PRELIMINARY REPORT ON THE GEOLOGY AND WATER RESOURCES OF THE MUD LAKE BASIN, IDAHO

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INTRODUCTION

LOCATION AND EXTENT OF THE REGION INVESTIGATED

The region covered by this report lies some distance north of Idaho Falls, Idaho. It is approximately bounded on the east and southeast by Henrys Fork and Snake River; on the west by Birch Creek; on the north by the crest of the Rocky Mountains, which form the Continental Divide and the north boundary of this part of the State; and on the south by rolling lava plains that terminate the Mud Lake drainage basin. (See Pl. I.) This region is about 80 miles long from east to west, has a maximum width of about 60 miles, and covers approximately 4,000 square miles. It is crossed by the 112th meridian and the 44th parallel and includes all of Clark County and parts of Fremont, Jefferson, Butte, and Lemhi counties. It includes approximately that part of Idaho north of T. 4 N. and between Rs. 30 and 42 E. Boise meridian. Its altitude ranges from about 4,740 feet above sea level along Snake River in the southeast corner of the region to more than 10,000 feet in some of the peaks of the Continental Divide on the north. The altitude of Mud Lake is about 4,780 feet.

The region investigated covers the drainage basin of Mud Lake and such adjacent tracts as were suspected of influencing the surface-water or ground-water supply of this basin.

HISTORY OF THE WATER SUPPLY OF THE REGION

Irrigation was first practiced in this region in the early eighties, when a few scattered hay ranches were being developed along Camas, Beaver, and Medicine Lodge creeks. At that time, according to early inhabitants, Mud Lake was merely a more or less intermittent pond, never covering more than a few hundred acres, whereas Sand Hole Lake, from all known records, never went dry. As early as 1870 a stage station on the route from Salt Lake City to Butte was situated on Sand Hole Lake. About 1895 irrigation began on the terrace southwest of St. Anthony known as Egin

Bench. About 1900, according to F. J. Hagenbarth, of Spencer, Idaho, J. L. Hoffman, of Camas, Idaho, and Frank Reno, of Reno, Idaho, water began to be noticed standing in pools just east of the railroad about 1 mile north of the present site of Hamer.

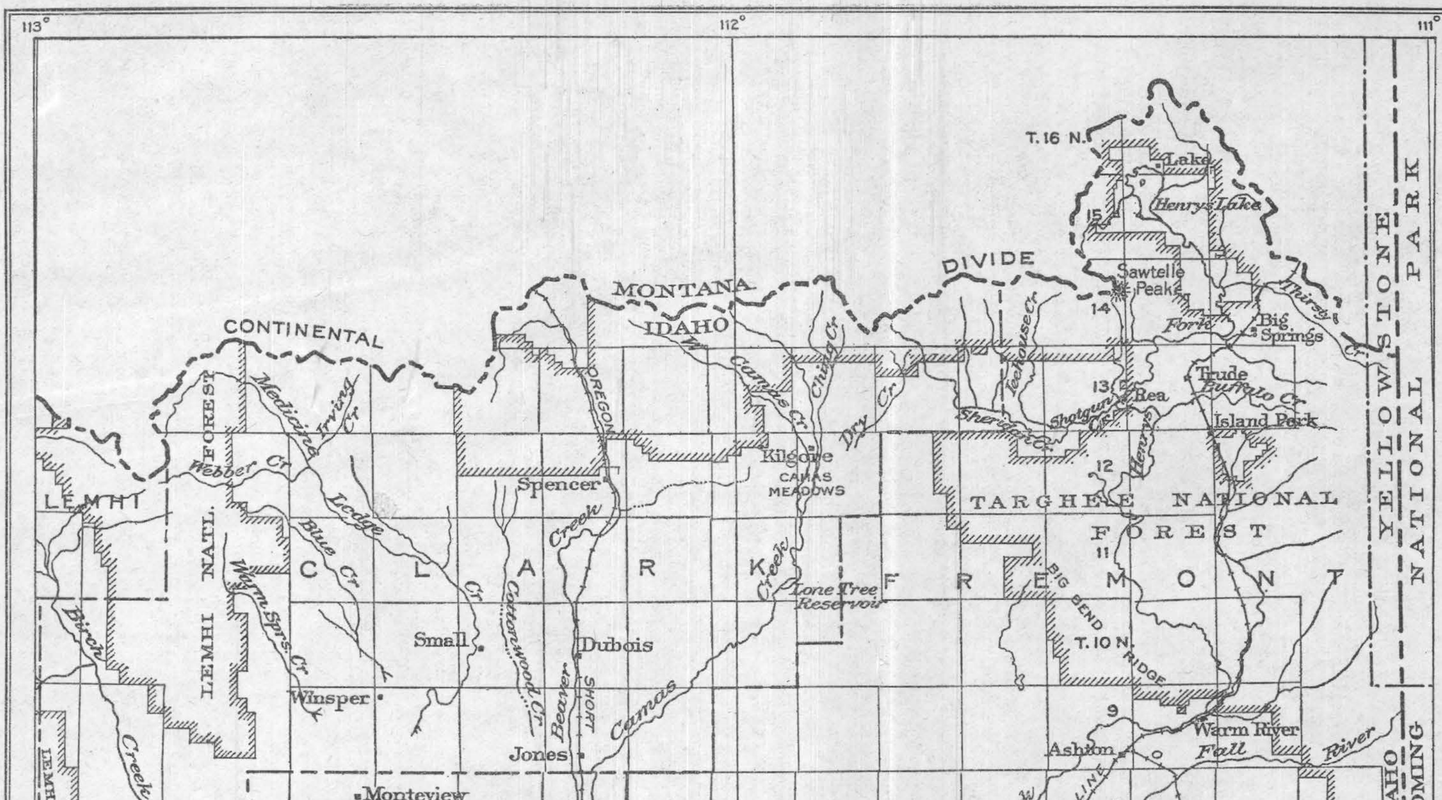
In May and June, 1899, a meander of Mud Lake by the United States General Land Office indicated a water surface of 2,460 acres and dry lake beds to the south and west of Mud Lake occupying approximately 3,000 acres. From 1899 to 1908 the lake rose very little, if at all. In 1908 a survey of the lake made by O. E. Peterson showed practically the same area covered by water as was shown by the survey made by the United States General Land Office 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 approximately 14,200 acres. This is the latest survey of any consequence until the present investigation was commenced. Unfortunately, no gage readings were made prior to 1921 to show the rise and fall of Mud Lake.

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 near-by lakes and sloughs. This acreage was divided among two large Carey Act projects aggregating approximately 30,000 acres and numerous private irrigation enterprises.

PURPOSE AND HISTORY OF THE INVESTIGATION

No thorough investigation of the water supply of the region has hitherto been made. Moreover, in view of the changing conditions caused by the relatively recent rise of the lake and of the surrounding water table, some of the studies and reports that have been made are likely to be misleading. Urgent need for a comprehensive and detailed investigation of the water supply of Mud Lake and the adjacent tracts of small lakes and shallow ground water has been felt for some time to afford a basis for intelligent decision by State and Federal authorities regarding numerous land and water filings that have been made by private and Carey Act irrigation enterprises proposing to obtain their water supplies from Mud Lake or from adjoining water bodies.

To protect investors and settlers it is necessary to know approximately the annual water supply and to limit the amount of land brought under irrigation from this supply. Otherwise there will be overdevelopment, and the water that accumulates in the lake each year will all be diverted before the need for irrigation is over. Thus those holding early rights will be deprived of their legitimate



INDEX MAP SHOWING LOCATION OF MUD LAKE BASIN, IDAHO supply, and the owners of later rights who may likewise have attempted in good faith to reclaim land will also suffer. Estimation of the available annual supply of Mud Lake is peculiarly difficult because of the large amount of ground water which it receives through seepage and because of variations in seepage accretions and evaporation losses with fluctuating levels of the lake and of the ground water. The problem is made more complex by the outstanding fact that within the last 25 years the water supply has notably increased.

On account of these conditions a thorough investigation, including an inventory of the water supply, was necessary in order to appraise the possibilities for reclamation and to take definite and proper action upon the pending questions regarding desert-entry applications and the sale of water rights for the Carey Act lands. This investigation should serve a twofold purpose—it should result in full development of the available water resources and it should protect prospective investors and settlers from financial loss by showing the futility of development where no water supply is available.

Financial support was given to the investigation by the Idaho Department of Reclamation, the United States General Land Office, the Idaho Bureau of Mines and Geology, and the United States Geological Survey. The investigation was conducted under the technical supervision of C. G. Paulsen, district engineer, and O. E. Meinzer, geologist in charge of the ground-water division, both of the Geological Survey. The geologic work was assigned to H. T. Stearns and the hydraulic engineering to L. L. Bryan.

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. 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 detailed geologic map of most of the Mud Lake basin and a reconnaissance geologic map of the rest of the region were made. Many miles of levels were run, and contour maps of the land and of the water table were constructed. With these data the source, movement, and disposal of the ground water were largely determined, and inventories were made of the total water supply of the basin.

In June, 1922, a preliminary report on the region covering the period from April 1, 1921, to March 31, 1922, was made public in mimeographed form. Field work was continued during the summer of 1922, and records of precipitation, evaporation, stream flow, pumpage from the lake, and water levels in wells are still being obtained. A final report on the geology and water supply of the Mud Lake basin is in preparation. The present report is a brief description of the geology and hydrology of the basin, with inventories of its water supply for the years ending March 31, 1922, and March 31, 1923.

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 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 alignment 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 report. 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.

TOPOGRAPHY

The northern part of the region is occupied by the Rocky Mountains. Farther west are the Lemhi and other ranges, forming an extensive mountainous country. South of the mountains lie the Snake River Plains, which are underlain for the most part by great deposits of basalt that has been poured out at different times from many widely distributed craters. These erratic lava flows have piled up the basalt to higher levels at some distance from the mountains than in the vicinity of the mountains and have thus produced a large but shallow, undrained depression. Into this depression the streams from the mountains discharge, and if their waters are not entirely absorbed or diverted on the way they come to rest in the lowest parts of the depression. Thus, in flood stages, Camas Creek discharges into Mud Lake, whereas Birch Creek, Little Lost River, and Big Lost River discharge into "sinks" farther west, which are at nearly the same level as Mud Lake and are separated from it by only an imperceptible divide.

The Mud Lake basin is regarded as including the drainage areas of Camas Creek and of all other streams that are tributary or potentially tributary to the lake. Thus, it includes the drainage area of Medicine Lodge Creek, which flows toward the lake but in all seasons dries up before it reaches the lake, but not that of Birch Creek, whose flood waters come to rest in another "sink." The investigation, however, was carried east to Henrys Fork and west to Birch Creek in order to determine whether the adjacent tracts contribute in any way to the water supply of this basin. In this report the term "Mud Lake region" is used in a general sense to include the Mud Lake basin and adjacent areas.

The Rocky Mountains form a rugged belt 20 to 30 miles wide, with peaks rising to about 10,500 feet above sea level. The lowest pass through the mountains is at the point where they are crossed by the Oregon Short Line, at an altitude of 6,700 feet.

Big Bend Ridge is approximately 8 miles wide and extends north from Henrys Fork near St. Anthony for 18 miles. It reaches a maximum altitude of about 7,500 feet. The ridge is separated from the Rocky Mountains to the north by the wide valley of Sheridan Creek, which is tributary to Henrys Fork.

From the edge of the mountains a smooth alluvial slope, built up of gravelly débris deposited by streams, extends down to the lower parts of the basin with constantly decreasing gradient. The lowest part of the basin, lying farthest from the mountains, is, however, nearly level, and south of Mud Lake it has a very gentle northward gradient. This exceedingly flat plain adjacent to Mud Lake extends southwestward from the lake fully 30 miles with very little change in altitude. It is apparently the bed of an ancient lake.

The alluvial slope and low, flat plain are in many places interrupted by lava buttes and undulating lava plains. Some of these are older than the slope and plain and stood too high to be covered with the sediments deposited by the streams and lake. Others are younger and are composed of lava that was extruded through the sediments and poured out over them. The part of the region lying east of the railroad that passes through Hamer consists largely of undulating lava plains with numerous lava buttes. Thus Camas Creek has practically no alluvial slope.

About 6 miles west of St. Anthony are the Juniper Buttes, a small group of lava and sand hills that are nestled together more or less in the form of a circle with a depression in the center. Sandhill Mountain is one of these hills whose rock core is almost buried by migrating dunes. North of Mud Lake is an extensive lava plain with fantastic buttes. Southwest of Mud Lake are Antelope and Circular buttes, two volcanic cones that project above the low plain. South of the low plain the lava fields of the Snake River Plains extend indefinitely, forming the south rim of the Mud Lake basin.

Mud Lake and the "sinks" farther west occupy shallow but definite depressions in the low plain which were formed, at least in part, by wind erosion. Some of the numerous small lakes, ponds, and sloughs north and east of Mud Lake occupy depressions made by the wind, and others occupy depressions in the lava. The depression occupied by the main body of water of Mud Lake owes its origin to a recent fault that forms a part of its north boundary.

Stretching southwestward from St. Anthony, on the left bank of Henrys Fork, is a river terrace known as Egin Bench. It is approximately 14 miles long and 4 miles wide. It is underlain by gravel and sand, and, although it appears flat, it has an average gradient of about 10 feet to the mile. It lies outside of the Mud Lake basin but within the region covered in this investigation.

GEOLOGY

Archean system.—The oldest rocks that crop out in the region are of Archean age. They are exposed in the region of Sawtelle Peak southwest of Henrys Lake and consist of marble and quartzite.

Carboniferous system.—Between the headwaters of Sheridan Creek and Sawtelle Peak thick beds of Carboniferous age crop out along the Continental Divide. Fossils collected on the divide were identified by G. H. Girty as belonging to the Madison limestone (lower Mississippian). The Phosphoria formation (Permian) also crops out in this region. Thick deposits of Carboniferous rocks are exposed in the Rocky Mountains from Medicine Lodge Creek westward. Approximately 2,000 feet of Carboniferous strata are exposed in the canyon of this creek. Throughout the region the Carboniferous beds have a general dip to the east. They consist of bluish-gray sandy fine-grained limestone. A few fossils were collected in this region which Mr. Girty identified as belonging to Mississippian and Permian deposits. He provisionally referred the Permian fossils to the Phosphoria formation. Thus there is in this region a series of beds that correspond probably to the phosphate beds at the headwaters of Shotgun Creek, and this suggests the possibility that economic phosphate deposits will be discovered in the future in this region. The Carboniferous rocks in an adjacent area have been described by Umpleby [1] and bear an important relation to the drainage of the region, for it was the deformation of these strata, together with subsequent erosion, that determined the valleys of Birch and Medicine Lodge creeks.

Triassic system.—In the course of the field work a series of thick-bedded red sandstone and conglomerate with thin beds of fossiliferous limestone was discovered at the headwaters of Irving Creek, a tributary to Medicine Lodge Creek. Fossils collected at this

[1] Umpleby, J. B., Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, p. 29, 1917.

locality were identified by G. H. Girty as coming from the Thaynes limestone, of Lower Triassic age. The Triassic deposits are several thousand feet thick and form the crest of the Rocky Mountains for a number of miles. The beds in general dip to the northeast.

Cretaceous system.—Overlying the Triassic beds and extending eastward beyond the limits of the region investigated are light-yellow clay and sandstone, believed to be of Cretaceous age. They are extensively exposed in the mountains along Beaver Creek. Along the Continental Divide north of Camas Creek the Cretaceous rocks contain a bed of bituminous coal 32 inches thick. The abandoned Scott & Bucy mine is located on an outcrop of this coal bed.[2]

Tertiary and Quaternary systems.—The Paleozoic and Cretaceous formations are largely covered by Tertiary and Quaternary volcanic and sedimentary deposits. The volcanic rocks consist of rhyolite, obsidian, tuff, andesite, and basalt; the later eruptions are almost entirely basalt. Rhyolite, obsidian, and tuff are found chiefly in the mountains, but they also form the Juniper Buttes, which are outliers of the Yellowstone plateau. Basaltic lavas erupted from vents in the mountains flowed down the principal stream valleys. Later the beds of basalt were eroded by the streams, which cut narrow gorges in the black rock. Great quantities of basalt have been erupted from about 150 craters and fissures throughout the Mud Lake basin from the Pliocene epoch of the Tertiary period almost to the present time.

During the Miocene epoch, before most of the lava was poured out, a huge lake existed in southern Idaho and adjacent areas, as is shown by numerous outcrops of a thick series of strata of sand, clay, and gravel. This ancient lake is called Lake Payette, and the lake deposits are called the Payette formation.[3] How far these lake beds extend toward the northeast beneath the thick deposits of lava has presented a problem for many years. Umpleby[4] found Miocene lake beds of sand and clay extensively exposed in Lemhi Valley and believes that these beds extend southward under the Birch Creek valley and belong to the Payette formation. According to Frank Reno, the well at the Reno ranch penetrated 160 feet of sandstone below 380 feet of gravel. This record tends to confirm Umpleby's conclusion and to suggest that the Payette beds extend beneath the Mud Lake basin, although they are not known to crop out anywhere in this region.

[2] Mansfield, G. R., Coal in eastern Idaho: U. S. Geol. Survey Bull. 716, pp. 123–153, 1921.

[3] Lindgren, Waldemar, U. S. Geol. Survey Geol. Atlas, Boise folio (No. 45), 1898.

[4] Umpleby, J. B., Geology and ore deposits of the Mackay region, Idaho: U. S. Geol. Survey Prof. Paper 97, p. 20, 1917.

Beneath the alluvial slope and the low plain of the Mud Lake basin lie deposits of gravel, sand, silt, and clay that have been penetrated by many wells. Near the mountains these deposits consist chiefly of coarse gravel. Down the alluvial slope the gravel gradually becomes finer and eventually gives way largely to sand. Beneath the low plain the sand, for the most part, gives way to silt and clay. The clay beds underlying the low plain are consistently fine textured and indicate deposition in the quiet waters of a lake. They range in thickness from a few feet east of Hamer to at least 180 feet south of Mud Lake. Their southerly extent is unknown at present because of vast unexplored lava fields extending in that direction. It is not known whether these beds were laid down after the present depression came into existence, and are therefore terminated by the lava on the south side, or whether they continue southward and pass under the upper beds of lava.

Fragments of fossil bones were found at two localities in the gravelly deposits of Medicine Lodge Creek (NW. ¼ sec. 15, T. 7 N., R. 33 E., and SW. ¼ sec. 28, T. 8 N., R. 33 E.) and in volcanic ash at a point northwest of Dubois (NW. ¼ sec. 9, T. 11 N., R. 35 E.). These bones were identified by J. W. Gidley, of the United States National Museum, as belonging to species of camels and elephants of probable Pliocene or early Pleistocene age. The silt and clay beds underlying the low plain are apparently of about the same age as the deposits in which the fossil bones were found and are therefore distinctly younger than the Payette formation.

The large numbers of volcanic cones in the region probably range in age from early Pliocene nearly to the present. Their differences in size and shape are due to many causes. Such low cones as Circular and Antelope buttes, southwest of Mud Lake, are relatively very old and have been greatly weathered and partly buried by clay deposits of later origin. The Mud Lake craters, which in perfect symmetry rise so abruptly north of the lake, show by their degree of preservation that they are much more recent. Moreover, in the walls of some of these craters are found large chunks of baked clay and sandstone brought up from the sediments through which the lava came. They are evidently younger than some of the sedimentary deposits underlying the Mud Lake basin.

As volcanic eruptions have occurred at many different times, now in one part of the region and then in another, the lava has become interbedded with the deposits of gravel, sand, and clay in a very intricate and irregular manner. The structural relations between the lava and the gravel, sand, and clay have to some extent been deciphered through the study of well logs, but they are far too complicated to be completely determined. The investigation has shown clearly that these structural relations absolutely control the occurrence and head of the ground water and the available supply of both ground water and surface water in the Mud Lake basin.

SOIL

In the mountains of this region there is very little agriculture because of the high altitude and the lack of soil, but in the main valleys agriculture is successful because of protection from severe storms, plenty of water, and good soil.

Wherever fresh lava does not lie at the surface the Snake River Plains are generally covered with a clayey soil, most of which is deposited from dust-laden winds sweeping across the desert. Wherever it is irrigated this soil produces excellent crops. 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 loess-like soil, tens of thousands of acres of rather recent lava which are now so valuable for sheep grazing would be barren and worthless. Here truly, " it is an ill wind that blows nobody good."

The soil south and west of Mud Lake is a clayey loam, which is very productive when irrigated. It is remarkably free of any coarse material and does not vary notably in texture except where the clayey material is covered by wind-blown sand. In the region north of New Monteview the soil is clayey loam with a few streaks of pea-sized gravel.

The Mud Lake basin as a whole is remarkably free from alkali. 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 are, however, covered with migrating sand dunes of the cusp type, some of which reach heights of 200 feet.

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

VEGETATION

As can be seen from the records of precipitation, the Mud Lake basin is an arid region. Sagebrush is the most abundant native plant, growing luxuriantly almost everywhere except in the swampy tracts, where it has been killed by the rise of the water table. White or sweet sage, rabbit brush, and Russian thistle are also common throughout the region. Above altitudes of 4,500 feet buck brush and chaparral are found.

Around Mud Lake and the sloughs near by are luxuriant growths of marsh grass and tules. Where the sagebrush has been killed by the rise of the water table, greasewood, wild rye, and squirrel tail have grown up in its place.

The mountain areas support good stands of Douglas fir and lodgepole pine.

CROPS

Dry farming, or farming without irrigation, has been tried in several parts of the region. It 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. In the country adjacent to Mud Lake dry farming has been a complete failure.

Average yields of irrigated crops per acre in the vicinity of Mud Lake are as follows: Alfalfa, 3 to 4 tons; wheat, 30 to 40 bushels; oats, 50 to 60 bushels; potatoes, 100 sacks. In the Camas Meadows the main crop is hay.

CLIMATE

Precipitation.—Precipitation records covering a number of years have been obtained by the United States Weather Bureau at several points in or near the Mud Lake region. In connection with the present investigation records have been obtained since the early part of 1921 at the First Owsley pumping plant and at Camas, Monteview, and Magill's ranch, near the West Hamer bridge. (For locations of rain gages see Pl. II; for precipitation data see pp. 101–102.) The First Owsley pumping plant is about 1 mile east of Terreton and about 1 mile south of Mud Lake. At this plant, which is in what is probably the driest part of the region under investigation, only 8.29 inches of precipitation was recorded for the year ending March 31, 1922, and 8.20 inches for the year ending March 31, 1923. At Camas a five-year record (1908–1912) shows a mean annual precipitation of 10.85 inches. At higher altitudes the precipitation is somewhat greater. Thus at Spencer, about 1,000 feet higher than Mud Lake, the mean annual precipitation (1915–1921) is 17.22 inches, and at Kilgore, which is at nearly the same altitude as Spencer, the mean (1912–1916) is 22.32 inches. At Arco, on the plain 40 miles west of Mud Lake, the mean (1901–1921) is only 9.61 inches. At Idaho Falls, 40 miles southwest of Mud Lake and slightly lower, the mean (1880–1921) is 14.22 inches. At Sugar City, 33 miles directly east of Mud Lake, the mean (1907–1921) is 12.26 inches.

Temperature.—The mean temperature during the year ending March 31, 1922, was 38° at Mud Lake (First Owsley pumping plant), 42.8° at Idaho Falls, 36.2° at Lake, and 40.9° at Lost River. During the same period the mean was 47.6° at Pocatello and 50.6° at Boise. The mean temperature at Mud Lake for January, 1922, was 3°, which, according to the United States Weather Bureau, was a lower mean for the same month than at any other station in Idaho. During the year ending March 31, 1922, the minimum temperature at Mud Lake was 36° below zero, on January 19, 1922, and the maximum was 96° above zero, on July 9 and 21, 1921.

Wind movement.—Records obtained from April 1, 1921, to March 31, 1922, from the anemometer installed at the First Owsley pumping plant in connection with the evaporation pan at that place, which is about 3 feet above the ground surface, showed the mean wind movement to be 4.7 miles an hour. The prevailing direction of the wind was from the southwest. During the spring the wind velocity was usually high. The mean monthly velocity ranged from 7.3 miles an hour in May, 1921, to only 2.7 miles an hour in January, 1922. The mean hourly wind movement during 1921 was 5.3 miles at Boise, 8.97 miles at Pocatello, and 8.24 miles at Yellowstone.

Evaporation and transpiration.—It was necessary to determine as closely as possible the heavy losses due to evaporation and transpiration from Mud Lake and from the large adjoining water-covered and marshy areas. A land evaporation pan was installed at the First Owsley pumping plant, in connection with other Weather Bureau instruments, on April 27, 1921. (See Pl. II.) 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 well on the outside of the pan. It rests on 1-inch planks laid flat on the ground. It was kept filled with water within 2 or 3 inches of the top. The height of water in the pan was read daily at 7 a. m. by Paul D. Bonnel. Readings were obtained to thousandths of an inch by means of a micrometer.

A floating evaporation pan 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. (See Pl. II.) 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. 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. A platform from the bank to the pan was constructed on piles. The water level in the pan was read daily to sixteenths of an inch by C. O. Magill. A standard rain gage was installed 300 feet east of the pan, and rainfall records were obtained while the pan was in operation.

The tule-covered parts of the lakes and the adjoining marsh lands together occupy about three times as much area as the tracts of open water (where there is no vegetation), and they undoubtedly discharge vast 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. (See Pl. II.) This pan 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 so that the rim was 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 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 at those times the pan was refilled within 3 inches of the rim. The tules in the pan showed the same growth as the plants in the adjoining marsh.

The results of the observations on the three pans are shown graphically in Figure 7. Monthly summaries and means are shown in the table on pages 101–102. The following conclusions have been reached from a study of the data:

1. Evaporation from the land pan varied directly with the temperature and also showed considerable variation due to the strong winds that intermittently swept the region in the spring.

2. Evaporation from the floating pan was only about 75 per cent as great as evaporation from the land pan. The difference is explained partly by the fact that the temperature of the water was considerably higher in the land pan than in the floating pan and partly by the fact that the sides of the land pan were warmer than the sides of the floating pan, causing a larger loss from the land pan. Moreover, the floating pan is east of the lake, on the leeward of the prevailing southwest winds, and is therefore in the belt of comparatively high humidity, whereas the land pan is on the south side of the lake and receives the dry southwest winds before they have touched the lake.

3. 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 the loss from wave action on the inside of the

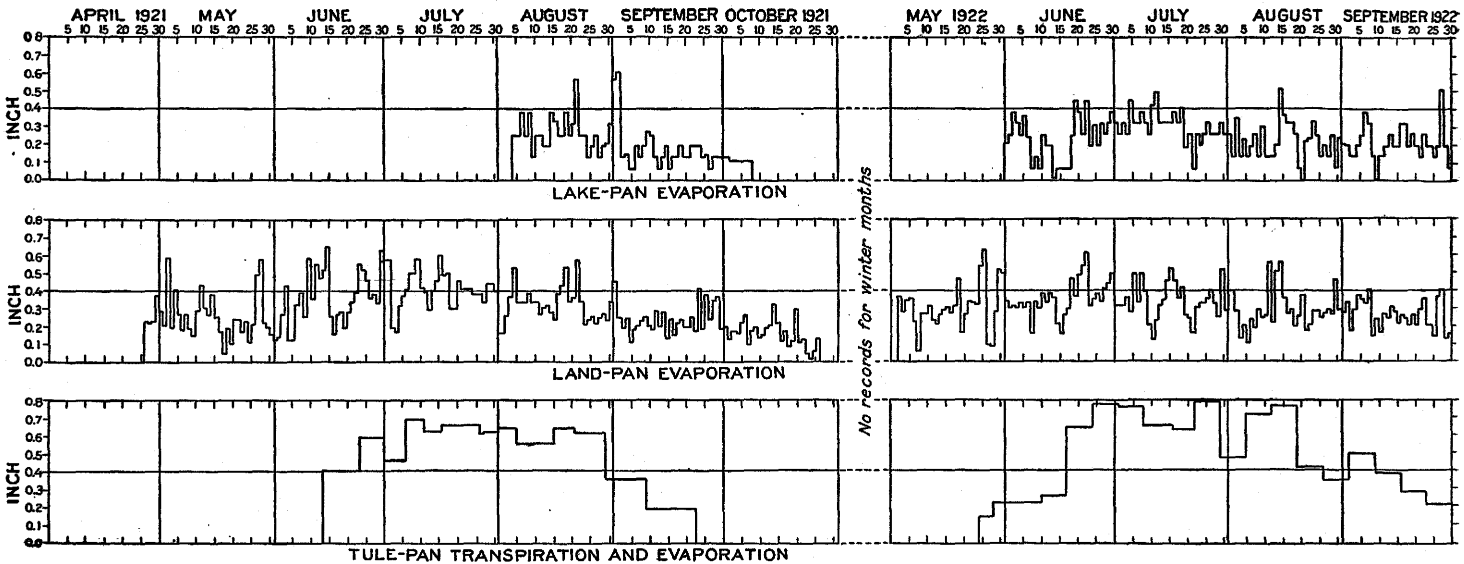


FIGURE 7.—Graphs showing evaporation from land pan, lake pan, and tule pan, Mud Lake, Idaho

rim of the floating pan tends to make the evaporation from it greater. The effect of the wind on the lake surface in increasing evaporation is not believed to be large enough to balance the conditions that favor 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 [5] 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 0.83×0.75, 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.

4. The evaporation from the land pan from April 1 to November 30, 1921, was 4.94 feet (including estimates for April 1–23 and October 28 to November 30, when records were not obtained). If the coefficient 0.65 is applied to this figure, the loss by evaporation from the open water of Mud Lake during the same period is found to have been 3.21 feet. The evaporation from the land pan from April 1 to November 30, 1922, was 4.83 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 3.13 feet.

5. During the season of plant growth the total losses by evaporation and transpiration from the marsh and tule-covered water areas are considerably larger than the loss by evaporation from open-water surfaces. Thus in July the loss was about 12.6 inches from the land pan and 19 inches from the tule pan, and in August it was about 9.8 inches from the land pan and 18 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.

[5] Mead, D. W., Hydrology, p. 151, New York, McGraw-Hill Pub. Co., 1919.

Summary of meteorologic data at Mud Lake, Idaho

Month	Air temperature (° F.)			Precipitation (inches)	Evaporation (inches)				Transpiration and evaporation from tule pan (inches)		Wind movement (miles)	
					Land pan		Lake pan					
	Mean maximum	Mean minimum	Mean		Total	Daily mean	Total	Daily mean	Total	Daily mean	Total	Mean per hour
1921												
April	[a]50.5	[a]23.7	[a]37.1	[a]0.05	[b]1.05	[b]0.26	------	------	------	------	[a]1,226	[a]7.3
May	66.1	41.3	53.7	2.24	7.94	.26	------	------	------	------	5,409	7.3
June	78.6	49.5	64.0	.36	10.49	.35	------	------	[c]8.85	[c]0.49	4,040	5.6
July	87.0	50.0	68.5	.62	12.56	.40	------	------	18.98	.61	3,640	4.9
August	84.8	47.5	66.2	.23	9.78	.32	[d]7.14	[d]0.26	17.98	.58	3,020	4.1
September	69.9	32.8	51.4	.42	7.06	.24	5.06	.17	[e]5.54	[e].24	4,020	5.6
October	67.1	26.5	46.8	.16	[f]4.23	[f].16	[g].87	[g].11	------	------	2,439	3.3
November	49.0	18.3	33.6	.08	[h]2.40	.08	------	------	------	------	3,076	4.3
December	32.5	8.7	20.6	1.95	[i]1.60	.05	------	------	------	------	2,473	3.3
Total or average	------	------	------	6.11	57.11	.23	13.07	.18	51.35	------	29,343	5.1
1922												
January[j]	15.7	−9.6	3.0	.79	------	------	------	------	------	------	1,990	2.7
February[k]	26.2	−4.4	10.9	.39	------	------	------	------	------	------	3,204	4.8
March	[l]34.8	[l]5.6	[l]20.1	1.00	------	------	------	------	------	------	2,603	3.5
April	[m]50.6	[m]24.6	[m]37.5	.68	[h]4.00	.13	------	------	------	------	4,237	5.9
May	66.7	37.2	51.6	1.18	[n]9.48	.31	------	------	[o].94	.13	5,600	7.5
June	81.9	45.3	63.6	.62	10.47	.35	6.79	.23	13.47	.45	3,485	4.8
July	85.8	49.2	67.5	.63	10.41	.34	9.16	.30	21.42	.69	3,160	4.2
August	84.4	40.9	62.6	2.02	8.99	.29	6.40	.21	17.33	.56	2,865	3.8
September	80.0	[p]43.4	[p]61.7	.00	7.65	.26	6.01	.20	10.26	.34	2,660	3.7
October	64.1	[p]33.5	[p]48.8	.35	4.83	.16	------	------	------	------	2,730	3.7
November	[p]40.4	[p]16.4	[p]28.4	[q].55	[h]2.00	.07	------	------	------	------	[r]2,940	4.1
December	30.4	8.4	19.4	.75	------	------	------	------	------	------	2,740	3.7
Total or average	55.1	24.2	39.6	8.96	57.83	.24		------	63.42	.49	38,214	4.4
1923												
January	30.0	6.1	18.0	[p].82	------	------	------	------	------	------	2,430	
February	[p]26.7	[p]2.1	[p]14.4	.45	------	------	------	------	------	------	2,180	3.3
March	[v]33.4	[v]12.8	[v]18.1	[t].15	------	------	------	------	------	------	Incomplete.	3.2
April	[w]57.7	[w]28.4	[w]43.0	.95	[h]3.00	.10	[x]1.99	.12	------	------	4,540	6.3
May	[y]67.2	[y]38.8	[y]53.0	1.59	7.14	.23	4.62	.15	------	------	4,460	6.0
June	[y]71.0	[y]43.0	[y]57.0	1.80	7.61	.25	7.36	.25	[z]5.79	.31	4,060	5.6
July	[aa]87.5	[aa]53.1	[aa]70.3	1.40	11.42	0.37	9.43	0.30	11.70	0.38	3,590	4.8
August	[aa]83.3	[aa]47.3	[aa]65.3	1.05	9.19	.30	8.17	.26	13.38	.43	[bb]4140	[bb]5.6
September	[cc]76.9	[cc]39.8	[cc]58.4	.50	7.20	.24	6.31	.21	11.06	.37	4,275	5.9
October	[cc]56.2	[cc]27.2	[cc]41.7	1.40	[dd]3.02	.10	------	------	[ee].97	.06	2,955	4.0
November	[aa]48.7	[aa]15.7	[aa]32.2	.00	[h]1.92	.06	------	------	------	------	1,580	2.2
December	[ff]31.0	[ff]2.6	[ff]16.8	.00	------	------	------	------	------	------	Incomplete.	[ff]2.3
Total or average	55.8	26.4	41.1	10.11	50.50	.21	------	([gg])	------	------	------	------

[a] April 24–30.
[b] April 27–30.
[c] June 13–30.
[d] 27.5 days, Aug. 3–31.
[e] Sept. 1–23.
[f] Oct. 1–27; pan froze Oct. 27.
[g] Oct. 1–8.
[h] Estimated.
[i] Estimated. Lake ice-covered Dec. 20–31.
[j] Lake ice-covered. Minimum temperature, 36°, Jan. 19.
[k] Lake ice-covered.
[l] 17 days.
[m] 29 days.
[n] Estimated May 1–2.
[o] May 24–30.
[p] Dubois record used.
[q] Monteview record used Nov. 18–30.
[r] Estimated Nov. 18–30.
[s] Corrected by Dubois record.
[t] Monteview record used.
[u] Estimated Dec. 1–4.
[v] Dubois record Mar. 1–28.
[w] 7 days from Idaho Falls record.
[x] Apr. 15–30.
[y] 28 days.
[z] June 12–30.
[aa] 26 days.
[bb] Uncertain.
[cc] 24 days.
[dd] Estimated Oct. 7–13, 18–31.
[ee] Oct. 1–16.
[ff] 22 days.
[gg] Tule-pan record lower for 1923 than for 1921 and 1922 because plant growth in pan was not normal.

Summary of meteorologic data at Mud Lake, Idaho—Continued

Month	Air temperature (° F.)			Precipitation (inches)	Evaporation (inches)				Transpiration and evaporation from tule pan (inches)		Wind movement (miles)	
					Land pan		Lake pan					
	Mean maximum	Mean minimum	Mean		Total	Daily mean	Total	Daily mean	Total	Daily mean	Total	Mean per hour
1924												
January	[hh]26.1	[hh]−7.8	[hh]9.2	[t].18							1,460	2.0
February	[y]39.1	[y]16.1	[y]27.6	.35							1,860	2.7
March	[m]40.8	[m]15.3	[m]28.0	[t].45							4,140	5.6
April	[cc]57.0	[cc]25.6	[cc]41.3	[t].11							4,065	5.7
May	[aa]74.5	[aa]39.2	[aa]56.8	[t].17							4,855	6.5
June	[ii]79.2	[ii]41.6	[ii]60.4	[t].10							5,000	7.0
July	[y]90.5	[y]43.3	[y]66.9	[t]1.14							3,900	5.2
August	[m]88.1	[m]41.6	[m]64.8	[t]Trace.							3,660	4.9
September	[aa]75.3	[aa]34.7	[aa]55.0	.80							3,150	4.4
October	[y]63.5	[y]29.0	[y]46.2	.95							2,850	3.8
November	[aa]44.7	[aa]11.7	[aa]28.2	[t].19							3,340	4.6
December				[t].72							1,820	2.5
Total or average				5.16							40,100	4.6

[m] 29 days.
[t] Monteview record used.
[y] 28 days.
[aa] 26 days.
[cc] 24 days.
[ii] Based on 23 days' record.
[hh] Based on 30 days' record.

STREAMS

The streams that are contributors to the water supply of the Mud Lake basin are Camas, Beaver, Dry, Cottonwood, and Medicine Lodge creeks. 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. In addition to these Blue, Warm, Crooked, and Birch creeks were investigated.

CAMAS CREEK

Camas Creek heads in several branches that rise in high and heavily timbered parts of the Rocky Mountains and flow into the high basin known as the Camas Meadows (Pl. I). 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.

Continuous records were obtained at two gaging stations on the creek. The Camas Mutual Irrigation District, which proposes to impound water in a reservoir in the upper reaches of the creek for irrigation in the vicinity of Camas, had previously installed a gaging station from which partial records during the flood periods of 1919 and 1920 were obtained. On April 16, 1921, this station was taken over by the United States Geological Survey, and a Stevens continuous recording gage was installed. The station is in the NE. ¼ SE. ¼ sec. 13, T. 11 N., R. 38 E., 2 miles above the Lone Tree reservoir, 7½ miles south of Kilgore, and 19 miles northwest of Dubois. The drainage area above this point is 216 square miles. Another station, consisting of a staff gage, was installed April 2, 1921, in the NE. ¼ sec. 34, T. 9 N., R. 36 E., a quarter of a mile south of C. J. Thompson's ranch and 5 miles northeast of Camas, or about 23 miles below the upper station. Late in the fall of 1921 an eight-day Stevens recording gage was installed.

The discharge from April 1, 1921, to March 31, 1922, was about 92,600 acre-feet at the upper station and 35,300 acre-feet at the lower station. Thus the difference in flow at the two stations during the year amounted to about 57,300 acre-feet. Approximately 5,730 acre-feet was diverted for irrigation and watering stock between the two stations during 1921. Deducting this amount from 57,300 acre-feet leaves a balance of 51,570 acre-feet, which was evidently contributed to the ground-water supply. Doubtless some of the diverted water also percolated down to the water table. The discharge from April 1, 1922, to March 31, 1923, was about 77,700 acre-feet at the upper station and 28,160 acre-feet at the lower station.

A considerable part of the water lost from Camas Creek went through Lone Tree reservoir, about 2 miles below the upper gaging station. This reservoir, which has a maximum capacity of approximately 3,000 acre-feet, was constructed by the Wood Live Stock Co. Recently it was bought, together with certain water rights, by the Camas Mutual Irrigation District.

The miscellaneous measurements tabulated on page 104 indicate that most of the water disappearing in Camas Creek sinks in the Lone Tree reservoir. There was no gage installed in the reservoir at the time these measurements were made, but as no changes in the outlet gates had been made prior to those dates it can be assumed that the normal flow of Camas Creek was passing through the reservoir.

Approximately 15,000 acres in the Camas Meadows, above the upper gaging station, is under cultivation, including the hay land. This land is watered largely by subirrigation. As the ground water is near the surface throughout this section, it evidently does not have free escape toward the south. Nevertheless a substantial amount of ground water may find its way to the lower lands adjacent to Mud Lake or to other regions. Two large stock-watering ditches diverted approximately 8,670 acre-feet during the year from points above the upper station and carried this water several miles out into the lavas, where some of the water doubtless percolated down to the water table.

Losses in Camas Creek from gaging station 2 miles above Lone Tree reservoir to Jacoby's ranch, about 6 miles below the reservoir, 1923–1924

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

[a] Estimated.
[b] 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's Live Stock ditch No. 1, about sec. 30, T. 11 N., R. 39 E. (diverts water ½ mile above Lone Tree reservoir).
3. Woodie ditch No. 2, sec. 26, T. 11 N., R. 38 E. (diverts water from 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's ranch, sec. 20, T. 10 N., R. 38 E., 6 miles below reservoir.

The Frazier reservoir, on West Camas Creek, stores between 2,000 and 3,000 acre-feet for watering stock of the Wood Live Stock Co. This small reservoir and the Lone Tree reservoir are the only existing storage units on the creek above Mud Lake.

The water master reports that between the lower gaging station and Mud Lake 870 acres are irrigated from Camas Creek, of which about 500 acres are partly watered by subirrigation. The water table is 25 feet below the surface at the lower gaging station and comes progressively nearer the surface downstream until it forms sloughs in the vicinity of Hamer. The water lost in Camas Creek below the lower gaging station is doubtless chiefly contributed to Mud Lake or evaporated from the wet lands that lie northeast of the lake.

BEAVER CREEK

Beaver Creek heads in the high peaks along the Continental Divide and 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 its water rapidly in coarse gravel. During the flood period, which usually lasts about two months, the water flows across the porous gravel from Dubois to Camas, where it joins Camas Creek and contributes to the supply of Mud Lake. During the remainder of the year the creek loses all of its flow before it reaches a point 3 miles south of Dubois.

Two gaging stations were established on the creek in April, 1921. The upper station is in the NW. ¼ sec. 21, T. 10 N., R. 36 E., at E. F. Palmer's ranch, half a mile north of Dubois. The drainage area above this point is 220 square miles. The discharge at this station for the year ending March 31, 1922, was about 48,000 acre-feet and for the year ending March 31, 1923, 39,180 acre-feet. The lower station is in sec. 21, T. 8 N., R. 36 E., about three-eighths of a mile above its confluence with Camas Creek at Camas and below all diversions. As mentioned before, there is no flow past this station except during flood periods. The discharge during the flood periods of 1921 and 1922 was 11,400 acre-feet and 10,000 acre-feet, respectively.

In 1920 the water master reported that approximately 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.

As about 48,000 acre-feet was discharged past the upper station and 11,400 acre-feet past the lower station in 1921, the total loss of water for that year, including diversions between the two stations, was about 36,600 acre-feet. If 4,500 acre-feet was diverted for irrigation below Dubois (an estimate based on a duty of 3 acre-feet during the season for 1,500 acres) about 32,100 acre-feet was contributed to the ground-water supply as a result of losses in the channel below Dubois. About 11,400 acre-feet was contributed to the lake as surface water during 1921 and 10,000 acre-feet in 1922.

Miscellaneous measurements made during 1922 and 1923 indicate a loss of about 1.5 per cent to the mile in the 14-mile section of Beaver Creek between Spencer and Dubois during the spring floods and less than 0.5 per cent to the mile during low water. The loss occurring in this stretch of the stream is an additional contribution to the ground-water supply.

MEDICINE LODGE CREEK

Medicine Lodge Creek rises in the high mountains and owes considerable of its flow to springs. A number of small perennial streams enter from each side of the creek as it wends a southeasterly course. None, however, enter below the gaging station, which is at the mouth of the canyon. This station was installed April 19, 1921, and consists of a staff gage in sec. 25, T. 11 N., R. 34 E., at the H. W. Small ranch, about 3 miles northwest of Small and 12 miles west of Dubois. The drainage area above this station is 270 square miles.

The discharge at the gaging station for the year ending March 31, 1922, was 51,500 acre-feet, and for the year ending March 31, 1923, 50,200 acre-feet. No stream-flow records prior to these are available.

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 commences to lose water through its porous channel below the gaging station and sinks entirely, even in the flood season, about 6 miles northwest of the Jefferson reservoir. If during the year ending March 31, 1922, 3 feet of water was lost by evaporation and transpiration on 6,000 acres of irrigated land, a total of 18,000 acre-feet, a balance of 33,500 acre-feet must have been lost by percolation. Thus the contribution to the ground-water supply from water that passed the gaging station was probably not less than 33,500 acre-feet in 1921–22 and 32,200 acre-feet in 1922–23.

BIRCH CREEK

Birch Creek has its origin in a series of springs a few miles upstream from the ranch of the Wood Live Stock Co. The flow of the stream is practically constant throughout the year. During 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 what is known as the Birch Creek Sinks.

A gaging station that had been in operation from September 5, 1910, to June 30, 1912, was reestablished on April 6, 1921. It consisted of a staff gage installed in sec. 13, T. 10 N., R. 29 E. Boise meridian, about 6 miles northwest of Reno, above practically all diversions.

The records show that for the year ending March 31, 1922, a discharge of 59,900 acre-feet passed the station. Previous published records[6] show that during the year ending September 30, 1911, a flow of 65,100 acre-feet passed the station, and for the period October 1, 1911, to June 30, 1912, 52,100 acre-feet. Though the records show that the discharge was slightly less during the year ending March 31, 1922, than during the corresponding period in 1911–12, yet the annual yield from this particular drainage basin has not changed materially during the last 12 years.

About 1,200 acres is being irrigated from this creek. An application has been filed 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 the map of this region (Pl. II), demonstrate conclusively that no water from Birch

[6] U. S. Geol. Survey, Water-Supply Papers 312 and 332.

Creek or from Lost or Little Lost rivers contributes to the ground-water supply in the vicinity of Mud Lake.

INTERMITTENT STREAMS

Of the small intermittent streams that have their sources in the region north of Mud Lake the principal ones are Dry, Cottonwood, Blue, Warm, and Crooked creeks. Each of these has a comparatively large flood run-off of short duration. All these streams lose water rapidly after leaving the foothills, for the flow of each rarely exceeds 2 second-feet a short distance from the hills. They doubtless all contribute to the ground-water supply, but a study of the water table indicates that only the ground water contributed by Dry and Cottonwood creeks has any chance of reaching 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 Live Stock Co. on Sheridan Creek, which flows into Shotgun Creek and thence into Henrys Fork. The point of diversion in Dry Creek is about 2 miles above the point where the measurement was made.

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 which 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. As ground water, like surface water, tends to move down grade, it generally moves in the direction that the water table slopes, about at right angles to the water-table contours.

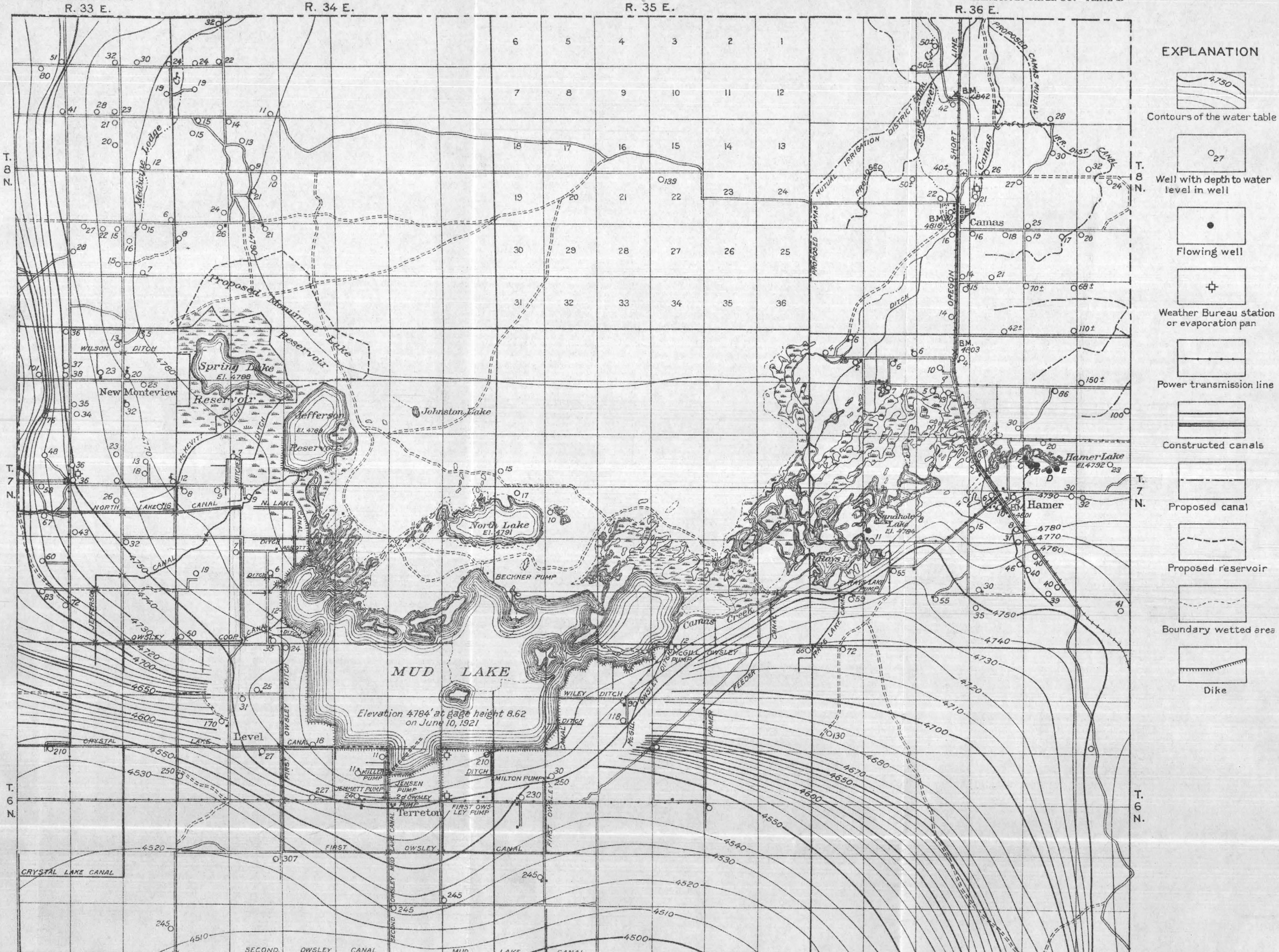
As the water supply of the Mud Lake basin was known to be derived largely from ground water, it was evident that the investigation must include the preparation of an accurate contour map of the water table. In order to prepare such a map records were obtained of about 400 wells, including nearly all 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 during the last 20 years was verified by mapping the areas of dead sagebrush, for it has been found that if the water table rises high enough to wet the roots of sagebrush continually the sagebrush soon dies. 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 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 doubtless extends beneath the lake, as shown in Plate II. From all indications, Mud Lake lies upon the thick clay



R. 33 E. R. 34 E. R. 35 E. R. 36 E.

Culture by H.T.Stearns
Drainage by L.L.Bryan
Surveyed in May and June, 1921

DETAILED MAP OF MUD LAKE AND VICINITY, JEFFERSON COUNTY, IDAHO

Showing wells and contours of the water table

0 1 2 3 4 5 Miles

Wells and contours of the water table by H.T.Stearns strata, which are mainly the cause of its perched situation. 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. In time, with continued irrigation, this water table will be extended farther from the lake. The lower water table south of Mud Lake is continuous with the water table west of Roberts and has a general slope to the southwest.

WATER TABLE NORTH OF MUD LAKE

There seems to be a sort of cascade of the ground water after it reaches the lava plains at the foot of the mountains and south of the Camas Meadows. A short distance from the mountains the water table assumes a more gentle gradient and slopes in general toward the southwest until it 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 disposal of this ground water depends chiefly on the slope of the water table at the edges of the basin and on the relation of this ground water to the deep ground water south and west of Mud Lake.

The flatness of the water table north and east of Hamer indicates that the ground water in that area is in pervious strata of lava. Whether the water table extends across the large lava field north of Mud Lake is uncertain. Much of this lava is, in all probability, porous enough to allow water to percolate through it, although the volcanic necks below the craters may be impervious. 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 in the lava field north of the lake. The craters north of Mud Lake are younger than any of the water-bearing formations near by, and the lava extruded from them must have come up through all underlying formations.

The water-table contours indicate that the water lost from Camas and Beaver creeks 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 probably percolates westward into the lava that lies north of Mud Lake, whence it may pass farther westward to the wet areas of the vicinity of the Jefferson reservoir and Spring Lake or may escape from the basin by deep percolation.

A part of the water from these creeks may also escape from the basin by percolating southward in the vicinity of Hamer, where the water table drops off rapidly toward the south.

The water lost by Medicine Lodge Creek sinks to this water table and doubtless furnishes the principal supply encountered by numerous wells near Winsper, Old Monteview, and New 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 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 apparently 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 the rise 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 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.

EGIN BENCH IN RELATION TO THE WATER SUPPLY OF THE MUD LAKE BASIN

The great and progressive increases in the visible supply of water in the Mud Lake basin during the last 25 years has attracted wide attention. This increase has long been attributed by the inhabitants of the region to percolation of water used in irrigation on Egin Bench. (See Pl. I.) In this investigation an effort has been made to determine conclusively whether water percolates from Egin Bench to the Mud Lake basin, and, if so, in what quantities.

The problem can be approached in two different ways—(1) by establishing the fact that there has been an increase in water supply and then attempting to eliminate all other possible causes, or (2) by determining the geologic structure, the slope of the water table, and the movement of ground water between 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 has been a large increase in the size of Mud Lake and a substantial rise in the water table 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 west areas and of submerged houses and wells.

There is also evidence that the increase in water supply is not due to a succession of wet years. The available records of precipitation do not indicate any change in climate competent to produce so great an increase in water supply. However, very long records are not available, and even if they were, weather cycles might be hard to detect. Evidence was found that no comparable increase in water supply has occurred in other basins in the same part of the State, such as those of Birch Creek, Little Lost River, Big Lost River, and Pahsimeroi River. Records of the flow of Birch Creek in the year ended March 31, 1922, and in previous years indicate that there has been no increase in that creek. (See under "Streams.") The conclusion therefore appears unavoidable that the increase of water supply in the Mud Lake basin is not due to climatic change but to some natural or artificial change that has specifically affected 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 unfortunately its occurrence can not 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 Egin Bench. Hence, though this method of approaching the problem does not lead to any positive conclusion, it establishes a strong a priori assumption that the increase in the water supply of the Mud Lake basin is due to irrigation on Egin Bench.

It has been assumed by some persons that the water from 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 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 NE. ¼ 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 Egin Bench by way of Hamer.

During the later part of 1922 a careful survey was made of all the deep wells north of Egin Bench. A water-table map constructed from the data obtained indicates that on the north side of Egin Bench there is a ground-water cascade which causes 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 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.

Monthly discharge, in second-feet, of canals diverting water on Egin Bench, for the year ending March 31, 1922

Canal	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
Dewey	-------	[a] 300	604	630	560	302	0	0	0	0	0	0	-------
Last Chance	-------	[a] 1,000	2,206	1,804	1,614	982	0	0	0	0	0	0	-------
St. Anthony Union	-------	12,631	12,433	12,514	9,300	5,117	3,680	950	3,930	1,824	1,671	2,389	-------
Egin	-------	9,109	7,467	8,714	6,519	3,016	3,376	1,960	548	[b] 0	[b] 0	543	-------
St. Anthony Union Feeder	-------	2,630	1,948	1,593	1,525	593	1,408	966	49	0	0	0	-------
Independent	-------	9,171	7,416	6,543	4,806	3,605	6,352	4,080	882	0	0	0	-------
Total:													
Second-feet	[a] 10,000	34,841	32,074	31,798	24,324	13,615	14,816	7,956	5,409	1,824	1,671	2,932	181,260
Acre-feet	19,800	66,600	63,700	63,300	48,200	27,900	29,400	15,800	10,400	3,620	3,320	5,820	357,860

[a] Estimated. [b] Reported practically dry.

The foregoing table gives results derived from records obtained by G. C. Baldwin, district engineer of the United States Geological Survey at Idaho Falls, in connection with the distribution of water on Henrys Fork. Ordinarily records of these diversions are procured only during the irrigation season, but to assist in this investigation arrangements were made whereby records were obtained throughout the winter of 1921–22. However, the diversions of all canals in April, 1921, and of two canals in May, 1921, were estimated because of lack of records. The records and estimates indicate that a total of 357,860 acre-feet was diverted upon Egin Bench in the year ending March 31, 1922.

Diversions and return flow of Henrys Fork between St. Anthony and Rexburg gaging stations and approximate losses on Egin Bench, 1919–1921

	June	July	Aug.	Sept.	Total
1919					
Total diversions on Egin Bench .... second-feet	32,808	25,724	22,561	15,721	96,814
Other diversions between St. Anthony and Rexburg .... do	20,093	5,783	7,673	8,255	-------
Total diversions between St. Anthony and Rexburg .... do	52,901	31,507	30,234	23,976	-------
Gain between St. Anthony and Rexburg .... do	14,040	9,110	7,940	7,990	-------
Gain between St. Anthony and Rexburg .... per cent	26	29	26	33	-------
Probable return flow from Egin Bench .... second-feet	8,500	7,470	5,860	5,200	-------
Approximate losses due to evaporation and vegetation on Egin Bench, based on cultivated area of 30,000 acres .... second-feet	[a]8,520	[a]10,200	[a]7,950	[a]5,740	-------
Approximate total losses on Egin Bench .... do	17,020	17,670	12,810	10,940	-------
Approximate permanent contribution to ground water table on Egin Bench .... second-feet	15,788	8,054	9,751	4,781	38,374
Approximate permanent contribution to ground water table on Egin Bench .... acre-feet	31,300	16,000	19,400	9,460	76,160
1920					
Total diversions on Egin Bench .... second-feet	39,780	31,259	24,128	6,343	101,510
Other diversions between St. Anthony and Rexburg .... do	22,125	17,406	11,836	3,076	-------
Total diversions between St. Anthony and Rexburg .... do	61,905	48,665	35,964	9,419	-------
Gain between St. Anthony and Rexburg .... do	8,341	17,714	12,487	6,682	-------
Gain between St. Anthony and Rexburg .... per cent	13½	36	35	71	-------
Probable return flow from Egin Bench .... second-feet	5,370	11,200	8,450	4,500	-------
Approximate losses due to evaporation and vegetation on Egin Bench, based on cultivated area of 30,000 acres .... second-feet	[a]8,520	[a]10,200	[a]7,950	[a]2,870	-------
Approximate total losses on Egin Bench .... do	13,890	21,400	16,400	7,370	-------
Approximate permanent contribution to ground water table on Egin Bench .... second-feet	25,890	9,859	7,728	0	43,477
Approximate permanent contribution to ground water table on Egin Bench .... acre-feet	51,400	19,600	15,300	0	86,300
1921					
Total diversions on Egin Bench .... second-feet	32,074	31,798	24,324	13,015	101,811
Other diversions between St. Anthony and Rexburg .... do	54,396	50,447	35,053	19,819	-------
Total diversions between St. Anthony and Rexburg .... do	86,470	92,245	59,377	33,434	-------
Gain between St. Anthony and Rexburg .... do	12,827	17,875	16,162	10,383	-------
Gain between St. Anthony and Rexburg .... per cent	15	19	27	31	-------
Probable return flow from Egin Bench .... second-feet	4,810	6,040	6,570	4,220	-------
Approximate losses due to evaporation and vegetation on Egin Bench, based on cultivated area of 30,000 acres .... second-feet	[a]8,520	[a]10,200	[a]7,950	[a]5,740	-------
Approximate total losses on Egin Bench .... do	13,330	16,240	14,520	9,960	-------
Approximate permanent contribution to ground water table on Egin Bench .... second-feet	18,744	15,558	9,804	3,655	47,761
Approximate permanent contribution to ground water table on Egin Bench .... acre-feet	37,200	30,900	19,400	7,260	94,760

[a] Determined on evaporation loss of 6.816 inches during June, 8.166 inches during July, 6.360 inches during August, 4.592 inches during September, based on land-pan evaporation records corrected by 65 per cent. (Land-pan records obtained at Mud Lake.) Probable additional loss due to transpiration assumed to be offset or compensated by probable decrease in cultivated and evaporated area as the irrigation season advanced.

The foregoing table gives some idea of the quantity of irrigation water that may percolate from Egin Bench toward the west and northwest. It was prepared from records obtained by Mr. Baldwin in connection with the distribution of water from Henrys Fork during the irrigation seasons of 1919, 1920, and 1921. It shows the diversions upon Egin Bench and the return flow into Henrys Fork between the St. Anthony and Rexburg gaging stations during these three seasons. As a basis for computing the part of the return flow that probably comes from Egin Bench it was assumed that the return on the opposite sides of Henrys Fork is in proportion to the diversions. Probably, however, the return flow from Egin Bench is much greater, owing to the porous character of its formation and its higher altitude with respect to the river.

The losses due to evaporation and transpiration were estimated to be 65 per cent of the recorded losses during 1921 from the land evaporation pan at Mud Lake, applied to a cultivated area of 30,000 acres, which includes the entire area of the Egin bench after deducting 10 per cent for houses, roads, etc. The table shows that the losses by return flow, evaporation, and transpiration amount to about 60 per cent of the water annually diverted upon Egin Bench, leaving about 40 per cent that may flow toward the west and northwest into the lavas. Forty per cent of the total diversion during the year ending March 31, 1922, which was probably a normal year, is about 140,000 acre-feet. A part of this water reaches Mud Lake basin in the way already described.

INVENTORY OF WATER SUPPLY

The units of storage in the Mud Lake basin are Hamer Lake, Mud Lake (including Rays and Sandhole lakes), the Jefferson reservoir, the Jefferson reservoir addition, Spring Lake, and North Lake. (See Pl. II.)

MUD LAKE

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 included and considered a part of Mud Lake, and all deductions and conclusions are based on this definition of area. Hamer Lake, the Jefferson reservoir, the Jefferson reservoir addition, and Spring Lake are not included. North Lake was not tributary to Mud Lake during 1921. During the spring of 1922, however, North Lake spilled over into Mud Lake. Its area, capacity, and supply is considered a separate unit from Mud Lake in this report for the sake of convenience and because it was physically connected with Mud Lake only during 1922.

AREA AND CAPACITY

Plane-table surveys outlining the areas covered by the high and low stages of Mud Lake in 1921 were made during the season. (See Pl. II.) From these surveys and from soundings obtained through ice cover in January, 1922, area and capacity curves were constructed (fig. 8). Daily gage heights were obtained from a gage at the First Owsley intake, and these were supplemented by occasional readings from the Beckner gage, on the north shore of the lake, during periods when operation of the pumps at the First Owsley station caused erratic fluctuations in the intake. By means of these data the following table was prepared:

Gage height and contents of Mud Lake, April 1, 1921, to March 31, 1923

Date	Gage height (feet)	Contents (acre-feet)	Increase or decrease in storage during month (acre-feet)	Date	Gage height (feet)	Contents (acre-feet)	Increase or decrease in storage during month (acre-feet)
Mar. 31, 1921		[a] 42,490		Apr. 30, 1922	8.53	53,520	+6,260
Apr. 30, 1921	7.95	46,440	+3,950	May 31, 1922	8.90	58,240	+4,720
May 31, 1921	8.49	53,020	+6,580	June 30, 1922	8.00	47,020	−11,220
June 30, 1921	7.69	43,470	−9,550	July 31, 1922	6.60	33,040	−13,980
July 31, 1921	5.79	26,840	−16,630	Aug. 31, 1922	5.68	26,100	−6,940
Aug. 31, 1921	4.11	17,030	−9,810	Sept. 30, 1922	5.23	23,250	−2,850
Sept. 30, 1921	3.95	16,220	−810	Oct. 31, 1922	5.79	26,840	+3,590
Oct. 31, 1921	4.72	20,280	+4,060	Nov. 30, 1922	([b])	32,470	+5,630
Nov. 30, 1921	5.50	24,930	+4,650	Dec. 31, 1922	7.14	37,770	+5,300
Dec. 31, 1921	6.38	31,250	+6,320	Jan. 31, 1923	7.67	43,110	+5,340
Jan. 31, 1922	7.07	37,170	+5,920	Feb. 28, 1923	8.18	48,970	+5,860
Feb. 28, 1922	7.54	41,850	+4,680	Mar. 31, 1923	8.58	53,820	+4,850
Mar. 31, 1922	8.02	47,260	+5,410	Net increase in storage during year			6,560
Net increase in storage during year			4,770				

[a] Estimated. [b] Interpolated.

It is reported that 160 acres has been diked off since the capacity of Mud Lake was calculated. The total increase in storage from April 1, 1921, to March 31, 1923, was 11,330 acre-feet.

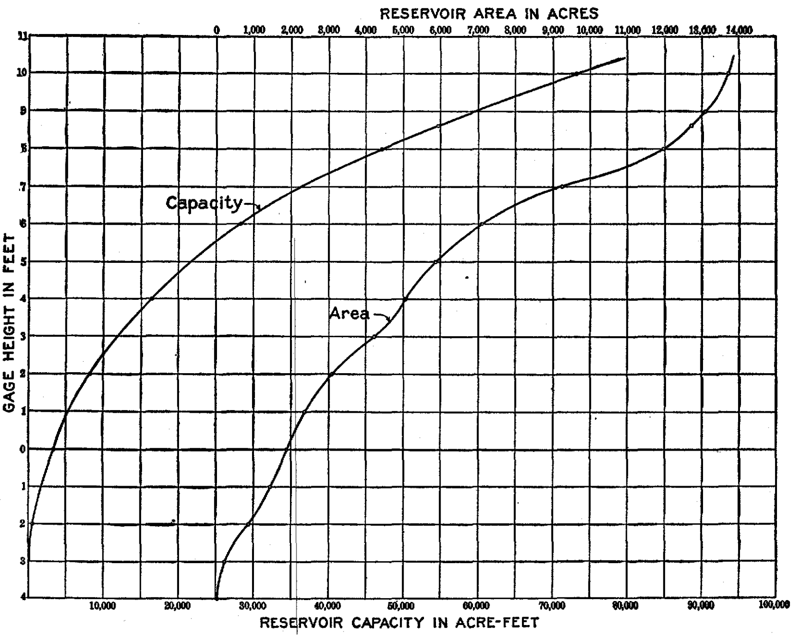


FIGURE 8.—Area and capacity curves for Mud Lake, Idaho, 1921–22

The maximum stage recorded during the year 1921 was at a gage height of 8.65 feet on June 7 to 9. This area of the water surface at this stage was 12,670 acres and the corresponding contents of the lake 55,040 acre-feet. The minimum stage was at a gage height of 3.94 feet on September 14 to 19. The area at this stage was 5,000 acres and the corresponding contents 16,160 acre-feet. Investigation of the dikes on the east, south, and west sides of the lake indicates that the lake could rise 1.5 feet above the highest level reached in 1921 without causing damage to surrounding territory. This would correspond to a capacity of 73,000 acre-feet, which is probably the maximum quantity of water that the lake with its present diking system could safely hold. Zero on the gage is 4,775.33 feet above sea level.

DIVERSIONS

On account of the levelness of the land surrounding Mud Lake most of the diversion canals are built in fills, and the water from the lake is pumped into them by means of electrically driven centrifugal pumps. Fifteen pumping plants have been installed around the lake, with maximum lifts ranging from about 2 feet at the Owsley Cooperative pumps to about 11 feet at the First Owsley pumps. The size of the units varies with the acreage under the several projects. The Second Owsley Co. has three pumps with a total capacity of 240 cubic feet a second, the Mud Lake project has two pumps with a total capacity of 160 cubic feet a second, and the First Owsley Canal Co. has three pumps with a total capacity of about 180 cubic feet a second. Power was supplied to each pumping unit by the Ashton-St. Anthony Power Co. at a flat seasonal rate. Most of these plants are designed and installed to pump water from a level corresponding to the deepest part of Mud Lake.

Eleven gravity ditches were used for diverting water for irrigation during 1921. Four of these, the Wiley, Melton, Welchman, and Owsley Cooperative, were used as intakes for their respective pumping plants later in the season when the lowering of the lake made pumping necessary.

A total of 40,690 acre-feet was diverted from the lake during the irrigation season of 1921 and 37,430 acre-feet during the season of 1922. These results were obtained from records that each operator kept indicating the number of hours each pump was in operation and the amounts pumped. These records were checked frequently by current-meter measurements. Estimates of the flow in gravity ditches, the amount of which is small compared with the total diversions, were based largely upon the capacities of the canals and the number of acres irrigated.

No shortage of water was experienced for irrigating the land under cultivation during 1921 or 1922. Several thousand acres of new land was put into cultivation during these years.

The facts in regard to diversions, irrigation, and storage can be summarized as follows:

1. During the irrigation season of 1921 a total of approximately 11,050 acres was irrigated with water from Mud Lake.

2. During the same season 40,690 acre-feet was diverted from the lake for irrigation, indicating a use of approximately 3.7 acre-feet to the acre.

3. At the end of the irrigation season 16,000 acre-feet remained in the lake.

4. There was 4,770 acre-feet more water in the lake on April 1, 1922, than on the same date the year before. (See table on p. 115.)

5. During the irrigation season of 1922 a total of approximately 11,218 acres was irrigated with water from Mud Lake.

6. During the same season 37,430 acre-feet was diverted from the lake for irrigation, indicating a use of approximately 3.3 acre-feet to the acre. The smaller use per acre in 1922 was probably due to favorable weather conditions, as there was more rain in August, 1922, than in August, 1921.

7. On October 1, 1922, at the end of the irrigation season, the gage height of Mud Lake was 5.24 feet, corresponding to 23,310 acre-feet of water, which was left in the lake.

8. There was an increase in storage from April 1, 1922, to March 31, 1923, of 6,560 acre-feet, making the total increase in storage from April 1, 1921, to March 31, 1923, 11,330 acre-feet.

LOSSES

Estimates of the losses due to evaporation and transpiration from the area occupied by the lake at its highest stage in 1921 are based on records obtained at the Mud Lake stations. (See "Climate" and table on pp. 101–102.) The evaporation from the open-water surface of the lake was taken to be 65 per cent of the evaporation from the land pan. The reasons for using the coefficient 0.65 have been discussed under "Climate." Of the total area of about 12,600 acres occupied by the lake at its highest stage, about 6,600 acres was covered with a rank growth of tules or other marsh plants and therefore lost heavily by transpiration. The records given on pages 101–102 show that this area lost water more rapidly than the open water of the lake. The additional loss from the submerged part of the 6,600 acres was computed for each month by multiplying the average area of this part by the difference between the loss from the land pan and the loss from the tule pan. The loss from the unsubmerged part of the 6,600 acres was computed by multiplying the average area by the loss from the tule pan. However, the figures for evaporation and transpiration are unavoidably less accurate than the other figures that are given in the inventory.

As the lake is underlain by nearly impervious clay, the loss due to seepage out of the lake is believed to be small.

WATER SUPPLY

Mud Lake receives most of its supply from Camas Creek, which flows into the lake about at the West Hamer bridge. The surface flow at this point, however, includes considerable ground water that is picked up from the near-by sloughs and flows into the creek above the bridge. In addition some surface inflow is derived from sloughs fed by ground water immediately west of the West Hamer bridge.

The following table gives a summary of the water supply of Mud Lake for the years ending March 31, 1922, and March 31, 1923, taking into account the measured surface inflow, precipitation upon the 12,600 acres of lake bed, losses due to evaporation and transpiration from the same area of 12,600 acres, diversions for irrigation, and storage in the lake.

Summary of the water supply of Mud Lake, years ending March 31, 1922 and 1923, in acre-feet

	1922	1923
Visible supply:		
Flow under West Hamer bridge	64, 700	74, 600
Other surface inflow	12, 400	12, 200
Total observed surface flow into the lake	77, 100	86, 800
Precipitation	8, 700	8, 600
	85, 800	95, 400
Withdrawals and storage:		
Water stored in Mud Lake at end of year	47, 300	53, 800
Water stored in Mud Lake at beginning of year	42, 500	47, 300
Increase in storage	4, 800	6, 500
Evaporation and transpiration	49, 600	55, 700
Diversions for irrigation	40, 700	37, 400
	95, 100	99, 600
Difference between total withdrawals and storage and total visible supply	9, 300	4, 200

The table summarizes the water supply of the lake in two different ways, which in a measure afford a check on the results obtained. The total visible supply takes into account all the measurable intake. On account of severe backwater conditions in Camas Creek at the West Hamer bridge the flow at that point was determined by means of miscellaneous measurements and careful graphic comparison with the flow at Wood's ranch and at Camas. These results, however, are believed to be fairly reliable, because at Camas the flow of the creeks was accurately measured and below Camas the inflow by seepage was very uniform. The flow into Mud Lake from sloughs west of the West Hamer bridge was also summarized by means of miscellaneous measurements, and as this flow was likewise very uniform the determination should be fairly reliable. If all the figures are accurate, about 9,300 acre-feet of water entered the lake during the year ending March 31, 1921, and 4,200 acre-feet during the year ending March 31, 1922, either through its bed or from other unseen sources. While soundings of the lake were being made through the ice in January, 1922, two distinct springs in the center of the lake were noticed to be discharging water under some pressure. The flow from these springs could easily amount to 4,200 to 9,300 acre-feet a year.

The following table shows approximately the part of the water supply of Mud Lake that came from underground sources:

Summary of contributions of ground water to Mud Lake, years ending March 31, 1922 and 1923, in acre-feet

	1922	1923
Total surface flow into the lake	77,100	86,800
Total flow of surface water (in Camas and Beaver creeks) near Camas	46,700	38,200
Surface inflow derived from ground water	30,400	48,600
Ground water discharged directly into the lake	9,300	4,200
Total quantity of ground water contributed to the lake	39,700	52,900

It must, of course, be borne in mind that the figures obtained as summarized in these tables are not absolutely correct. Many of the data could not be obtained by definite measurements, owing to the peculiar conditions that were involved, and it is therefore reasonable to expect some error in the results.

The table indicates a smaller flow of Camas and Beaver creeks into Mud Lake during the year ending March 31, 1923, than in the preceding year. To judge from records of precipitation and run-off in adjoining drainage areas, the run-off during 1921 was probably somewhat above the normal, yet during the year ending March 31, 1923, when the run-off was lower than in 1921, there was an increase in the visible supply, indicating definitely that there was a larger contribution of ground water. The difference is 13,200 acre-feet, which suggests that Mud Lake has not yet reached an equilibrium. This is also indicated by the steadily increasing stage of the lake.

ESTIMATE OF SUPPLY OF WATER AVAILABLE FOR IRRIGATION

By J. F. Deeds

Records obtained during the years 1921, 1922, 1923, and 1924 have been used in preparing the following tabulation of the water supply available for diversion from Mud Lake. The tabulation is made on the assumption of a yearly irrigation demand of 60,000 acre-feet, distributed through the irrigation season substantially in accordance with records showing the demand heretofore made on the Mud Lake and Minidoka pumping projects—that is, 13 per cent in May, 26 per cent in June, 26 per cent in July, 22 per cent in August, and 13 per cent in September. It is assumed also that if the lake is about empty on October 1, it will contain 35,000 acre-feet of water by the following April 1. The basis for this assumption is the fact that in one such period (October 1, 1921, to April 1, 1922) the lake, while receiving a measured surface inflow of 35,370 acre-feet, had its contents increased from 16,220 to 47,260 acre-feet, a gain of 31,040 acre-feet; and that in the following period (October 1, 1922, to April 1, 1923) the lake, while receiving a measured surface inflow of 41,940 acre-feet, had its contents increased from 23,310 to 53,840 acre-feet, a gain of 30,510 acre-feet. During the corresponding period of the next year (October 1, 1923, to April 1, 1924), the measured surface inflow amounted to about 44,790 acre-feet and the lake contents increased from 23,100 acre-feet to 55,400 acre-feet, a gain of 32,300 acre-feet. In each period the gain exceeded 30,000 acre-feet and was larger in proportion to the inflow while the lake was maintained at the lower level. The inference is strong that there would be an even greater gain, assumed at 35,000 acre-feet, if the lake were maintained at lower levels in accordance with the assumptions stated. The table shows records of rainfall and of evaporation and transpiration and quantities derived from these records as applied to the area of the lake surface corresponding to the contents at the beginning of each month. Transpiration is tabulated as directly affecting the water supply only during June, July, August, and September, the months of appreciable growth of aquatic vegetation, and then only on areas of lake surface in excess of 6,000 acres, as there is little or no vegetation in the central part of the lake that has this area.

The water-supply tabulation indicates shortages of 8,060, 1,340, and 11,880 acre-feet late in the irrigation seasons of 1921, 1922, and 1924, respectively, and a surplus of 3,580 acre-feet in 1923. The deficiencies would be at least partly absorbed by the unmeasured ground-water inflow during the irrigation season, for which no allowance was made in the tabulation. It appears, therefore, that approximately 60,000 acre-feet, distributed as needed for irrigation, could have been supplied from Mud Lake in each of the years 1921, 1922, 1923, and 1924, except for part of the 1924 shortage, which probably was abnormally great owing to the unusual low-water conditions that prevailed during the year in Idaho.

Estimated supply of water that would have been available for diversion from Mud Lake in 1921, 1922, 1923, and 1924, if there had been complete utilization

[Based on records of surface inflow and rainfall, taking into account observed losses through evaporation and transpiration, and assuming an annual irrigation demand of 60,000 acre-feet]

Month	Irrigation demand		Losses			Condition of lake on first day of month		Rainfall on lake		Flow of surface water into lake (acre-feet)	Surplus or shortage at end of irrigation season (acre-feet)
	Per cent	Acre-feet	Evaporation from free water surface (feet)	Evaporation and transpiration from water with tules (feet)	Total (acre-feet)	Contents (acre-feet)	Area (acres)	Feet	Acre-feet		
1921											
April	0	0	0.239	-------	2,120	35,000	8,850	0.004	35	6,125	-------
May	13	7,800	.431	-------	4,350	39,040	10,100	.190	1,920	20,430	-------
June	26	15,600	.568	0.737	8,030	49,240	12,270	.030	368	9,570	-------
July	26	15,600	.682	1.58	8,830	35,550	9,000	.052	468	1,430	-------
August	22	13,200	.530	1.5	2,340	13,020	4,420	.020	88	1,200	−1,230
September	13	7,800	.382	.462	0	0	0	.035	-------	970	−6,830
1922											
April	0	0	.217	-------	1,920	35,000	8,850	.057	504	5,060	-------
May	13	7,800	.513	-------	5,280	40,560	10,290	.098	1,010	16,900	-------
June	26	15,600	.568	1.12	9,590	45,390	11,520	.052	600	10,400	-------
July	26	15,600	.563	1.78	6,670	31,200	7,850	.052	410	4,900	-------
August	22	13,200	.486	1.44	2,250	14,240	4,630	.170	790	3,800	-------
September	13	7,800	.414	.85	780	3,380	1,880	.000	0	3,860	−1,340
1923											
April	0	0	.162	-------	1,430	35,000	8,850	.080	710	6,870	-------
May	13	7,800	.387	-------	4,040	41,150	10,440	.132	1,380	8,200	-------
June	26	15,600	.413	.48	4,330	38,890	9,860	.150	1,480	8,900	-------
July	26	15,600	.619	.97	5,030	29,340	7,360	.120	880	6,070	-------
August	22	13,200	.497	1.12	2,430	15,660	4,880	.090	440	5,670	-------
September	13	7,800	.392	.92	990	6,140	2,520	.042	105	6,130	+3,580
1924											
April	0	0	[a].200	-------	1,770	35,000	8,850	.009	80	10,180	-------
May	13	7,800	[a].440	-------	4,860	43,500	11,040	.014	155	7,150	-------
June	26	15,600	[a].520	[a].80	6,705	38,145	9,665	.008	77	3,100	-------
July	26	15,600	[a].620	[a]1.60	3,360	19,020	5,425	.095	515	2,770	-------
August	22	13,200	[a].510	[a]1.35	964	3,340	1,890	.006	11	3,310	−7,500
September	13	7,800	[a].396	[a].75	-------	0	0	.051	-------	3,420	−4,380

[a] Evaporation and transpiration losses estimated during 1924.

MINOR LAKES

HAMER LAKE

Hamer Lake is a natural reservoir supplied entirely by seepage of ground water, supplemented during the irrigation season of 1921 by a flow of approximately 6 cubic feet a second from the six artesian wells of the Hamer Canal Co. A ditch has been dug from Hamer Lake northwestward through several ponds and sloughs and drains water from them into Hamer Lake during the irrigation season, when the lake is low. A plane-table survey of Hamer Lake, made in 1921, showed a high-water area of 184 acres. At the high stage, about June 1, 1921, the lake had an average depth of 3 feet and a content of 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. show that 2,370 acre-feet was diverted during 1921 to irrigate between 450 and 500 acres. Because the surrounding water table was at approximately the same altitude as the surface of the lake there were apparently no seepage losses. The total loss from evaporation during the year was about 590 acre-feet as calculated from an estimated loss of 3.2 feet over an area of 184 acres. On March 10, 1922, the gage in Hamer Lake read 2.90; on June 16, 1921, it read 2.16. The total quantity of water taken from the lake from April 1, 1921, to March 31, 1922, by diversions and by loss due to evaporation was about 2,960 acre-feet. In addition some water flowed from this lake into Mud Lake and has been reckoned with the supply of Mud Lake.

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 during a period of high water. Because it was not tributary to Mud Lake in 1921 it was not considered in the measurements of area or capacity of Mud Lake, and its area and capacity were not included in 1922 because the calculations for the two 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 on that date. 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, and on October 10 it read 4.92. A plane-table survey of the lake, made in June, 1921, indicated a high-water area 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 3.21 feet (the figure obtained for Mud Lake, as explained on p. 100), because of the small additional loss by transpiration on the marshy area. According to this estimate, the total loss through evaporation and transpiration for the year was 4,010 acre-feet.

There are at present no diversions from the lake for irrigation. Hence 4,010 acre-feet can be assumed as the approximate annual supply. No soundings were made of the lake, but from careful 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, Idaho, 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. It is now 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. Very little water probably 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 upon the lands of the reservoir project or flows over the spillway into the Jefferson reservoir addition to the south.

3. As shown by the map (Pl. II), 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 also removed, 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 its high stage, on June 21, 1921, was 1,104 acres. On the same date the altitude, at a gage height of 3.09, 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 about 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 per cent of the reservoir consists of tule marsh, in which the loss by transpiration is doubtless high.

The above data show a total supply throughout the year, 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.

JEFFERSON RESERVOIR ADDITION

Between the Jefferson reservoir and Mud Lake is the Jefferson reservoir addition. A dike about 200 feet long prevents the flow from the sloughs and any waste water from the Jefferson reservoir from entering Mud Lake. The area of the water surface 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 and transpiration and diversions for irrigation during the summer, and 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 approximately 75 per cent 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 for 1921 is estimated at 1,500 acre-feet.

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 out 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 from evaporation and transpiration is probably high, as about 60 per cent of the reservoir 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 10,200 acre-feet. In addition there were seepage losses toward the west from the lake. At the high stage the reservoir is estimated to have an average depth of 1.5 feet and a capacity of 3,300 acre-feet.

A study of the meager data available leads to the conclusion that the present irrigated area is sufficient to utilize the entire available flow of the springs rising in this reservoir.

GROUND-WATER SUPPLY

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

The water supplies of the minor lakes (diversions for irrigation plus losses by evaporation and transpiration) as determined during 1921 are about as follows: Hamer Lake, 2,960 acre-feet; North Lake, 4,010 acre-feet; Jefferson reservoir, 7,690 acre-feet; Jefferson reservoir addition, 1,500 acre-feet; Spring Lake, 10,200 acre-feet; total, 26,360 acre-feet. Practically all of this water is derived from springs and seepage except that which falls on the lakes as rain or snow. The areas of these lakes used in the preceding calculations are as follows: Hamer Lake, 184 acres; North Lake, 1,180 acres; Jefferson reservoir, 1,104 acres; Jefferson reservoir addition, 250 acres; Spring Lake, 2,200 acres; total, 4,918 acres. If the precipitation during 1921 was 8.29 inches, the total amount of water that fell on the lake areas as rain or snow was 3,390 acre-feet. Deducting 3,390 acre-feet from the total supply of 26,360 acre-feet leaves 22,970 acre-feet, which was derived from ground water during the year ending March 31, 1922.

The total area covered by lakes, reservoirs, and marshy lands where the water table is not more than 5 feet below the surface is approximately 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 17,520 acres. Deducting 17,520 acres from 27,670 acres leaves 10,150 acres of wetted area which has not been taken into consideration but which was subjected to losses by evaporation and transpiration of ground water. Ground water that stands within a few feet of the surface will suffer loss by capillary raise and evaporation and by absorption and transpiration of plants. The depths from which ground water is discharged by these processes depends on the character of the soil and the kind of plants.

About 75 per cent 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 10,150 acres not previously considered. On this basis about 40,600 acre-feet was lost by evaporation and transpiration from the area in 1921. The precipitation upon the area, reckoned at 8.29 inches, amounted to 7,000 acre-feet. Deducting 7,000 acre-feet from 40,600 acre-feet leaves 33,600 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 13, 1921, in acre-feet

Mud Lake	39,700
Five minor lakes	22,970
Marshes not included with lakes	33,600
	96,270

The ground-water supply of the Mud Lake basin for the year ending March 31, 1923, was probably somewhat higher, for, as shown on page 119, 13,200 acre-feet more of ground water was contributed to Mud Lake in that year than in the previous year. Moreover, the fact that North Lake spilled over for a short time during the high water of 1922 indicates that there was an increase in the amount of ground water entering the basin. The total amount for the year ending March 31, 1923, was probably about 120,000 acre-feet.

ARTESIAN CONDITIONS

Conditions in lava.—Some of the lava is very permeable and yields large supplies of water with but little drawdown. As a rule, it is too permeable to confine the water under artesian pressure. During the geologic development of the Mud Lake region a period of sedimentation was often interrupted by volcanism. Thus lava sometimes flowed out upon impervious clays and, with the renewal of deposition, was some times buried by more clay beds. Such a condition produced the artesian basin that underlies Hamer. Here the water has found its way into permeable lava and has become confined between two nearly impervious beds of clay. Thus the formations in the Mud Lake basin produce only local artesian conditions. The impervious clay beds between successive lava beds are of much more practical value in preventing the water from sinking than in holding it under artesian pressure.

Seven flowing wells have been obtained in the vicinity of Hamer. Six of these (wells A to F, Pl. II) belong to the Hamer Canal Co., and one, in the SW. ¼ SW. ¼ sec. 20, T. 7 N., R. 36 E., belongs to Robert Clinton. All are 8 inches in diameter except wells A and B, which are 6 inches in diameter, and well F, 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 the vesicular, water-bearing lava of Monument Butte, where they obtain large quantities of water. The water in the lava is here confined under sufficient head 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 into the main canal.

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

Yield and head of flowing wells of the Hamer Canal Co.

	Depth (feet)	Yield		Head [a] (feet)	Specific capacity (gallons a minute for each foot of draw-down)
		Second-feet	Gallons a minute		
A	96	1.11	498		
B	120	1.11	498		
C	100	.95	427	[b] 2.75	155
D	60	1.35	605	1.18	512
E	60	1.24	556	1.25	445
F	100	2.23	[c] 1,003		

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

The table shows that the specific capacities of the wells are very large, especially those of wells D and E. Because of their large specific capacities, wells A and B, 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.

Conditions in deposits of gravel and sand.—Some areas in the Mud Lake region are underlain by great deposits of sand and gravel with intervening beds of clay, but no artesian water has been found in these deposits. However, few wells have gone very deep below the water table. It is possible that flowing wells may yet be obtained from deeper parts of these deposits, but the great depth to the water table to the south and west is distinctly unfavorable.

QUALITY OF WATER

Analyses of 17 samples of water 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 near-by sloughs. The water throughout the region is rather good for an arid basin where there is no outlet for the surface water. The good quality of water in the deposits of sand and gravel indicates that alkali and salts are 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 that contains 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, Idaho

[Analyzed by Margaret D. Foster. 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	NW. ¼ NE. ¼ 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	[a] 140	7	6.4	2.9	178	106		Do.
J. Hendrickson	NW. ¼ SE. ¼ 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	SE. ¼ NE. ¼ 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	NW. ¼ SW. ¼ 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	SE. ¼ SE. ¼ 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	SE. ¼ sec. 5, T. 7 N., R. 34 E.			27	.22	71	70	415	[a] 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	182	60	

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

RECOVERY OF GROUND WATER

Some of the lava is compact and dense and therefore not adapted for yielding water, but much of it is vesicular or jointed and yields water very abundantly. The yield of the Hamer flowing wells is typical. Two drilled wells, 1 mile north of Spring Lake, end in lava at depths of 44 and 40 feet and supply enough water for irrigation. Each of these wells is reported to have yielded over 70 miner's inches (1.4 cubic feet a second) with little drawdown during a test of one hour in July, 1921.

The recognized methods of developing irrigation wells in sand and gravel deposits are the result of a vast amount of costly experience by innumerable drillers, and those who wish to develop such wells should use these recognized methods and should preferably have the work done by drillers who are experienced in well work of this kind. There are different types of successful irrigation wells in sand and gravel, but the most generally successful type consists of double stovepipe casing that is inserted as the hole is made and that is later perforated at all satisfactory water-bearing beds as determined by a carefully kept log of the well.[7] The perforations are generally rather large—perhaps a quarter of an inch across—and the well is pumped hard and long to remove the fine sand and leave a natural strainer of coarse material around the intake of the well. If no coarse material is penetrated in the well it is sometimes practicable to shut out the sand and increase the yield by inserting gravel according to one of several methods.[8] However, this process of developing a well by inserting gravel is likely to be difficult and uncertain. If the sand is very fine and incoherent and there is no coarse material mixed or interbedded with it, successful irrigation wells may be impossible. It is not necessary to obtain all the water that is required for a farm from one well. It may be entirely feasible to get the required yield by sinking two or more wells and pumping them by suction, the suction pipes all being connected at about the water level with a single centrifugal pump. Caisson wells, such as have been dug on several farms in this area, have also been successful in some places where the water-bearing bed occurs near the surface, but they have not come into such general use as the stovepipe wells, which are very extensively used in California for irrigation.[9] If it is found that in this area water-bearing beds of sand and gravel occur only near the surface or that the water in the

[7] See U. S. Geol. Survey Water-Supply Papers 110, 140, 257, and 375; also 467, which describes a model irrigation well drilled by the Geological Survey.

[8] Meinzer, O. E., and Hare, R. F., Geology and water resources of Tularosa Basin, N. Mex.: U. S. Geol. Survey Water-Supply Paper 343, pp. 120–122, 1915.

[9] See U. S. Geol. Survey Water-Supply Paper 375, pp. 1–49, 1916. Experiments with caisson wells have been made by the Arizona Agricultural Experiment Station. See Smith, G. E. P., A concrete caisson well: Cement Age, vol. 7, pp. 304–308, 1908.

deeper beds has too low a head to be available for pumping for irrigation, the caisson wells may prove best adapted to the local conditions. However, an adequate test should, if possible, be made with a properly constructed stovepipe well that is carried to considerable depth.

CONCLUSIONS

The data given in this report indicate that the total supply of water which appeared at the surface in Mud Lake and vicinity from April 1, 1921, to March 31, 1922, amounted to about 162,000 acre-feet, of which 95,000 acre-feet appeared in Mud Lake, 26,000 acre-feet appeared in five smaller lakes or reservoirs, and 41,000 acre-feet was discharged by evaporation and plant growth without reaching any of these lakes or reservoirs. Of the total that appeared at the surface about 96,000 acre-feet or a little more came from underground sources, 47,000 acre-feet or nearly that amount flowed into Mud Lake from Camas Creek without having passed underground, and 19,000 acre-feet fell upon the wetted area as rain or snow. In addition to the 162,000 acre-feet that appeared at the surface an unknown but probably considerable quantity of water escaped from the basin by percolation toward the south and west.

The aggregate flow of Camas and Beaver creeks at the upper gaging stations amounted during the year ending March 31, 1922, to 143,000 acre-feet. A large part of this water doubtless reappeared at the surface in Mud Lake and vicinity. The data given in the preceding paragraph indicate that 143,000 acre-feet appeared in Mud Lake and vicinity exclusive of the rain and snow that fell upon the wetted area. The exact agreement of these two quantities is, of course, accidental. Other possible sources of ground water are losses of Camas and Beaver creeks above the upper gaging stations, losses from Medicine Lodge Creek, losses from several smaller creeks in the same region, percolation of water from rain and snow that did not reach any of these creeks but sank in certain areas of permeable gravel or lava, and water that percolated westward from the irrigated district of Egin Bench.

The results given on page 118 show that the supply of Mud Lake for the year ending March 31, 1923, was greater than that for the previous year, indicating that the supply of Mud Lake is still increasing.

Of the total of 162,000 acre-feet that appeared at the surface in Mud Lake and vicinity in the year ending March 31, 1922, 4,800 acre-feet was stored in Mud Lake, about 49,000 acre-feet was used for the irrigation of about 13,300 acres, and about 108,000 acre-feet was discharged by evaporation or by transpiration from tules and other native plants of small economic value. These data show that the natural losses were very large in proportion to the quantity used for irrigation. They at once raise the question whether the supply for irrigation can be increased by reducing the natural losses.

The question arises whether the natural losses can be diminished by further diking the lakes so as to decrease their areas. This question can not be definitely answered in the present stage of the investigation, but the conditions do not appear to be promising for improvement by such means. A restriction of the area of the lakes would result in a rise in the water level, and this rise would tend to extend the swampy areas and to increase percolation out of the basin. It is therefore not evident that further diking would increase the supply available for irrigation. The natural losses will, however, be diminished by more nearly complete utilization of the water, as is explained by Mr. Deeds on pages 119–121.

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.

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