKevitt.
347	NW¼NW¼	25	7	33	O. Lotrich.
348	SE¼SW¼	25	7	33	—— O'Briens?
349	NE¼SW¼	27	7	33	S. Horsman.
350	NW¼NE¼	34	7	33	G. Van Houten.
351	SE¼NE¼	34	7	33	H. Mitchell.
352	NE¼NE¼	4	8	44	Fred J. Lenz.
353	SW¼SW¼	8	8	44	Squirrel Store.
354	NW¼NW¼	15	8	44	
355	SE¼SE¼	2	8	43	
356	NW¼NW¼	6	8	43	J. E. Taylor.
357	SW¼NW¼	7	8	43	Abe Casey.
358	NE¼NE¼	7	8	43	—— Thompson.
359	SW¼SW¼	11	8	43	J. M. Andersen.
360	NW¼NW¼	20	8	43	Allan Hendrickson.
361	SE¼SW¼	23	8	43	George Thorsted.
362	NW¼NE¼	28	8	43	
363	NE¼NW¼	29	8	43	Walter Brett.
364	NE¼SE¼	4	8	42	R. W. Honess.
365	SW¼SW¼	5	8	42	A. P. Free.
366	NE¼NE¼	6	8	42	R. A. Fuqua.
367	NE¼SE¼	7	8	42	—— Wood.
368	SE¼NE¼	8	8	42	B. M. Wood.
369	NE¼NW¼	10	8	42	L. H. Sheetz.
370	NE¼NE¼	10	8	42	C. I. Brown.
371	NW¼NW¼	12	8	42	Mark White.
372	SE¼NE¼	13	8	42	A. J. Sack.
373	NE¼NE¼	14	8	42	Wm. A. Upham
374	SE¼NE¼	15	8	42	R. R. Rankin.
375	SW¼NW¼	17	8	42	—— Farnsworth.
376	SW¼SW¼	19	8	42	E. H. Potter.
377	SE¼SW¼	19	8	42	Joe Campbell.
378	NE¼NE¼	29	8	42	Harry Burt.
379	NE¼SE¼	29	8	42	
380	NW¼NW¼	3	8	41	

Wells in Mud Lake Basin—Continued

[See plate 12]

Well no.	Location: Quarter	Section	Township N.	Range E.	Owner
381	NE¼SE¼	4	8	41	
382	NW¼SE¼	12	8	41	Fred Eckman.
383	SW¼SW¼	13	8	41	T. Winters.
384	NW¼SW¼	21	8	41	H. L. Olsen.
390	SE¼SE¼	23	8	41	O. W. Winters.
391	SE¼NE¼	23	8	41	C. E. Seeley.
392	SE¼NE¼	24	8	41	P. P. Worrell.
393	SW¼NW¼	25	8	41	Byron Blanchard.
394	SW¼SW¼	27	8	41	F. Mayne.
395	NE¼NE¼	27	8	41	George Busby.
396	NE¼	32	8	41	Edward Frok.
397	NE¼NW¼	1	8	40	E. Ricks.
398	SE¼NE¼	6	8	40	J. Rudd.
399	SE¼SE¼	25	8	40	
400	SW¼NW¼	27	8	40	E. Gould.
401	SW¼SW¼	29	8	40	George Ricks.
402	SW¼SW¼	31	8	40	W. A. Ritchell.
403	SW¼SW¼	33	8	40	G. Rickman.
404	SE¼SE¼	33	8	40	—— Jackson
405	SE¼NE¼	33	8	40	Peter Schaat.
406	SW¼SE¼	34	8	40	J. L. Sorensen.
407	SE¼SW¼	34	8	40	Do.
408	SW¼SE¼	34	8	40	P. Fletcher.
409	NW¼NE¼	14	8	39	R. Holcomb.
410	NW¼SW¼	2	8	38	Ed Tuck.
411	NW¼SW¼	18	8	38	Roy Brown.
412	NE¼NE¼	31	8	38	McGeary & Hillman.
413	SW¼NW¼	19	8	37	O. Hughes.
414	NW¼NW¼	20	8	37	F. Spaulding.
415	SE¼SE¼	22	8	37	Do.
416	SW¼NW¼	24	8	37	S. E. Brown.
417	SW¼NE¼	26	8	37	A. E. Bramwell.
418	NW¼NW¼	26	8	37	H. T. Bigler.
419	SE¼SW¼	32	8	37	J. Woods.
420	NE¼NW¼	34	8	37	R. W. Jackson.
421	SE¼SE¼	35	8	37	H. Dudley.
422	SE¼NW¼	4	8	36	S. Farnesworth.
423	SE¼SE¼	5	8	36	Mike Bisko.
424	NE¼SE¼	9	8	36	Hannigen & Rausch
425	SW¼SE¼	11	8	36	E. C. Richards.
426	SE¼SE¼	13	8	36	A. Hughes.
427	SW¼SW¼	13	8	36	D. Mahan.
428	SW¼NE¼	14	8	36	Martin Nave.
429	SW¼SW¼	15	8	36	B. F. Johnson.
430	SW¼SE¼	16	8	36	C. O'Toole.
431	NE¼NE¼	20	8	36	G. E. Weber.
432	SE¼NW¼	21	8	36	J. Blackburn.
433	NW¼SE¼	21	8	36	J. Hendrickson.
434	NE¼SE¼	21	8	36	Camas School.
435	SE¼NE¼	21	8	36	J. L. Hoffman.
436	NE¼NE¼	22	8	36	C. L. Sharp.
437	SW¼SW¼	23	8	36	M. C. Pratt.
438	NE¼SE¼	24	8	35	J. Fiedrow.
439	SW¼NW¼	24	8	36	R. Tolman.
440	NW¼NE¼	24	8	36	F. Edwards.
441	NW¼NW¼	25	8	36	William Somers.
442	NW¼NE¼	26	8	36	A. R. Young.
443	NW¼NW¼	26	8	36	E. E. Clasen.
444	NE¼NE¼	27	8	36	J. Hendrickson.
445	NW¼NW¼	27	8	36	R. L. Jolly.
446	SE¼SW¼	27	8	36	C. Wiberg.
447	SE¼SE¼	28	8	36	P. Stephenson.
448	NE¼NE¼	33	8	36	R. Bloom.
449	NE¼SE¼	33	8	36	B. W. Osborne.
450	SW¼SE¼	34	8	36	D. Poetker.
451	NW¼NW¼	35	8	36	F. Rose.
452	NE¼NE¼	35	8	36	P. Larson.
453	SE¼SE¼	35	8	36	E. Holman.
454	NW¼NW¼	22	8	35	Mr. Nielsen.
455	NE¼NE¼	6	8	34	S. S. Mishler.
456	NW¼NW¼	6	8	34	F. Mishler.
457	SE¼SE¼	6	8	34	
458	SE¼SW¼	6	8	34	G. Nagley.

Well no.	Location: Quarter	Section	Township N.	Range E.	Owner
459	SE¼NW¼	7	8	34	C. O. Jeffery.
460	SW¼SE¼	8	8	34	J. Johnson.
461	SW¼SE¼	17	8	34	J. Skavedahl.
462	NE¼SW¼	17	8	34	Do.
463	NW¼SE¼	17	8	34	John Cline.
464	NW¼NW¼	17	8	34	Harry Bell.
465	NW¼NE¼	18	8	34	J. Gillam.
466	NE¼NW¼	18	8	34	William Walters.
467	SE¼SE¼	19	8	34	W. Ludke.
468	SW¼NE¼	20	8	34	Fred Rising.
469	NE¼NE¼	20	8	34	A. A. Rising.
470	NW¼NE¼	29	8	34	Charles Rising.
471	NE¼NE¼	30	8	34	Roy Hare.
472	NW¼SW¼	30	8	34	J. Thornton.
473	SE¼SE¼	1	8	33	Ed. McFarlane.
474	SE¼SW¼	1	8	33	J. W. Ludke.
475	SE¼SE¼	2	8	33	G. Campbell.
476	SE¼NE¼	3	8	33	—— Stockbridge.
477	SE¼SE¼	3	8	33	George Boshert.
478	NW¼NW¼	6	8	33	—— Nixon.
479	NE¼NW¼	7	8	33	F. Reno.
480	SE¼NE¼	9	8	33	
481	SE¼SW¼	10	8	33	
482	NW¼NE¼	10	8	33	
483	SE¼SE¼	10	8	33	
484	SW¼SE¼	11	8	33	
485	SE¼SE¼	11	8	33	Guarantee Trust Co.
486	SE¼NE¼	12	8	33	P. Jeffery.
487	SW¼SE¼	13	8	33	E. Massingale.
488	NE¼SE¼	14	8	33	M. G. Munsey.
489	NE¼NE¼	14	8	33	M. Munsey.
490	SW¼SW¼	24	8	33	G. C. Gulick.
491	SE¼SE¼	24	8	33	R. French.
492	NE¼NW¼	25	8	33	A. Barrett.
493	SW¼SE¼	25	8	33	Chris Rapp.
494	NW¼SW¼	25	8	33	A. Nielson.
495	SE¼SE¼	26	8	33	Do.
496	NE¼NE¼	26	8	33	A. Hickman.
497	NW¼SW¼	26	8	33	Mrs. S. Werts.
498	NE¼NW¼	26	8	33	M. Langren.
499	NW¼NE¼	26	8	33	C. Hickman.
500	NE¼NE¼	14	8	31	J. F. Reno.
501	SW¼SE¼	18	9	44	
502	SW¼NW¼	20	9	44	
503	SW¼SW¼	21	9	44	Fred Hossner.
504	SE¼SW¼	22	9	44	W. L. Chittock.
505	S½SW¼	32	9	44	I. F. Lenz.
506	SW¼NW¼	19	9	43	—— Strum.
507	NW¼SW¼	20	9	43	A. B. Hillam.
508	NE¼SE¼	21	9	43	
509	SE¼NW¼	23	9	43	F. J. Francis.
510	SE¼SE¼	25	9	43	William Atley.
511	SW¼SE¼	26	9	43	Jess. L. Colwell.
512	NE¼NW¼	28	9	43	—— Wood.
513	NE¼NE¼	29	9	43	W. H. McCormick.
514	SE¼SE¼	29	9	43	William Baum.
515	NE¼NW¼	31	9	43	L. K. Kappelman.
516	W½SW¼	32	9	43	—— Heseman.
517	SW¼SW¼	33	9	43	
518	SW¼SW¼	36	9	43	R. Habekost.
519	SE¼SW¼	22	9	42	
520	SE¼SW¼	23	9	42	Paul Thoeson.
521	NW¼SE¼	25	9	42	
522	SW¼SE¼	26	9	42	
523	NW¼NE¼	27	9	42	
524	SE¼NW¼	27	9	42	—— Williams.
525	SW¼SW¼	28	9	42	W. H. Pierce.
526	SE¼NW¼	28	9	42	E. E. Pence.
527	SE¼SE¼	28	9	42	Barney Andresen.
528	NW¼NW¼	32	9	42	E. M. Bowman.
529	SE¼SE¼	33	9	42	—— Bonneru.
530	NE¼SW¼	35	9	41	J. McQuarter.
531	NE¼NE¼	23	9	40	H. S. Miller.

Wells in Mud Lake Basin—Continued

[See plate 12]

Well no.	Location				Owner	Well no.	Location				Owner
	Quarter	Section	Township N.	Range E.			Quarter	Section	Township N.	Range E.	
532	NE¼NE¼	4	9	39	Sheep Association.	570	SE¼SE¼	23	9	33	Harry Taylor.
533	SE¼SW¼	33	9	39	H. E. Jenkins.	571	NE¼NW¼	24	9	33	William Hankins.
434	NE¼NE¼	35	9	39	Sam E. Rigby.	572	SE¼NE¼	24	9	33	
535	SW¼SE¼	27	9	38	R. Jenkins.	573	NE¼NE¼	25	9	23	F. D. Hutton.
536	SW¼SW¼	8	9	36	F. L. Roberts.	574	NE¼NW¼	25	9	33	T. Guilfoyle.
537	SE¼SE¼	17	9	36	Mountain View School.	575	SE¼SE¼	34	9	33	Ed. Palmer.
						576	SE¼SW¼	34	9	33	
538	SE¼SW¼	19	9	36	A. Heffel.	577	NW¼SW¼	3	10	42	U.S. Forest Service.
539	NW¼SW¼	22	9	36	B. H. Schmidt.	578	SW¼SW¼	13	10	42	Do.
540	NE¼SE¼	29	9	36	C. C. Koehn.	579	SE¼NE¼	12	10	40	Hamilton Bros.
541	NW¼NW¼	32	9	36	H. Repp.	580	SE¼	14	10	39	S. W. Orme.
542	SW¼SE¼	3	9	35	C. Tiahrt.	581	NE¼SW¼	21	10	36	Oregon Short Line R. R.
543	NE¼SE¼	7	9	35	S. Call.						
544	SE¼NE¼	8	9	35	Dan Madson.	582	NW¼SW¼	21	10	36	City of Dubois.
545	SE¼SW¼	13	9	35	Ben Wibie.	583	SW¼SW¼	21	10	36	Dubois School.
546	NE¼NE¼	24	9	35	Ed Wibie.	584	SE¼NW¼	28	10	36	Laird Bros.
547	SE¼SW¼	35	9	35	P. Butherns.	585	SE¼SE¼	14	10	35	O. C. Brown.
548	NE¼NE¼	3	9	34	J. Dietrich.	586	NW¼NW¼	20	10	35	P. D. Ellis.
549	NE¼NW¼	7	9	34	Winsper post office.	587	NE¼NW¼	20	10	35	B. D. Thomas.
550	SE¼NE¼	7	9	34	Harvey Fry.	588	SW¼	6	11	39	Camas Mutual Irrigation District.
551	NW¼SW¼	8	9	34	J. Fisher.						
552	NE¼SE¼	8	9	34	—— Daniels.	589	NW¼SW¼	1	11	38	H. Heggsted.
553	NE¼NW¼	9	9	34	R. Henderson.	590	NW¼SW¼	9	11	38	T. Morgan.
554	NE¼NW¼	15	9	34	Ed. Swantz.	591	NE¼NE¼	34	11	36	Government Sheep Experiment Station.
555	SE¼SE¼	17	9	34							
556	SW¼SW¼	18	9	34	Ed Gullingson.						
557	NW¼SW¼	19	9	34	—— Holman.	592	NW¼NW¼	9	11	35	J. Rock.
558	NW¼NE¼	20	9	34		593	NW¼NE¼	24	11	35	E. Hardy.
559	SW¼NW¼	21	9	34	Chet Soss.	594	SW¼SW¼	24	11	35	John Cerney.
560	SW¼SW¼	21	9	34	O. Kuhns.	595	NW¼NW¼	24	11	35	C. P. Dasch.
561	NW¼SW¼	28	9	34	—— Smallwood.	596	SE¼SE¼	29	11	35	R. Guaschay.
562	SW¼SW¼	30	9	34	Dan Conrad.	597	SE¼NE¼	29	11	35	Do.
563	NE¼NW¼	31	9	34	Ed Mack.	598	SE¼SE¼	36	11	35	B. Partridge.
564	NE¼SW¼	31	9	34	Do.	599	SE¼SE¼	24	11	34	Ray Stark.
565	SE¼SE¼	31	9	34	J. T. Doyle.	600	SE¼SW¼	8	12	40	Wood Livestock Co.
566	SE¼SW¼	32	9	34	C. Miller.	601	SE¼SE¼	24	12	39	Do.
567	NE¼NE¼	32	9	34	Amos Miller.	602	NW¼SW¼	26	12	38	C. Devaney.
568	NE¼NE¼	12	9	33	G. H. Fry.	603	SW¼	26	13	40	Mary Hunts.
569	SE¼NE¼	13	9	33	G. Wellingson.	604	SE¼NE¼	33	13	40	Wood Livestock Co.

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