Geology and Ground-Water Resources of the Lower Marias Irrigation Project Montana

By FRANK A. SWENSON

With a section on

CHEMICAL QUALITY OF THE GROUND WATER

By HERBERT A. SWENSON

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1460-B

Prepared as part of the program of the Department of the Interior for the development of the Missouri River Basin

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1957

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C.

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CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GEOLOGY AND GROUND-WATER RESOURCES OF THE LOWER MARIAS IRRIGATION PROJECT, MONTANA

By Frank A. Swenson

ABSTRACT

The Lower Marias irrigation project is in northern Chouteau County, southern Hill County, and southeastern Liberty County in north-central Montana. According to plans of the U. S. Bureau of Reclamation, water of the Marias River will be stored in the Tiber reservoir and will be used to irrigate approximately 127,000 acres of farmland, about two-fifths of which is in the drainage basin of the Marias River and three-fifths in the drainage basin of the Milk River.

A succession of sandstones and shales of Cretaceous age underlies the entire report area. These rocks consist of the Colorado shale, Telegraph Creek formation, Eagle sandstone, Claggett shale, and Judith River formation and have an aggregate thickness of about 3,300 feet. All but the Colorado shale are exposed in the area. Mantling the bedrock are unconsolidated deposits of Quaternary age. These deposits consist principally of ground moraine deposited by one or more continental glaciers that advanced over the area during Pleistocene time, of outwash deposits laid down by glacial melt water, of paludal or lake deposits in depressions, and of alluvium deposited by postglacial streams. The deposits of Quaternary age range in thickness from a little more than 250 feet where they fill buried valleys to a featheredge where they border exposures of bedrock.

The Virgelle sandstone member of the Eagle sandstone and the Judith River formation are the two principal bedrock aquifers. The Virgelle sandstone member is about 450 feet below land surface in the western part of the area and about 750 feet in the northeastern part. Faulting 3–5 miles north of the Big Sandy has raised the Virgelle close to the surface, and relatively shallow wells drilled close to the faults on the upthrown side would reach this aquifer. Water in the Virgelle is highly mineralized, except possibly near the faults. The mineralization increases northward and eastward down the dip of the formation. The Judith River formation is present only in the eastern part of the area and is tapped by many relatively shallow wells. The water in this formation is of good quality and is preferred wherever it is available.

Fairly large supplies of water of moderately good quality can be obtained from the alluvial fans along the base of the Bearpaw Mountains at the eastern edge of the area and from the deposits filling the buried valleys of the ancestral Missouri and Marias Rivers. Small supplies of water are available at shallow depth from lenses of permeable material in the ground moraine.

Unless only small amounts of water are used for irrigation or unless provision is made for the disposal of irrigation water in excess of crop needs, many parts of the Lower Marias irrigation project are likely to become waterlogged. It is recommended that a network of observation wells be installed in all irrigated areas and that measurements of the water level in these wells be made periodically for at

least several years after irrigation begins so that waterlogging can be detected in its incipient stage and drainage measures started soon enough to prevent serious damage.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The investigation upon which this report is based is one of several made as part of the program of the United States Department of the Interior for the development of the Missouri River basin. The purpose of the investigation was to obtain and interpret data on the occurrence and chemical quality of the ground water and to relate these data to the geology of the area. This information will be helpful in determining the effect irrigation will have on the ground-water regimen.

That part of the area included in the Lonesome Lake no. 2 and Goose Mountain no. 1 and no. 2 quadrangles was mapped in detail by J. F. Smith, I. J. Witkind, D. E. Trimble, and E. G. Duckworth, of the Geological Survey, during the same field season that the writer mapped the remainder of the area by reconnaissance methods. Much of that part mapped by the writer is included in the Boxelder, Kenilworth, and Big Sandy quandrangles which were mapped in detail by R. M. Lindvall, also of the Geological Survey, subsequent to the writer's reconnaissance field work. A large part of the geologic map (pl. 2) accompanying this report is adapted from the detailed mapping; only the extreme eastern part was mapped solely by the writer.

In addition to his geologic investigation, the writer visited 207 wells throughout the area and recorded data pertaining to the depth and diameter of each well, the depth to water, the method of lift, and the quantity, quality, and geologic source of the water. To determine the thickness and nature of the material filling the buried valley of the ancestral Missouri River, the Geological Survey contracted for the drilling of 18 test holes. From this information and that obtained from the logs of existing water wells and from the logs of seismograph shot holes drilled by oil companies, a map showing the thickness of the unconsolidated deposits that mantle the bedrock was prepared for a large part of the area. Measurements of the water level in selected wells were made monthly by the writer as part of the field investigation; the U. S. Bureau of Reclamation has continued measurements in some of these wells to date (1953). Chemical analyses were made of 25 samples of water collected from wells in the area.

Although the principal part of the field work for this investigation was done during the summer of 1946, additional visits to the area were made by the writer during subsequent years. The study was made under the direct supervision of G. H. Taylor, regional engineer in charge of ground-water studies in the Missouri River basin. The quality-of-water study was made under the immediate supervision of P. C. Benedict, regional engineer in charge of quality-of-water studies in the Missouri River basin.

PREVIOUS INVESTIGATIONS

The bedrock in north-central Montana has been described in several geologic reports, the authors and titles of which are listed in the selected bibliography at the end of this report. Many of these reports pertain principally to the occurrence of oil, gas, and coal, and only one (Perry, 1931) is concerned primarily with the occurrence of ground water. Reports describing the unconsolidated deposits of Pleistocene age in north-central Montana have been written by Calhoun (1906) and Alden (1932), but neither report describes in detail the glacial and postglacial deposits within the area covered by the Lower Marias irrigation project.

ACKNOWLEDGMENTS

The writer is grateful to the many persons who contributed information and assistance. Vic Case and Robert McCutcheon, well drillers, furnished detailed logs of several wells they had drilled in the area. Lee Waddell, owner of the Western Drilling Co., Garden City, Kans., and his drilling crews were of assistance beyond the requirements of the contract to drill test holes for the investigation. T. R. Smith, of the Bureau of Reclamation, construction engineer for the Lower Marias irrigation project, furnished photostat copies of original topographic maps and arranged to continue the periodic measurement of water levels in the observation wells after the writer's field work was completed. Others of that Bureau determined the altitude of the measuring point of several wells. G. E. Bowery, county surveyor, furnished maps of Hill County and data concerning gravel deposits in the county. Residents of the area permitted examination and measurement of their wells and supplied pertinent information about them.

WELL-NUMBERING SYSTEM

The wells listed in this report are numbered according to their location within the United States Bureau of Land Management's survey of the area. The first numeral of the well number denotes the township; the second, the range; and the third, the section in which the well is located. Lowercased letters following the section number show the location of the well within the section. The first letter indicates the quarter section, and the second, the quarter-quarter section. These subdivisions are designated a, b, c, and d, the letters being assigned counterclockwise. If two or more wells are located within the same quarter-quarter section, consecutive numbers beginning with 1 follow the lowercased letters. (See fig. 1.)

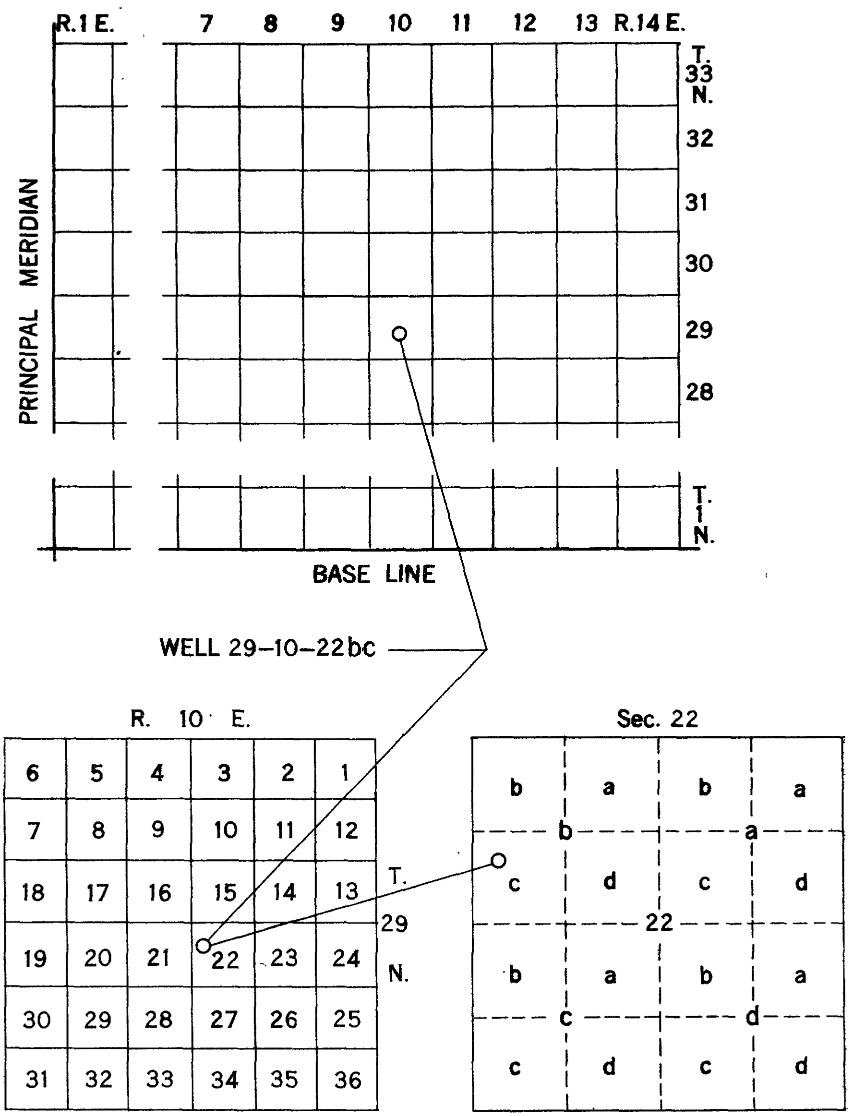

FIGURE 1.—Well-numbering system.

HISTORY

The history of the area described by this report is an interesting story of exploration and settlement but can be discussed only briefly here.

The first white men in the region were wandering trappers who crossed it when going to and coming from the trapping grounds in the mountains to the south and west. The earliest of these probably were associated with the Hudson's Bay Company and other Canadian companies, and they left little record of their visits. The first records that are well authenticated were made by members of the Lewis and Clark Expedition.

In July 1806 on his way back to St. Louis, Mo., after reaching the Pacific Ocean, Capt. Meriwether Lewis, accompanied by several men, traveled north from the Great Falls of the Missouri, and it is thought, from their description of streams that the party reached the Marias River near the mouth of Pondera Creek. They recorded that buffalo, deer, antelope, and wolves were abundant, that trees grew only along the river bottoms, that the broad plains between stream courses were covered with short prairie grasses and prickly pear, and that the undrained depressions contained small ponds of strongly mineralized water or alkali-rich mud which baked "firm as a brickbat." In general, Lewis did not consider the land fertile because of the great quantity of small gravel in the soil; this impression, however, probably was occasioned in part by the contrast between this area and the fertile, well-watered Columbia River plains he had recently crossed.

Cattlemen began moving into Montana about 1870. Within a few years thousands of cattle were grazing the prairie grasses; the lowland range was completely utilized, and in summer large herds were taken to mountain pastures.

Considerable clamor to open the country to homesteaders attended the building of the Great Northern Railway. The illustrious Jim Hill, the "Empire Builder," took an active part in this agitation in order to secure freight shipments for the new railroad. When homesteading was finally authorized, the Great Northern conducted a great publicity campaign to interest possible homesteaders.

After considerable study of the arid lands in the Western United States and with a view toward proper utilization of these areas, Maj. John Wesley Powell, the second Director of the U. S. Geological Survey, made some pertinent statements which, if they had been followed, would have saved great expenditures of labor and money in settling the West. In his report (1878) Powell says:

> * * * Experience teaches that it is not wise to depend on rainfall where the amount is less than 20 inches annually, if this amount is somewhat evenly distributed throughout the year; but if the rainfall is unevenly distributed, so that "rainy seasons" are produced, the question whether agriculture is possible without irrigation depends upon the time of the "rainy season" and the amount of its rainfall. * * *
>
> The limit of successful agriculture without irrigation has been set at 20 inches, that the extent of the Arid Region should by no means be exaggerated; but at 20 inches agriculture will not be uniformly successful from season to season. Many droughts will occur; many seasons in a long series will be fruitless; and it may be doubted whether, on the whole, agriculture will prove remunerative. * * *

Powell stated also that only a small part of the arid region could be irrigated by private means and that the effective utilization of major streams could take place only under arrangements for cooperative labor or aggregated capital. From his studies throughout the region, Powell concluded that land which could not be irrigated should be kept in permanent pasture. "Pasturage farms," as he called them, would require small tracts of irrigable land for gardens, grain, and winter feed for cattle, and he stated that—

> Four square miles may be considered as the minimum amount necessary for a pasturage farm, and a still greater amount is necessary for the larger part of the lands; that is, pasturage farms, to be of any practicable value, must be of at least 2,560 acres, and in many districts they must be much larger.

If these early warnings by Powell had been followed, the land in much of Montana would not have been opened for homesteading on quarter-section (160-acre) tracts, and people would not have come into the country hopeful of owning prosperous farms and becoming independent, only to be faced with crop failures that plunged them deeper and deeper into debt and brought financial ruin to many.

On each quarter section of land now included in the Lower Marias irrigation project are abandoned buildings, or foundations of those which have collapsed—graphic evidence of lost hopes and great financial loss. Some of the early homesteaders, however, survived these reverses and gradually were able to acquire the tracts formerly owned by their less fortunate neighbors. At present, the average farm contains probably more than 1,500 acres. The use of modern mechanized equipment, the planting of drought-resistant strains of wheat, and the practice of stripcropping and summer fallowing accounts in a large measure for the present relative prosperity of the farmers in the area. Ever since the land was originally homesteaded, the general tendency has been to increase the size of the farms, until now the limits recommended by Powell in 1878 are being approached.

The earliest well for which a record is now available (well 28–13–18ac) was drilled by the McNamarra and Marlow Cattle Co. in 1888 on the north edge of the present town of Big Sandy. In 1912, filings were made on the first homesteads in the western part of the area. By 1917 many small-diameter wells had been drilled into bedrock, and some of these wells are still in use. No wells in the area, however, produce water in sufficient quantity for irrigation, but some small plots along the east edge of the project are irrigated with water from streams draining the Bearpaw Mountains.

GEOGRAPHY

LOCATION AND EXTENT OF THE AREA

The Lower Marias irrigation project is in north-central Montana and includes a part of northern Chouteau County, southern Hill County, and southeastern Liberty County. (See fig. 2.) It covers an area of about 325 square miles and extends from a point about 18 miles southeast of Chester to within 6 miles of Havre. The only towns within the area are in the eastern part; their population in 1950 was as follows: Big Sandy, 743; Boxelder, 275; and Laredo, 150.

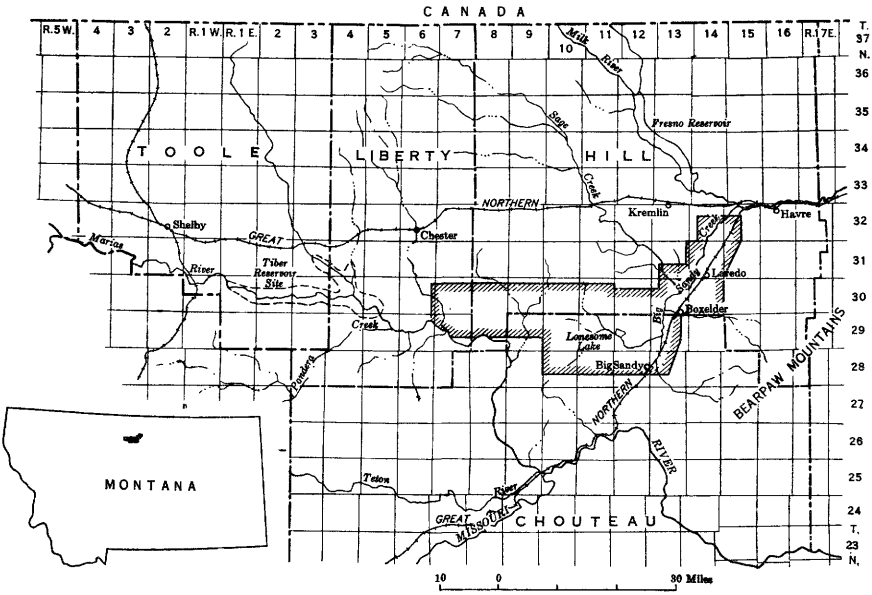

FIGURE 2.—Map showing the area described by this report.

CLIMATE

The climate of the report area is arid to semiarid and is characterized by wide deviations from average rainfall. Incomplete records of precipitation have been kept at Big Sandy since 1921; and at Chester (about 18 miles northwest of the report area), since 1942; and complete records have been kept at Havre (about 6 miles northeast of the report area) since 1880. The average annual precipitation from the beginning of the period of record through 1953 was 11.81 inches at

Big Sandy, 9.09 inches at Chester, and 13.02 inches at Havre. The average monthly precipitation at these towns is as follows:

Average monthly precipitation (in inches) at Big Sandy, Chester, and Havre, Mont.

Town	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Big Sandy	0.27	0.38	0.59	0.79	1.81	2.85	1.24	1.16	1.17	0.51	0.48	0.56	11.81
Chester	.28	.17	.30	.54	1.47	2.42	1.03	1.09	.82	.43	.21	.33	9.09
Havre	.65	.47	.58	.89	1.78	2.85	1.63	1.16	1.20	.68	.55	.58	13.02

At Havre the annual precipitation has ranged from 6.76 to 25.67 inches. The annual totals (see fig. 3) do not reflect the erratic distribution of rainfall during the year—several months of negligible precipitation may be followed by several months of heavy precipitation. Generally, the wettest months are May, June, and July. If the driest months (that is, the driest January, the driest February, during the

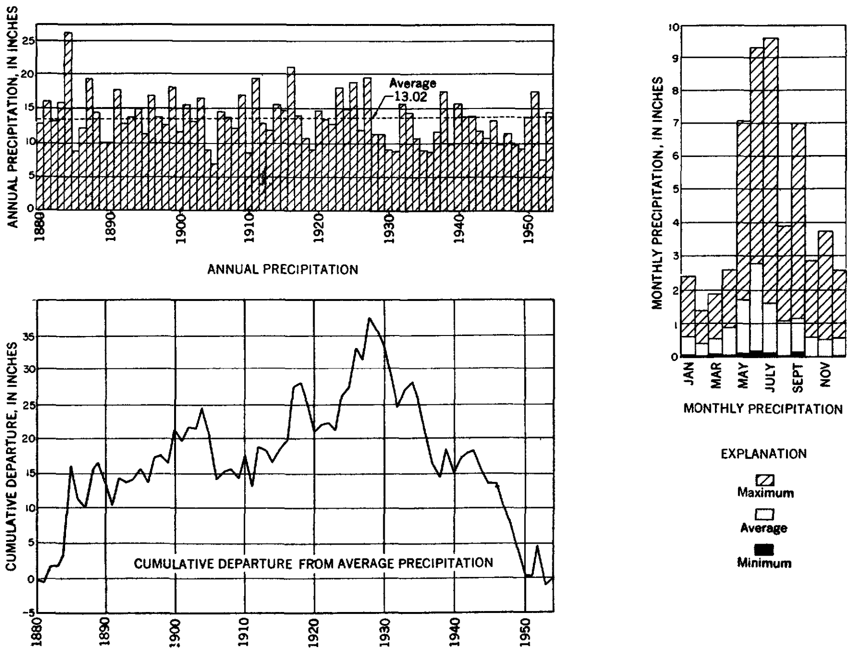

FIGURE 3.—Precipitation records at Havre, Mont., 1880-1953.

period of record had occurred in a single year, the total annual precipitation would have been only 0.86 inch. Likewise, if the wettest months had occurred in a single year, the total annual precipitation would have been 53.71 inches. The least, average, and greatest amounts of precipitation received at Havre during the period of record also are shown in figure 3.

Long-term deficiencies and excesses of precipitation at Havre are shown by a graph of the cumulative departure from average precipitation. (See fig. 3.) A rising line of the graph indicates above-average precipitation, and a falling line indicates less-than-average precipitation. For example, an excess of about 37 inches of precipitation was received from 1880 through 1927, despite the fact that precipitation during 19 of the years was less than average. Since 1927 the annual precipitation at Havre generally has been less than average, and the cumulative excess that existed at the end of 1927 has been offset completely by the cumulative deficiency from 1928 through 1953. Above-average precipitation was received during only 8 years of this latter period.

The average annual temperature is 41.7°F at Big Sandy, 41.0°F at Chester, and 41.6°F at Havre. Within the period of record the temperature at Havre has ranged from —57°F to 108°F. The average temperature of February, the coldest month, is 13.6°F and of July, the warmest month, 68.3°F. The average monthly temperature is below freezing from November to March, inclusive; and the average growing period between frosts is 124 days at Big Sandy, 105 days at Chester, and 129 days at Havre.

AGRICULTURE

The Lower Marias irrigation project and vicinity is considered to be one of the best areas in Montana for growing wheat. It is estimated that at least 90 percent of the cultivated area is planted to this crop. Nearly all farmers practice stripcropping and summer fallowing because fewer crop failures occur if fields are cropped in alternate years and if land lying fallow is cultivated to keep it in condition to receive and retain moisture and to keep down the weeds. The strips, usually 250–500 feet wide and half a mile long, are laid out normal to the prevailing westerly winds. During the dry, windy months in early spring, the alternate strips of fallow land effectively reduce blowing of soil from the planted strips. Almost all the farms are large, ranging from several hundred to several thousand acres, and all are mechanized. With modern equipment one man can easily farm 1,000 acres by practicing summer fallowing. Some livestock is grazed on the rougher, less fertile parts of the area.

Few trees break the monotony of the open prairie, and some farmers have planted shelter belts but generally the trees do not thrive. In the eastern part of the area, fairly large cottonwood, willow, and boxelder trees grow along Big Sandy Creek.

TRANSPORTATION

A branch line of the Great Northern Railway passes through Big Sandy, Boxelder, and Laredo and is the only railroad in the area. It joins the main line at a point about 4 miles west of Havre. U. S. Highway 87, the only paved road in the area, parallels the railroad.

The principal roads are graded up above the surrounding country and are bordered by deep wide ditches. These roads are so designed that the wind will sweep them free of snow; hence they are known locally as "snow roads." The deep ditch on either side of the road facilities drying of the road after rain and when the frost is leaving the ground. Some of the snow roads are graveled; those that are not are very slippery when wet. Other roads in the area are no more than tracks along section lines, but these "range roads," as they are called, often are used when the snow roads are too muddy because the tough sod can bear considerable weight and detours can be made easily if mudholes form.

GEOMORPHOLOGY

PRESENT TOPOGRAPHY AND DRAINAGE

The Lower Marias irrigation project is in the glaciated Missouri Plateau section of the Great Plains physiographic province, as described by Fenneman (1931). The major part of the area is a gently rolling drift-covered plain about 2,900 feet above sea level. At the east end of the area, a broad valley extends along the west base of the Bearpaw Mountains from a point a few miles south of Big Sandy to within a few miles of Havre. This valley was the course of the Missouri River during part of Pleistocene, and probably pre-Pleistocene, time. Low alluvial fans have been built in the valley by the streams that drain the Bearpaw Mountains. Small undrained depressions are common in many parts of the area. The steep-walled valley of the Marias River borders the south side of the extreme western part of the area. It is about 200 feet deep.

The western two-fifths of the report area is in the drainage basin of the Marias River. Although some of the runoff in this part of the area is direct to the Marias River, most of it is through Black Coulee, which connects with the Marias River. The north-central part of the area is drained by Fourteenmile Coulee, and the south-central part, by Twelvemile Coulee. These coulees join and drain into a depression, known as Lonesome Lake, about 8 miles northwest of Big Sandy.

Although Twelvemile and Fourteenmile Coulees drain a large area, they rarely carry any surface flow. During the summer of 1946, a rainstorm of cloudburst proportion centered over Fourteenmile Coulee, and this coulee had a considerable flow for a few hours where it enters T. 29 N., R. 11 E. The water spread over the dry bed of Lonesome Lake and rapidly sank into the ground. People living near Lonesome Lake say that, in the 15 or 20 years before 1947, water never remained in the lake longer than a few days. In the spring of 1947, however, sudden melting of the snow cover while the ground was still frozen caused the lower part of the lake basin to fill with water. Because the lake basin would have to be full before any water could flow from it into Lonesome Lake Coulee and thence into Big Sandy Creek, it is doubtful whether any surface flow through Lonesome Lake has reached Big Sandy Creek for many years.

The broad valley in the eastern part of the area is drained by Big Sandy Creek and its tributaries. Big Sandy Creek heads in the Bearpaw Mountains southeast of the report area. Measurements of its flow where it enters the Lower Marias irrigation project are given below. As it flows northeastward across the eastern part of the report area, Big Sandy Creek is joined by Lonesome Lake Coulee from the west, Duck, Camp, and Boxelder Creeks from the east, and Sage Creek from the northwest. Lonesome Lake Coulee rarely contributes appreciable flow to Big Sandy Creek. The combined flow of Duck and Camp Creeks is retained in several stock ponds near the east edge of the valley, and little, if any, water reaches Big Sandy Creek from these tributaries. A small perennial flow in Boxelder Creek through the town of Boxelder is maintained by releases from two reservoirs constructed on the creek by the U. S. Bureau of Indian Affairs. Many stock ponds catch and hold the meager flow of Sage Creek, so that in normal seasons it contributes minor amounts of water to Big Sandy Creek.

Discharge (in acre-feet) of Big Sandy Creek, 2.5 miles southeast of Big Sandy, Mont.

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1946	------	------	------	------	------	1,240	304	212	180	209	114	135
1947	323	261	198	76	181	2,190	949	352	178	83	68	69
1948	87	166	235	236	182	473	414	169	92	80	26	25
1949	166	125	80	43	16	448	238	66	25	109	0	0
1950	0	0	0	0	12	107	44	22	15	4.0	41	7.3
1951	80	108	136	60	12	928	173	195	105	136	30	111

In general, the drainage system is poorly developed, and there is little runoff from the area proposed for irrigation. Small undrained depressions are common in parts of the area remote from the established drainage courses.

PREGLACIAL TOPOGRAPHY AND DRAINAGE

When the first continental ice sheet advanced southward, the area described by this report had considerably greater topographic relief than it has now. At that time the ancestral Missouri River flowed northeastward along the west base of the Bearpaw Mountains from a point near Loma, about 28 miles southwest of Big Sandy. The bottom of the gorge occupied by the ancestral Missouri was about 250 feet lower than the valley now occupied by Big Sandy Creek. Streams entering this gorge from the Bearpaw Mountains had steep gradients, and probably both sides of the main valley were characterized by badlands. At that time the Marias River, instead of making a sharp turn to the south as it now does at the west edge of T. 29 N., R. 9 E., flowed in an eastward course across the report area and joined the ancestral Missouri River a few miles southwest of Boxelder. The floor of the gorge of the ancestral Marias River was about 300 feet below the present land surface. From logs of seismograph shot holes and records of wells, it has been possible to trace the approximate course of the Marias River at that time. (See fig. 4.) These data indicate also the existence of other valleys now so completely filled with glacial deposits that there is little surface indication of their presence.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

In the western part of the area rocks of Late Cretaceous age crop out along the valley of the Marias River; in the eastern part of the area, they crop out in only a few scattered places. Elsewhere, the bedrock is mantled by glacial deposits of Pleistocene age and by alluvium and by pond and lake deposits of Recent Age. (See following table.) The formations of the Upper Cretaceous series consist of sediments deposited under shallow marine, littoral, or continental conditions. The exposed boundaries between bedrock formations are shown on plate 2 by solid lines. The approximate positions of the buried boundaries between bedrock formations were mapped on the basis of data from available well logs and are shown on plate 2 by broken lines.

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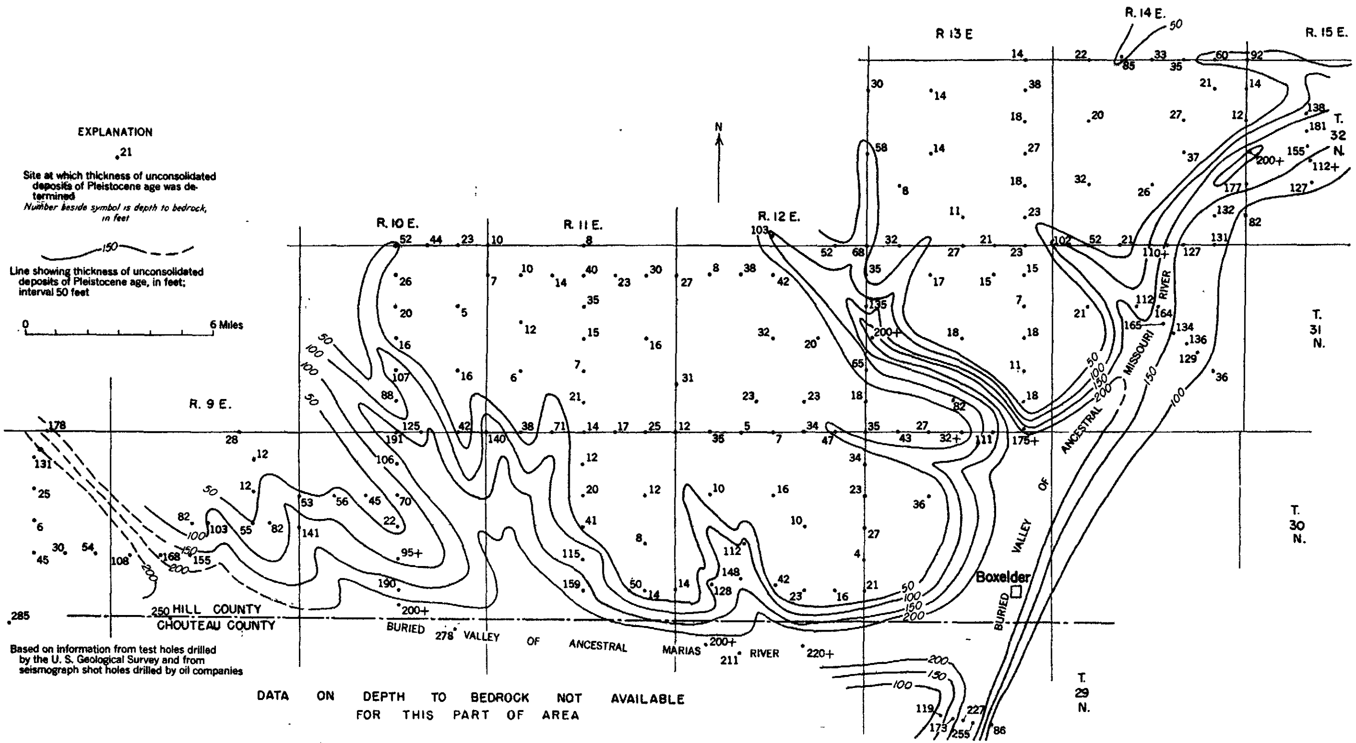

FIGURE 4.—Map of the Lower Marias irrigation project showing the thickness of unconsolidated deposits of Pleistocene age.

Geologic formations in the Lower Marias irrigation project area

System	Series	Formation	Thickness (feet)	Description	Water-bearing properties
Quaternary	Recent	Alluvial fans, flood-plain deposits, and pond and lake deposits.	0–50	Consist of clay, silt, sand, and gravel. Alluvial fans are present along base of Bearpaw Mountains at east edge of area. Flood-plain deposits along intermittent streams are narrow but along Big Sandy Creek are fairly broad. Paludal sediments form the floor of numerous undrained depressions, the largest being that along Black Coulee, that occupied by Lonesome Lake, and that along Big Sandy Creek near the town of Big Sandy.	Alluvial fans of Boxelder, Duck, and Beaver Creeks are a source of moderate supplies of water of good quality. About 40 wells in town of Boxelder tap an alluvial fan. In general, the flood-plain deposits and paludal sediments are too thin and fine grained to be a source of ground water.
	Pleistocene	Glacial deposits	0–300	Consist of unsorted clay, silt, sand, gravel, and boulders (glacial till) and stratified deposits of sand and gravel (kames, eskers, and ice-contact deposits). Fill-buried valleys of ancestral Marias and Missouri Rivers and mantle-buried bedrock uplands.	Wells tapping glacial till discharge only meager supplies of water. Saturated stratified deposits, particularly those present in the buried valleys, are sources of small to moderately large supplies. In some places water in till is considerably mineralized; elsewhere it is of good quality. Water from stratified deposits is generally of good quality.
Cretaceous	Upper Cretaceous	Judith River formation	0–200	Consists mostly of light-colored continental and brackish-water deposits of thin-bedded sandstone, massive sandstone, clayey carbonaceous shale, and lignite. Locally, a massive brown sandstone as much as 50 feet thick is present near the base. Rests conformably on Claggett shale; the boundary is arbitrarily set at base of lowest prominent sandstone bed.	Small to moderate quantities of water are obtained from this formation where it is sufficiently thick and adequately recharged. Wells drilled 20–50 feet into it discharge 5–15 gallons per minute. Although moderately mineralized, the water is soft and is extensively used for domestic and stock purposes in the northeastern part of the area.
		Claggett shale	0–500	Consists of black to dark-brownish-gray marine shale containing thin layers of gray shaly sandstone and lenses of dark-gray calcareous concretions in its upper part and thin beds of bentonite in its lower part. Rests conformably on the upper member of the Eagle sandstone; the boundary is at the contact of the dark shale with the lighter colored sandy shale of the upper member of the Eagle.	Yields little, if any, water to wells; probably only small amounts of highly mineralized water could be obtained from this formation.

		Eagle sandstone	Upper member	100–175	Consists of poorly cemented buff-gray to brown shaly sandstone and shale interbedded with carbonaceous shale and lignite. The base of the member generally is marked by a dark-gray to black sandy bed containing magnetite and titanite.	Yields small amounts of water to a few wells.
			Virgelle sandstone member	35–100	Consists of light-gray to buff fine- to coarse-grained massive crossbedded sandstone that forms prominent bluffs where it is exposed along the Marias River. In places the sandstone contains calcareous concretions.	This member is the most important aquifer in the area, although in some places the water is too highly mineralized for domestic use. Wells tapping the aquifer discharge at least 10 gallons per minute.
		Telegraph Creek formation		100	Consists of alternating fine-grained gray sandstone and light- to dark-gray marine shale.	Yields no water to wells in report area. Probably only small amounts of highly mineralized water could be obtained from this formation.
	Lower Cretaceous	Colorado shale		1,800–2,200	Consists of gray to blue-black fissile marine shale and numerous thin beds of bentonite; contains dark-gray calcareous concretions.	Yields no water to wells in report area. Probably only small amounts of highly mineralized water could be obtained from this formation.

CRETACEOUS SYSTEM (LOWER AND UPPER CRETACEOUS SERIES)

COLORADO SHALE

Although the Colorado shale underlies the entire report area, it is not exposed anywhere within the area. The nearest outcrop of this formation is in the valley of the Marias River about 1 mile west of the western boundary of the report area, and there the exposed upper 100 feet of the formation consists of gray to blue-black fissile marine shale interbedded with 16–18 thin beds of bentonite. Small dark-gray concretions are present in beds of irregular thickness. The driller's log of the Williston-Shelby-Flack oil test well 28–11–12ad indicates the Colorado shale to be 2,290 feet thick, but part of this thickness may be the Telegraph Creek formation, which overlies the Colorado shale. (See log in table 2.) The Colorado shale is not considered a potential source of ground-water supply. No water-bearing beds have been found in it, and any small amount of water that might be obtained probably would be too highly mineralized for most uses. At the present time it is not considered feasible to drill through this great thickness of shale in order to tap water-bearing beds in older formations, and it is not known whether any of the older formations contain potable water.

CRETACEOUS SYSTEM (UPPER CRETACEOUS SERIES)

TELEGRAPH CREEK FORMATION

Conformably overlying the Colorado shale is the Telegraph Creek formation, which consists of interbedded fine-grained gray sandstone and light- to dark-gray marine shale. The base of the formation has been set arbitrarily at the top of the uppermost bentonite bed in the upper part of the Colorado shale. Drilling of test hole 30–13–15 penetrated 96 feet of beds that can be identified as belonging to the Telegraph Creek formation. (See log in table 2.) Probably only small amounts of highly mineralized water could be obtained from this formation.

EAGLE SANDSTONE

VIRGELLE SANDSTONE MEMBER

The light-gray to buff fine- to coarse-grained massive crossbedded sandstone that overlies the Telegraph Creek formation is known as the Virgelle sandstone member of the Eagle sandstone. It is exposed along the Marias River valley, where it generally forms prominent fluted cliffs between the less resistant underlying and overlying strata, but in places it erodes to form pinnacles capped by large resistant calcareous concretions. In test hole 30–13–15 this member was 92 feet thick, and where exposed it ranges in thickness from 35 to 100 feet.

The Virgelle sandstone member is the most important aquifer in the report area. Livestock, an important source of income for the residents of the western part of the area, could not be raised if this relatively shallow source of water supply were not present. In recent years some farmers have installed water systems whereby water is pumped from the wells by windmills and is stored in large cisterns from which it is withdrawn as needed by means of small electrically powered rotary pumps. The electricity is generated by wind-chargers, which are very numerous in the area. Wells in the Virgelle discharge at least 10 gallons per minute, and only a few are reported to pump dry. Because the specific capacity (yield per unit of drawdown) of the wells is low, the pump cylinder generally is placed near the bottom of the well. As the water in the Virgelle sandstone member is highly mineralized, most farmers having a well that taps this aquifer also have either a cistern or one or more tanks in which they store water obtained from municipal-supply systems or hauled from the Marias River.

Before 1945 all the wells tapping the Virgelle sandstone member of the Eagle sandstone were in the western part of the report area, more than half of them in Tps. 28 and 29 N., R. 10 E. Most of these wells are a little less than 500 feet deep, although several are reported to be somewhat deeper. Most of them were drilled by means of jetting rigs during 1913–18. As the water in the Virgelle is under artesian pressure, it rises in the well when the water-bearing beds are penetrated. Most of the wells are small in diameter, and it is difficult to measure the depth to water in them; in two wells measured in T. 28 N., R. 10 E., the depth to water was about 240 feet. The pressure of natural gas in the water affects the water level in some wells, and many farmers have indicated that the gas hinders the steady pumping of the water. When the water level is lowered by pumping, the release of pressure permits a flow of gas which causes a vapor lock in the pump, and no water can be pumped until the gas has been discharged. Well 29–12–5dd2, drilled in 1945, is 629 feet deep and is reported to flow at times. According to the driller this well tapped sufficient natural gas in the upper part of the Virgelle to supply 20–40 families. Well 28–11–12ad, an oil test well drilled during 1928–31, and oil test well 31–13–26ab, drilled in 1949, were bored completely through the Virgelle but reportedly produced no gas. Six deep oil test wells drilled near Kremlin, Mont., about 28 miles north of Big Sandy, produced gas; one produced 1.65 million cubic feet of gas in 24 hours, but it was abandoned because the water could not be cased out.

UPPER MEMBER

The bluff-forming Virgelle sandstone member of the Eagle sandstone is overlain by the slope-forming upper member of the Eagle which is poorly cemented buff-gray to brown shaly sandstone and shale interbedded with carbonaceous shale and thin coal seams. Locally, pebbles of distinctive black chert are present in this upper member. The base of the member generally is marked by a dark-gray to black sandy bed containing magnetite and titanite. Test hole 30–13–15 entered the member at a depth of 605 feet and penetrated 167 feet of it before entering the Virgelle sandstone member. In the western part of the report area, the upper member of the Eagle sandstone is the youngest bedrock unit; and in much of this part of the area, the upper part of the unit probably was removed by erosion in preglacial time. The uppermost beds of the upper member of the Eagle are exposed in sec. 31, T. 29 N., R. 13 E., where faulting has brought the formation to the surface. Wells tapping this member, but not the underlying Virgelle sandstone member, yield only a small amount of water. Generally they can be pumped dry in a few hours with a cylinder pump powered by a windmill.

CLAGGETT SHALE

Except in the eastern and westernmost parts of the area, the Claggett shale immediately underlies the glacial deposits. This formation consists of black to dark-brownish-gray marine shale containing thin layers of gray shaly sandstone and lenses of dark-gray calcareous concretions in its upper part and thin beds of bentonite in its lower part. The Claggett shale conformably overlies the Eagle sandstone. The boundary between the two formations is drawn at the contact of the dark shale with the lighter colored sandy shale of the Eagle sandstone. In places this contact is a few feet below 3 or 4 thin beds of bentonite. In much of the area where the Claggett shale is present, the upper part of the formation was removed by erosion in pre-Quaternary time. The lower part of the formation is exposed in several places along the Marias River valley, aud the upper part is exposed along Lonesome Lake Coulee, about 4 miles north of Big Sandy. The thickness of the Claggett shale in the report area ranges from a featheredge to about 500 feet. Well 30–12–36aa is the only well known to have been drilled completely through the formation, and well 30–11–17da was drilled about 450 feet into the formation. The Claggett shale yields little or no water to wells, and any water that might be obtained from it probably would be too mineralized for use. Some wells are reported to obtain a few gallons of water per day from the upper, weathered part of the shale, but this water probably comes from the lower part of the overlying glacial deposits. Because the shale is almost impermeable, waterlogging of the soil is likely to result from unrestricted irrigation in areas where this formation is close to the surface.

JUDITH RIVER FORMATION

The youngest bedrock formation in the area described by this report is the Judith River formation, which underlies only the eastern and northern parts of the area. It consists largely of soft sandstone and shale of fluviatile origin and contains some carbonaceous beds. A massive brown crossbedded sandstone, which contains podshaped limonitic concretions as much as 15 feet long, is present in places near the base of the formation, and workable coal beds are present in the vicinity of Havre. The Judith River formation conformably overlies the Claggett shale, the contact being placed arbitrarily at the base of the lowest prominent sandstone bed in the Judith River formation. Within the report area the thickness of the Judith River formation ranges from a featheredge to about 200 feet. The formation is exposed in several places in the eastern part of the area where the mantle of glacial deposits has been removed by erosion. Wells drilled through sufficiently thick sections of sandstone in the Judith River formation produce water that is excellent for domestic use. Although somewhat mineralized, the water is soft and is preferred for domestic use to the water obtained from the glacial deposits. An outlier of this formation north, northwest, and west of Big Sandy and south of Lonesome Lake Coulee has a maximum thickness of about 50 feet and is tapped by at least 10 wells, each of which is capable of supplying 10–15 gallons per minute. Most of these wells were dug through the Judith River formation and are bottomed in the upper beds of the underlying Claggett shale. The Judith River formation is believed to supply water to several drilled wells northeast of Boxelder, but little information is available regarding it in that vicinity.

QUATERNARY SYSTEM (PLEISTOCENE AND RECENT SERIES)

GLACIAL DEPOSITS

The unconsolidated sediments that mantle the bedrock in the report area were deposited in part by the continental ice sheets as they advanced over the area or as they melted, in part by running water, and in part in intermittent ponds and lakes.

Considerable evidence indicates that at least two ice sheets advanced over the area. In the SW¼ sec. 27, T. 32 N., R. 14 E., Big Sandy Creek has cut through three layers of glacial deposits that are separated by varved clay. From stream level to about 15 feet above the stream is a dark-gray till containing pebbles as much as 3 inches in diameter. Overlying the till is a 12-inch deposit of varved buff to gray clay. The varves number about 130 to the inch, and if each varve represents an annual deposit, as is generally believed, an ice-free period of at least 1,500 years was required for their deposition. An unknown thickness of the upper part of the varved clay may have been removed by the readvance of the ice sheet, which deposited a layer of gray pebbly till 19 inches thick. Overlying this layer of till is another deposit of varved clay, at least 35 inches thick, above which is another thin layer of till. The varves are dark gray and number about 20 to the inch. At least the top 5 inches of varved clay has been incorporated into the overlying till by plowing. If it is assumed again that one varve is an annual deposit, the upper layer of clay was deposited during an ice-free period of at least 700 years. Similar deposits of varved clay are present in the coulee bank about 1 mile west of this location. The glacial till overlying the upper deposit of varved clay is light tan to buff and contains large boulders; it appears to be identical with the surficial till elsewhere in the area. Although possibly the varved clay indicates deposition during a period between the melting of the outer fringe of an ice sheet and the readvance of the same sheet, the marked difference in the appearance of the till deposits strongly suggests the past presence of at least two distinct ice sheets in the area.

Further indication of more than one glaciation of the area was obtained when the test holes were drilled in Big Sandy valley. The uppermost glacial till penetrated by most of the tests was yellow to brown, the next deeper till was blue, and the deepest was gray. A few of the test holes penetrated a layer of gravel between the gray and blue tills. (See pl. 3.) The presence of this gravel supports the hypothesis that at least the till underlying the gravel was deposited by a different glacier than that which deposited the till overlying the gravel.

The ice sheet that deposited the surficial mantle of till advanced from the Keewatin center of glaciation in the region west of Hudson Bay. Alden (1932, p. 96) believed this last ice sheet to have been of Wisconsin age, and no contradictory evidence has been reported to date. The lack of development of good drainage and the presence of undrained depressions and of fresh, unweathered rock materials indicate that the last time the area was glaciated was late in the Pleistocene epoch. The surficial till is tan to buff and consists of fine-grained material enclosing pebbles, cobbles, and boulders. Most of these are crystalline rock, but some are limestone of Paleozoic age, and some are concretions derived from younger rocks. In some places the till contains large limonitic concretions identical with those present in the Judith River formation in this area. Some of the rock fragments are striated and faceted; possibly the others were transported only a short distance.

In much of the area the glacial deposits are ground moraine, forming broad, gently rolling, featureless plains. In some places hills of bouldery deposits are present, and these are believed to be recessional or marginal moraines. In other places the surface has a definite grain characterized by parallel ridges and intervening depressions, most of which are nearly parallel to the moraines. Some evidence indicates that during the latest glaciation two distinct ice lobes advanced into the report area. Deposits left by these lobes disrupted the drainage and led to the formation of lakes and undrained depressions. The lake deposits in the northern half of T. 29 N., R. 9 E., and the southern half of T. 30 N., R. 9 E., probably are near the center of the area that was covered by the western lobe, and the many small areas of lake deposits and undrained depressions in the eastern half of T. 30 N., R. 11 E., and the western half of T. 30 N., R. 12 E., probably mark the former location of the eastern lobe. The chain of small ponds and lakes that once trended northeast from Lonesome Lake and that now are represented by paludal deposits are believed to have been formed in depressions caused by uneven compaction of the glacial fill in the buried valley of the ancestral Marias River.

The till generally does not yield water freely to wells, although in some places it encloses lenses of saturated sandy material sufficiently thick to yield small to moderate amounts of water to wells equipped with a screen of proper size. Wells drilled into the glacial fill of deep buried valleys are the most productive in the area. One of these, well 29–8–4aa, was drilled to a depth of 285 feet in the fill of the buried valley of the ancestral Marias River and for some years supplied water sufficient for 400 sheep, 50 cows, and 18 horses. After some years of use, however, this well caved back to a depth of 220 feet. Another well (29–13–22ab2) was drilled in 1945 to a depth of 248 feet in the fill of the buried valley of the ancestral Missouri River and penetrated water-bearing sand and fine gravel which probably were deposited by stream action before the advance of the continental ice sheet. Adequate pumps were not available for testing this well, but it was thought to be capable of yielding moderately large amounts of water.

Eighteen test holes were drilled in the fill of the buried valley of the ancestral Missouri River (see pl. 3 and table 2) to determine the extent and thickness of the water-bearing beds and the depth to bedrock. If recharge to them is available, the several beds of coarse sand and gravel penetrated by the test holes are potential sources of large water supplies. On the basis of the test drilling, however, none of the water-bearing beds appears to be very extensive.

Test holes 29–13–22ab3 and 29–13–22bb, which are on line *A–A′* (pl. 3) near Boxelder, penetrated a layer of coarse gravel and boulders directly overlying the bedrock. In the first test hole this layer was 9 feet thick (from 246 to 255 feet below the land surface), and heavy drilling mud was pumped into it at a rate of 90 gallons per minute. The water in the gravel layer was under hydrostatic pressure and rose

190 feet in the hole, to a level 56 feet below the land surface. A properly constructed well at this site probably would yield at least several hundred gallons per minute. In the other test hole (29–13–22bb) the gravel layer was 19 feet thick (from 208 to 227 feet below the land surface) but did not appear to be as permeable as that penetrated by test hole 29–13–22ab3. A well of moderately large yield probably could be constructed at this site.

Well 29–13–21aa2, also on line *A–A′*, was drilled through 41 feet of saturated coarse gravel and boulders and then through 80 feet of saturated fine sand. These materials were present between 52 and 173 feet, and the water rose to a level about 16 feet below the land surface. This well was cased with 2-inch pipe to a depth of 167 feet; the bottom 15 feet of the casing was slotted. After the well was flushed with clear water, a swab test was made to determine the drawdown of the water level at varying rates of yield. Two hours of testing at rates up to 50 gallons per minute resulted in a drawdown of 2 feet. If recharge to the aquifer is sufficient, properly constructed wells tapping it would have a moderately large yield. Apparently the same aquifer was penetrated by test hole 29–13–16cd, but at this site the aquifer was only 67 feet thick and consisted of fine sand. As a thick layer of fairly tight clay overlies the aquifer at both sites, it is assumed that the aquifer is not recharged locally.

It is not known if the thick water-bearing gravel penetrated by test well 29–13–21aa2 and test hole 29–13–16cd is hydraulically connected with the thinner layer of gravel penetrated by test holes 29–13–22ab3 and 29–13–22bb. The altitude of the static water level in well 29–13–21aa2 was about 2,663 feet, but that in test hole 29–13–22bb was 22 feet lower. Moreover, the water in the thicker layer is less mineralized than that in the thinner layer.

Although some thin layers of gravel were penetrated by the eight test holes drilled on line *B–B′* (pl. 3) near Laredo, no thick water-bearing beds were encountered. Furthermore, the materials penetrated were not sufficiently distinctive that they could be correlated from test hole to test hole. It is unlikely that wells drilled in the vicinity of these test holes would have even moderately large yields.

Several potentially productive water-bearing beds were penetrated by the test holes drilled along line *C–C′*, north of Fort Assiniboine State Experimental Farm. Test hole 32–15–28bb, drilled at the junction of State Highway 29 and the road into the farm, penetrated a layer of gravel between depths of 54 and 63 feet. Because this gravel is overlain and underlain by glacial till, it probably was deposited in an ice-free period between two glacial advances. The water in this gravel was under sufficient hydrostatic pressure to cause a flow of 15 gallons per minute at an altitude of 2,626 feet. This aquifer probably is recharged by infiltration from Beaver Creek. Test hole 32–15–21bc and well 32–15–17dd also were drilled into a gravel layer which possibly correletes with the gravel layer found by test hole 32–15–28bb.

Test well 32–15–17dd and test holes 32–15–17ad and 32–15–8dd penetrated a saturated gravel layer a few feet above bedrock. The water in this gravel, though under artesian pressure, did not rise to the surface. Because the artesian pressure is less and the water is more highly mineralized, it is thought that this gravel is distinct from that from which flowing water was obtained.

Glaciofluvial deposits, which are present chiefly along the broad valley of Big Sandy Creek, consist principally of benchlike deposits of sand and gravel. Also present in the area are eskers, which are long, sinuous ridges of well-sorted sand and gravel that stand above the surrounding plain much like a railroad embankment, and kames, which are hills of poorly sorted material derived from the melting ice and deposited by streams.

The low gravel bench, remnants of which extend from a point about 2 miles north of Big Sandy to a point about 5 miles north of Laredo, probably was deposited during the melting stage of the latest ice sheet. A stream of melt water carrying a heavy load of detrital material flowed between the then ice-free highland on the west and the lobe of stagnant ice then occupying the broad valley in which Big Sandy Creek now flows. The sediments carried by the melt water were deposited along its course, and after the ice melted the surface of these sediments became a bench along the west side of the valley last occupied by the ice. Sage Creek and Boxelder Creek also contributed sediments which were deposited against the ice mass. The sediments are fairly well sorted, and gravel for roads has been obtained from several pits opened in these deposits. The largest of these gravel pits is a short distance south of the graded road extending west from Boxelder. A large quantity of gravel from a pit opened in 1946 about 5 miles north of Big Sandy was used in repaving U. S. Highway 87.

One of the most interesting of the ice-contact deposits is the esker-like deposit about 6 miles northeast of Big Sandy. This deposit consists of extremely well-sorted material and appears to have been laid down by a stream flowing eastward either in a crevasse in the ice sheet or in a tunnel beneath the ice. At its west end this deposit consists of coarse cobbles grading out from a kame of poorly sorted material; eastward the material is progressively finer grained, and at its east end, near U. S. Highway 87, it consists of fine sand. Test holes augered into the deposit to a depth of 12 feet indicated that the coarse sand near the surface grades downward into fine sand and silt. Of the several sand pits that have been opened in this deposit, the largest, that of the Great Northern Railway, is at the east end on the south side of a low fan. Except where Big Sandy Creek cuts through it, this deposit forms a prominent ridge, and before being breached, it was a natural dam that created a lake extending nearly 5 miles to the southwest.

Within the report area are five typical eskers. One, on the northwest edge of Big Sandy, is more than a mile long and has a sinuous northeast course. Its north end rises gradually from drift-mantled hills, and its south end grades into the lowlands southwest of Big Sandy. Numerous pits have been opened all along this esker, and from observations made at these pits, the writer concludes that the esker was formed by a stream flowing in a tunnel under the ice and that deposition occurred as the tunnel was enlarged at the top and sides. Possibly the layers of poorly sorted material in the esker were derived from the overlying stagnant ice mass and then were buried by water-sorted material. The esker deposits extend at least 8 feet below the surrounding plain and, where the esker is highest, 10–15 feet above the plain. Although, in general, the deposits of sand and gravel are lenticular and well sorted, they contain lenses of poorly sorted material in some places. A cross section of the esker shows a longitudinal core of well-sorted sand overlain by beds of gravel containing lenses of sand. The bedding is parallel to the top and sides of the esker.

Many wells in the report area tap water-bearing deposits of Pleistocene age. Most of these wells have been dug in depressional areas, and the construction of numerous stock ponds for storage of the runoff from precipitation has helped make these wells more dependable as a source of supply. The yield of most of the wells is small, but a few have the capacity to yield larger amounts. Among the latter are the "Brown" and "Emson" wells (29–11–7bc and 29–12–32db, respectively). In former days these wells were the most dependable sources of supply in the area; in dry years, when other wells failed, farmers came from miles around to obtain water from them. The "Brown" well is in a coulee bottom and is equipped with a small centrifugal pump. The "Emson" well is on the south edge of the dry bed of Lonesome Lake and is equipped with two hand-operated cylinder pumps.

Several wells have been drilled into the unconsolidated deposits filling the buried valley of the ancestral Marias River, and moderate to large supplies of water are obtained. Supplies more than sufficient for domestic and stock needs are obtained from the shallow wells tapping the deposits filling the buried valley of the ancestral Missouri River, but to date no adequate test has been made of the capacity of these deposits to yield large supplies of water. Well 29–13–27dc, drilled in 1946 to a depth of 235 feet, was tested by bailing at a rate of 50 gallons per minute, and according to the driller the water level declined only 2 feet when water was withdrawn from the well at this rate. The test holes drilled in 1947 indicate that relatively large supplies of water are available in some places but that the individual water-bearing beds are of only local extent.

As most of the glaciofluvial deposits overlie glacial till, the precipitation absorbed by them rapidly drains away unless the permeable deposits extend below the general level of the adjacent plains. The esker deposits near Big Sandy possibly contain some ground water in their lower part, but the other eskers and the ice-contact deposits of sand and gravel are not known to contain any permanent zones of saturation.

PALUDAL AND ALLUVIAL DEPOSITS

Deposits of Recent age consist of paludal sediments in several places in the area, flood-plain alluvium along Big Sandy Creek downstream from a point 6 miles northeast of Big Sandy, and alluvial fans built out from the base of the Bearpaw Mountains by streams draining the mountains.

The most extensive of the paludal sediments are those in the western part of the area along Black Coulee and in the southeastern part of the area along Big Sandy Creek and on the dry bed of Lonesome Lake. These deposits consist principally of carbonaceous silty clay and fine sand.

The extensive flood-plain deposits of Big Sandy Creek consist of dark silty clay loam, dark-brown sandy loam, and black clay. These deposits probably are a thin veneer on sediments deposited in a temporary lake that occupied the north end of the broad valley during the waning stages of glaciation. Because Big Sandy Creek has shifted its course many times across the flat valley floor, the flood-plain surface is scored by its numerous abandoned channels. Other streams in the area have deposited minor amounts of alluvium.

The alluvial fans along the western base of the Bearpaw Mountains have low slopes and are characterized by numerous channels abandoned by the streams as they shifted course. The surficial material of the alluvial fans is mainly silt and clay, but at depth the fans are composed of somewhat coarser material. By building out onto the floor of the broad valley, the fans have forced Big Sandy Creek to flow close to the west side of the valley.

The relatively thin paludal and flood-plain deposits are of little importance as water-bearing materials. They are extremely fine grained and would yield little water to wells. In 1946 the water table was at a shallow depth beneath the surface of the more extensive of these deposits, and where it was shallowest evaporation from the capillary fringe that extends above the water table had resulted in the concentration of salts on the land surface. This condition existed in part of the alluvial plain west of Boxelder and of the lake plain near Big Sandy. As a result of the waterlogging, the wettest areas were devoid of vegetation, and salt grass and greasewood grew on the less affected areas nearby.

The alluvial fans are the most important water-bearing deposits of Recent age. The town of Boxelder is situated on the lower part of the fan of Boxelder Creek, and the numerous wells in the town tap one or the other, or both, of two aquifers present in the fan deposits. Formerly, wells tapping the shallower aquifer, at a depth of 16–18 feet below the land surface, would become dry in late summer; but now that the flow of Boxelder Creek is regulated by reservoirs, this aquifer is a perennial source of supply. The infiltration of irrigation water applied on the higher parts of this fan causes a marked annual rise of the water level in wells tapping this aquifer. The deeper aquifer lies at a depth of 40–48 feet below the land surface. The water in this aquifer is under artesian pressure, and the water level in wells tapping it is about 15 feet below the land surface. Because supplies adequate for domestic needs are obtained from this aquifer, no wells have been drilled into water-bearing beds beneath the fan.

IGNEOUS ROCKS

Two dikes of igneous rock have been mapped in the southeastern part of the report area; one in sec. 35, T. 29 N., R. 12 E., and the other in sec. 31, T. 29 N., R. 13 E. Similar dikes probably are present under the mantle of glacial deposits. The exposed igneous rock is deeply weathered but from appearance could be a porphyry. The dike in sec. 35 is somewhat more resistant than the Judith River formation into which it was intruded, and it stands as a prominent wall at the head of a northward-draining coulee. The shaly sandstone in contact with the igneous rock appears to have been baked slightly. Igneous rock similar to that in the report area was mapped by Pierce and Hunt (1937, p. 251) in the area adjacent to the report area on the north and northwest. Probably all these intrusions are related to the large bodies of igneous rock in the Bearpaw Mountains.

GEOLOGIC STRUCTURE

Although the mantle of unconsolidated sediments obscures the structure of the bedrock, correlations based on logs of wells and test holes indicate a regional dip to the northeast of about 35 feet per mile.

Two faults have been mapped where the bedrock is exposed in the southeast corner of T. 29 N., R. 12 E., and in the southwest corner of T. 29 N., R. 13 E. The upthrown block is on the east side of the faults, and the Claggett shale is in juxtaposition with the Judith River formation. The faulting brings the upper member of the Eagle sandstone to the surface in sec. 31, T. 29 N., R. 13 E., but the area of exposure is too small to be shown on the map. A spring issuing from the upper member of the Eagle at this place is the cause of marshy ground nearby. The presence of springs near the western of the two faults suggests that here the Eagle is at shallow depth. The maximum displacement caused by the faulting is about 500 feet, or about the thickness of the Claggett shale.

Folding and faulting probably have occurred elsewhere in the area, but because the bedrock is exposed in so few places, it is impossible to map such structures without drilling closely spaced test holes into the bedrock.

The origin of the faults surrounding the Bearpaw Mountains has been discussed at length by Reeves (1925, p. 71–114) and summarized by him in a later report as follows (personal communication):

> The thrust faulting in the plains on the north and south sides of the Bearpaw Mountains is apparently confined to the weak Upper Cretaceous and early Tertiary formations. The trend and extent of the faults indicate that they were produced by a thrust force acting outward from the mountains. The slight plainsward inclination of the strata toward the faulted area suggests the possibility that during the mid-Tertiary period of volcanic activity in the mountains these formations, being buried under an enormous load of extensive material and subjected to violent and frequent earthquake shocks, slipped plainsward on wet bentonite beds in the upper part of the Colorado shale, resulting in the compression and thrust faulting of these formations in the plains.

FLUCTUATION OF WATER LEVEL IN WELLS

As part of this investigation, 20 wells were selected for use as observation wells. Periodic measurement of the water level in 7 of the wells was begun in 1945 and in thc others in 1946. (See table 3.) By 1953, however, measurements had been discontinued in all except 6 wells in which fluctuations were typical of shallow wells throughout the report area.

Wells 30–13–26dc and 30–13–35bc1 are in areas irrigated by water diverted from Boxelder Creek, and the water-level fluctuations in these wells are affected by the infiltration of irrigation water. (See pl. 4.) Normally, the water level in these wells is highest in the middle or late summer when irrigation water is being applied, but after the growing season the water level declines until early spring when recharge from snowmelt, precipitation, and increased streamflow cause the water level to rise again. Since 1950 well 30–13–35bc1 has been pumped during the summer for garden irrigation, and the record of water-level fluctuations clearly shows this influence superposed on the influence of recharge from irrigation.

Well 28–13–5dd is in a nonirrigated area in the Big Sandy Creek valley. The water level in this well generally is highest in the late spring and then declines throughout the summer months. Depending on the amount of recharge received by the aquifer in the late fall, the water level either remains at a low stage during the winter or rises slowly. The hydrograph of the water level in this well (see pl. 4) is almost a mirror image of that for well 30–13–35bc1 before its use for garden irrigation.

The remaining hydrographs in plate 4 are for wells in the upland where irrigation is contemplated. Because these wells are in shallow depressions, the water level rises sharply in response to the infiltration of water that collects in the depressions during the period of snowmelt or during heavy rainstorms. Characteristically, the water level in these wells rises rapidly and declines slowly.

DEPTH TO WATER TABLE AND DIRECTION OF GROUND-WATER MOVEMENT IN THE GLACIAL DEPOSITS

Depth-to-water measurements indicate that the water table (surface of the zone of unconfined ground water) roughly parallels the land surface and, therefore, that the direction of ground-water movement is similar to that of surface runoff. In general, however, the water table is closer to the land surface in valleys than under broad interstream areas, a fact soon recognized by the early settlers. Because so few wells tap the surficial unconsolidated deposits in the interstream areas, little information regarding the depth to the water table in the upland can be obtained without drilling test holes. The depth to water in many of the wells in the report area is shown in table 4.

AREAS OF POTENTIAL WATERLOGGING

In 1946 the water table was less than 10 feet below the land surface throughout much of the bottom land along Big Sandy Creek and elsewhere in the report area where the surficial material is alluvium or paludal deposits. When irrigation is begun, the water table is certain to rise, and parts of the area will become waterlogged. Also, the evaporation of water from the capilliary fringe above the water table will result in the concentration of salts on the land surface, and unless these salts can be leached from the soil, the waterlogged land eventually will become unfit for further cultivation.

In places on the upland the top of the Claggett shale is less than 10 feet below the land surface. If irrigated, these places are likely to become waterlogged because the shale bedrock is too nearly impermeable to transmit the recharge downward and the permeability of the surficial unconsolidated material is so low that lateral movement of ground water is extremely slow unless a steep hydraulic gradient exists. In places waterlogging possibly could be controlled by applying only minimum amounts of irrigation water or by constructing artificial drains. Advance warning of potential waterlogging in the irrigated areas can be obtained by making periodic measurements of the water level in observation wells.

CHEMICAL QUALITY OF THE GROUND WATER

By Herbert A. Swenson

Chemical analyses were made of water from 25 wells in the Lower Marias irrigation project. (See table 1 and pl. 2.) Generally, the mineral content of the water differs with geologic source and with well depth. (See fig. 5.) The concentration of dissolved solids ranged

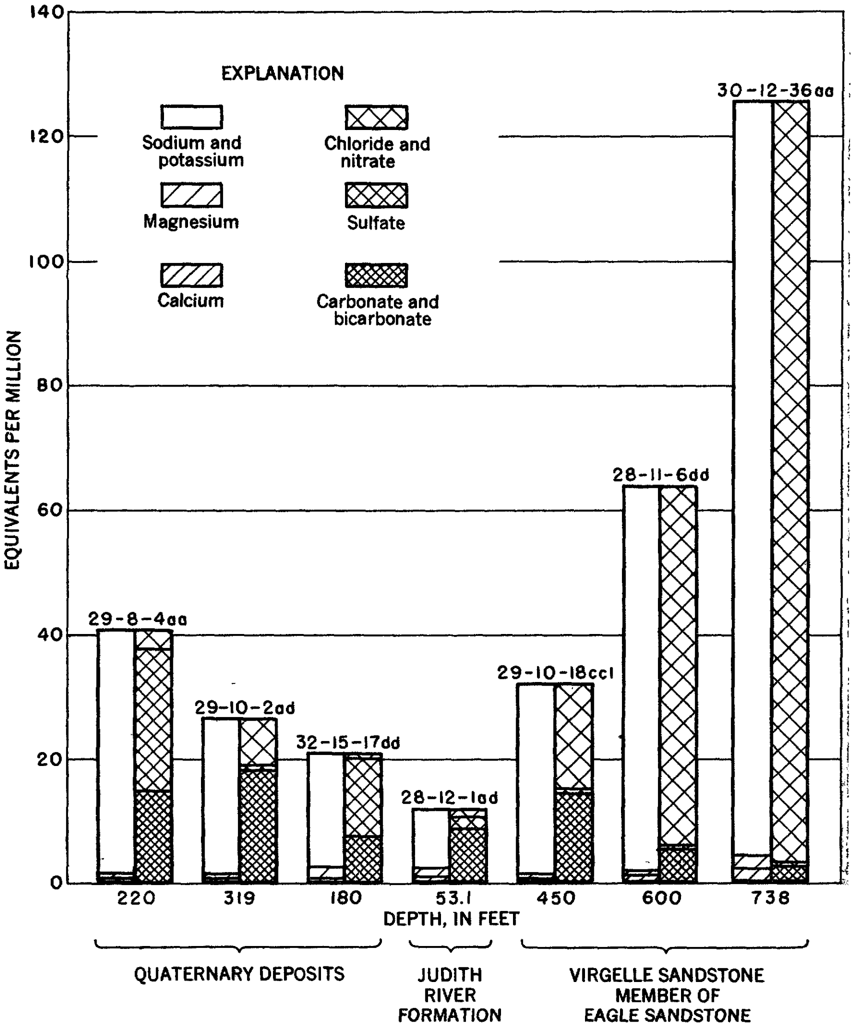

FIGURE 5.—Graphical representation of analyses of ground water in the Lower Marias irrigation project, Montana.

TABLE 1.—*Analyses of ground water*

[Analyses in parts per million except as indicated]

Well	Date of collection	Depth of well or test hole (feet)	Silica (SiO_2)	Total iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
Eagle sandstone (Virgelle sandstone member)																					
28-10-14dd	May 18, 1947	400	12	0.60	12	5.0	1,100	16	402	0	13	1,480	1.6	1.0	2.3	2,840	50	0	97	5,260	8.1
28-10-17dd	do	500	13	------	7.0	4.8	974	19	492	16	13	1,200	1.7	.5	2.6	2,500	37	0	97	4,740	8.2
28-11-6dd	May 20, 1946	600	------	------	19	6.3	1,430		336	0	6.2	2,050	1.5	------	1.4	3,780	73	0	98	------	8.3
28-11-14dd	May 18, 1947	604	18	------	4.0	3.3	1,100	21	1,090	39	72	975	1.4	.5	3.4	2,780	24	0	98	4,920	8.6
28-11-22bb	do	650	13	1.8	10	4.6	1,170	17	440	0	7.4	1,520	1.6	.5	3.1	2,960	44	0	97	5,660	8.0
29-10-18cc1	do	450	13	------	7.0	2.8	725	6.0	776	47	4.9	630	2.8	.9	3.6	1,830	29	0	98	3,070	8.4
29-10-22bc	do	580	12	.10	5.0	3.3	764	25	720	26	6.2	750	1.7	.8	3.1	1,950	26	0	97	3,540	8.2
29-10-23aa	do	495	16	------	7.0	7.2	748	14	776	10	11	730	1.6	1.0	3.1	1,930	48	0	96	3,580	8.2
29-10-31da1	May 29, 1946	470	------	------	7.5	9.6	732		921	27	16	585	3.0	.0	5.5	1,870	58	0	96	------	8.2
29-12-5dd2	May 15, 1946	629	------	------	30	20	2,670		211	0	3.1	4,100	3.0	------	1.8	7,060	157	0	97	------	8.0
30-10-29ab	May 18, 1947	453	11	------	3.0	1.7	839	5.6	502	214	3.7	760	2.0	.6	4.0	2,100	14	0	99	3,670	9.5
30-11-17da	May 17, 1946	742	------	------	36	15	2,750		138	15	4.3	4,250	.7	------	1.4	7,250	152	14	96	------	8.2
30-12-36aa	May 12, 1947	738	6.3	------	41	24	2,790	35	176	18	9.5	4,350	.7	1.5	4.5	7,360	201	27	96	13,100	8.3
Eagle sandstone (upper member)																					
29-10-26ba	May 18, 1947	400	14	------	12	4.6	1,030	22	618	30	25	1,180	1.6	1.0	2.7	2,630	49	0	97	4,800	8.3
Judith River formation																					
28-12-1ad	May 14, 1946	53.1	------	------	18	15	223		538	0	129	10	0.6	1.6	------	705	107	0	82	1,060	7.4

Quaternary deposits

29-8-4aa	June 12, 1946	220	------	------	10	4.4	915		904	0	1,100	102	2.0	4.0	------	2,630	43	0	98	3,660	7.5
29-9-5aa	June 11, 1946	250	------	------	5.0	2.8	518		866	20	372	10	1.4	3.0	2.8	1,400	24	0	98	------	8.5
29-10-2ad	May 24, 1946	319	------	------	6.0	6.6	582		1,090	8	6.2	274	2.8	.0	1.8	1,570	42	0	97	------	8.4
29-11-16cc2	May 22, 1946	23.5	------	------	89	48	43		331	0	139	14	.2	96	.1	611	419	148	18	------	8.2
29-12-32db	May 13, 1946	18.2	------	------	84	23	16		350	0	39	8.0	.2	.2	.1	377	304	17	10	----	7.9
29-13-21aa2	May 13, 1947	167	20	3.8	7.0	6.3	224	21	440	35	110	24	1.2	3.2	.52	701	43	0	87	1,100	8.7
29-13-22ab2	May 14, 1946	248	------	------	31	15	655		934	0	570	140	1.8	3.1	1.5	1,940	139	0	91	------	8.3
31-14-23b1	May 27, 1946	24	------	------	88	51	180		418	0	415	32	.4	.5	.2	1,020	429	86	48	------	8.0
32-15-17dd	May 22, 1947	180	23	7.0	16	21	405	26	414	18	618	30	1.4	6.5	1.8	1,370	126	0	85	2,090	8.5
32-15-28bb	May 20, 1947	130	17	.35	43	29	126	7.2	366	8	190	10	.3	2.6	.29	606	227	0	54	934	8.2

from 377 to 7,360 ppm (parts per million). Of the 25 samples collected, 20 contained dissolved solids in excess of 1,000 ppm, and 11, in excess of 2,000 ppm. The samples represented water that is used mainly for domestic purposes and the watering of livestock.

WATER FROM BEDROCK FORMATIONS

By ordinary standards, water from the Virgelle sandstone member of the Eagle sandstone would be classified as poor to fair; however, some people in this region tolerate the saline character of this water and for many years have used the water for general domestic purposes. The mineral content of 13 samples from wells tapping this aquifer ranged from 1,830 to 7,360 ppm and averaged 3,550 ppm. Down the dip to the north and east, the Virgelle yields water of increasing mineralization, although the increase is irregular. (See fig. 6.) As a general rule, water from this aquifer is soft and fairly uniform in chemical composition. Sodium chloride is the principal dissolved salt, and chloride is as much as 60 percent by weight of the dissolved solids in the more highly mineralized supplies. In places, the water is so highly mineralized that it can be consumed only by livestock, and water for drinking and cooking purposes must be hauled from a stream.

Well 29–10–26ba was not drilled deep enough to enter the Virgelle sandstone member; therefore, it probably derives its meager supply from the overlying upper member of the Eagle sandstone. Water from this well contained 2,630 ppm of dissolved solids, which is considerably more than that in water from nearby wells that tap the Virgelle sandstone member. However, water from both sources is of the sodium chloride type.

The quality of the water from well 28–12–1ad, which taps the Judith River formation, is relatively good. The water contained 705 ppm of dissolved solids and was of the sodium bicarbonate type.

WATER FROM UNCONSOLIDATED DEPOSITS

Ground water from unconsolidated deposits of Quaternary age is, with some exceptions, of better chemical quality than water from bedrock. The mineral content of 10 samples from wells tapping these deposits ranged from 377 to 2,630 ppm and averaged 1,220 ppm. The chemical characteristics of the water vary widely from place to place. For example, water from well 32–15–28bb, which taps the alluvial fan of Beaver Creek, contained only 606 ppm of dissolved solids. Although hard the water from this well is satisfactory for most uses. On the other hand, water from well 29–8–4aa, which taps the glacial deposits filling the ancestral valley of the Marias River, contained 2,630 ppm of dissolved solids. This water is soft and is used principally for watering livestock.

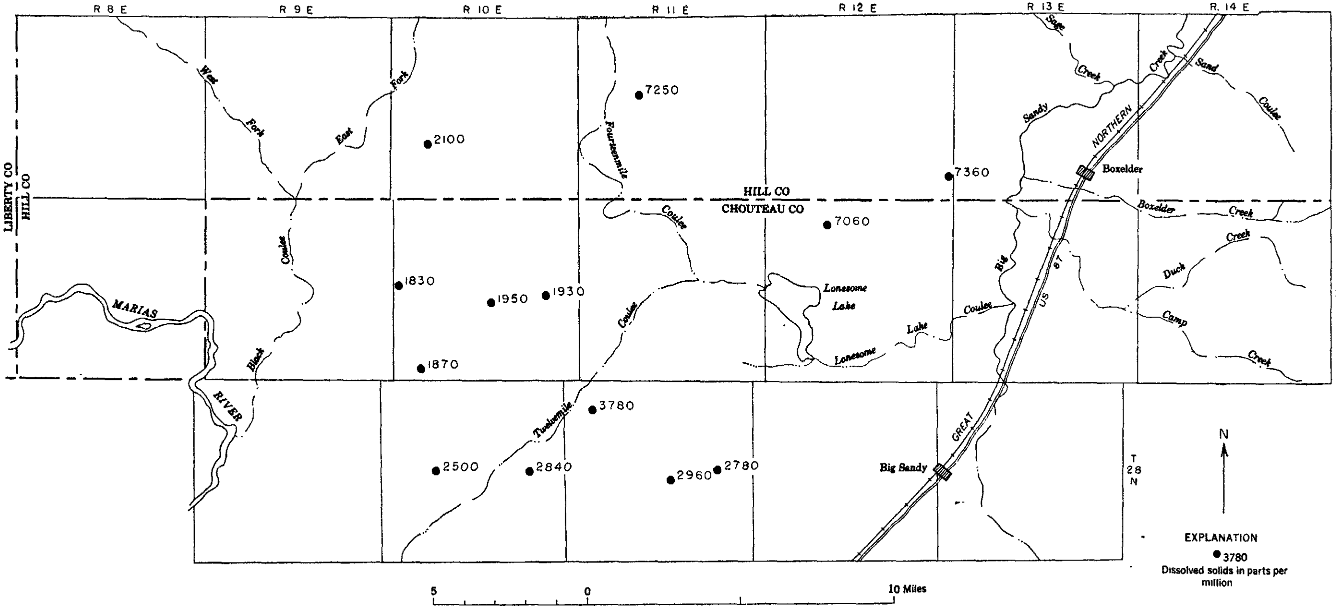

FIGURE 6.—Increase of dissolved solids in water from the Virgelle sandstone member of the Eagle sandstone.

Well 29–12–32db (the old "Emson" well) discharges water that is suitable for drinking by both humans and livestock but, by generally accepted standards, is excessively hard. This well was the only source of supply for early settlers living within a rather large radius. Unlike water from the Virgelle sandstone member of the Eagle sandstone, water from the unconsolidated deposits contains only small to moderate amounts of chloride and is less mineralized.

CONCLUSIONS

Water supplies in the Lower Marias irrigation project are obtained in part from bedrock aquifers and in part from the unconsolidated materials that mantle the bedrock throughout most of the area. The principal bedrock aquifers are the Virgelle sandstone member of the Eagle sandstone and the Judith River formation, both of Late Cretaceous age.

Because the land surface is comparatively flat and the bedrock formations dip northeast, the Virgelle sandstone member is nearer the surface in the western part of the area and is there tapped by numerous wells. An exception to the generally greater depth of this aquifer is a small area in the eastern part of the report area 3–5 miles north of Big Sandy where the Virgelle has been displaced upward by faulting. The water in this aquifer is highly mineralized and generally is more highly mineralized down the dip to the north and east. In the vicinity of the faults, the water in this aquifer may be of better quality. Because a better source of supply is not available in the western part of the report area, water from this aquifer is used for both domestic purposes and the watering of livestock.

The Judith River formation is present only in the eastern and northern parts of the report area. Several wells northwest of Big Sandy tap a buried outlier of this formation, and a few wells north and west of Boxelder are believed to derive water from the Judith River formation. Water in this aquifer is less mineralized than that in the Virgelle sandstone member and is considered suitable for general use.

Throughout much of the central part of the report area, the surficial unconsolidated deposits of Quaternary age are the only shallow source of ground water. Except where they fill the buried valleys of the ancestral Marias and Missouri Rivers, these deposits generally are less than 25 feet thick, and wells tapping them discharge only small amounts of water. Within the buried valleys the unconsolidated sediments are nearly 300 feet thick, and fairly large supplies of water may be obtained from the discontinuous lenses of more permeable materials. Alluvial fans built by streams from the Bearpaw Mountains yield moderate supplies of ground water. The chemical characteristics of the water in the surficial unconsolidated deposits differ widely from place to place; generally, however, the water is suitable for most uses, though hard.

The infiltration of irrigation water will increase the amount of recharge to the surficial unconsolidated deposits. The resultant rise of the water table may cause waterlogging in topographically low places, particularly in the valley of Big Sandy Creek and in places where impermeable bedrock is close to the land surface. Application of only minimum amounts of irrigation water would help to forestall waterlogging. It is recommended that a network of water-level observation wells be installed and that measurements of the water level in these wells be made regularly. In this way a persistent rise of the water table can be detected and drainage measures taken soon enough to prevent waterlogging of agricultural land.

TABLE 2.—*Drillers' logs of wells and test holes*

Well 28-11-12ad

	Thickness (feet)	Depth (feet)
Glacial drift	60	60
Claggett shale:		
Shale and thin limestone	370	430
Eagle sandstone:		
Sandstone and shale	230	660
Sandstone (Virgelle sandstone member)	100	760
Colorado shale:		
Shale, sandy	720	1,480
Shale, bentonitic	200	1,680
Shale	435	2,115
Colorado shale—Con.		
Concretionary zone (Mosby sandstone member)	65	2,180
Shale (Mowry shale equivalent)	265	2,445
Shale	320	2,765
Sandstone, muddy	30	2,795
Shale	260	3,050
Dakota formation:		
Sandstone	70	3,120

Well 29-12-5dd2

	Thickness (feet)	Depth (feet)
Glacial drift	217	217
Claggett shale:		
Shale	272	489
Eagle sandstone:		
Sandstone and shale	121	610
Eagle sandstone—Con.		
Sandstone (Virgelle sandstone member); brackish water and gas	19	629

Test hole 29-13-16cd

[Depth to water, 15.4 feet, May 21, 1947. Altitude of land surface, 2,670.0 feet]

	Thickness (feet)	Depth (feet)
Soil, sandy	1.5	1.5
Clay, sandy, yellow	1.5	3
Sand, fine, silty	2	5
Gravel, medium to coarse	6	11
Clay, yellow; contains some pebbles and large rocks	28	39
Clay, blue-gray, soft	6	45
Sand, fine, loose; contains some gravel	28	73
Sand, fine, loose; contains some gravel and layers of white clay	22	95
Sand, fine, loose; contains fragments of coal	17	112
Clay, blue-gray; contains some pebbles and coal	7	119
Clay, gray; contains fragments of shale	24	143
Shale, very hard	1	144
Clay, blue-gray; contains fragments of shale	13	157
Shale, very hard	1	158
Clay, blue-gray; contains fragments of shale	57	215

TABLE 2.—*Drillers' logs of wells and test holes*—Continued

Well 29-13-21aa2

[Depth of water, 16.42 feet, May 21, 1947. Altitude of land surface 2,679.5 feet]

	Thickness (feet)	Depth (feet)
Soil	4	4
Clay, yellow	2	6
Clay, yellow; contains cobbles	4	10
Clay, yellow; contains thin layer of sand	5	15
Clay, yellow, soft	15	30
Clay, gray-brown, soft	5	35
Clay, gray-brown; contains some sand	6	41
Clay, gray	4	45
Clay, gray, and fine sand; contains some coal	7	52
Gravel	3	55
Sand, fine; contains fragments of coal	10	65
Sand, fine	30	95
Sand, fine; contains fragments of coal	40	135
Gravel, coarse, and boulders	38	173
Clay, blue-gray; contains some sand and fragments of coal	18	191
Shale, hard	1	192
Clay, blue-gray; contains fragments of shale	9	201
Shale, black	1	202
Shale, dark-gray	8	210

Well 29-13-22ab2

	Thickness (feet)	Depth (feet)
Alluvium:		
Silt, sandy	15	15
Sand, brown	20	35
Sand; water	10	45
Clay, blue	60	105
Sand, gray; water, 4 gpm	5	110
Gravel	5	115
Alluvium—Continued		
Clay, blue	20	135
Sand	7	142
Clay, blue	104	246
Sand and gravel, loose; water	2	248

Test hole 29-13-22ab3

[Depth to water, 28.92 feet, May 21, 1947. Altitude of land surface, 2,691.9 feet]

	Thickness (feet)	Depth (feet)
Soil, sandy	8	8
Clay, sandy, brown	33	41
Clay, sandy; some gravel	4	45
Clay, very sandy, brown	9	54
Clay, sandy, blue	25	79
Clay, very sandy, blue	6	85
Clay, sandy, blue; contains fragments of coal	10	95
Clay, sandy, blue; contains some gravel and fragments of sandstone and coal	10	105
Clay, sticky, blue; contains cobbles and fragments of coal and sandstone	15	120
Clay, sticky, blue; contains cobbles and fragments of coal	11	131
Sandstone	2	133
Clay, sandy, blue; contains cobbles and fragments of sandstone and coal	14	147
Boulder (drilling time, 1 hr 30 min)	1	148
Clay, very sandy, blue; contains cobbles and fragments of coal	44	192
Clay, very sandy, blue; contains thin layers of gravel	2	194
Clay, very sandy, blue; contains some gravel and fragments of coal mixed in	15	209
Clay, very sandy, blue; contains cobbles	2	211
Clay, very sandy, blue; contains gravel and fragments of coal	33.5	244.5
Boulders; hole taking water	1.5	246
Boulders and gravel; circulation lost when pumping mud at 90 gpm	1	247
Boulders and gravel; taking some mud	8	255
Clay, sticky, blue-gray	5	260
Sandstone, hard (drilling time, 3 hr)	8	268
Clay, sandy, brown	2	270
Clay, sandy, blue-gray; contains fragments of sandstone	5	275
Clay, sandy, blue, gray, green, and brown; contains fragments of sandstone	10	285
Sandstone, hard, gray	12	297
Clay, sandy, blue, gray, and green; contains fragments of sandstone	13	310
Clay, sandy, blue, gray, green, and brown	10	320
Shale, black	2	322
Shale, gray	5	327
Shale, gray and brown; contains coal	3	330
Bentonite, light-gray	2	332
Clay, light-gray; contains layers of bentonite	3	335
Clay, gray and brown	3	338
Clay, brown; contains layers of bentonite	4	342
Clay, sandy, gray and brown	8	350
Clay, sandy, gray, blue, and brown	10	360
Clay, sandy, gray and blue; contains cobbles	17	377
Clay, blue, gray, and green	2	379
Clay, light-blue-green	6	385
Clay, blue, gray, and green; contains gragments of sandstone and shale	15	400

TABLE 2.—*Drillers' logs of wells and test holes*—Continued

Test hole 29-13-22bb

[Depth to water, 29.23 feet, May 21, 1947. Altitude of land surface, 2,687.3 feet]

	Thickness (feet)	Depth (feet)
Soil, sandy	2.5	2.5
Sand and gravel	6.5	9
Clay, yellow	2	11
Sand and gravel	5	16
Clay, yellow	9	25
Clay, yellow, and sand	5	30
Clay, soft, yellow	7	37
Clay, gray	5	42
Clay, blue-gray	7	49
Sand and fine gravel, loose	6	55
Clay, sandy, gray; contains layers of sand and pebbles	21	76
Cobbles and pebbles	1	77
Clay, sandy, blue; contains pebbles	22	109
Clay, soft, blue-gray; contains very thin layer of sand and fine gravel, also small fragments of sandstone	6	115
Clay, sandy, soft, blue-gray; contains layers of fine sand and gravel, also fragments of coal	20	135
Clay, very sandy, soft, blue-gray; contains pebbles and fragments of coal	28	153
Sand, fine; contains layers of blue-gray sandy clay	22	175
Clay, very sandy, blue-gray; contains pebbles and fragments of coal	33	208
Gravel, coarse	19	227
Sandstone, hard	1	228
Shale	27	255

Test hole 29-13-23bb

[Depth to water, 18.35 feet, May 21, 1947. Altitude of land surface, 2,711.0 feet]

	Thickness (feet)	Depth (feet)
Soil, sandy	1.5	1.5
Sand, medium and fine; some gravel and small cobbles	8.5	10
Sand, fine	3	13
Sand, medium; gravel and small cobbles	6	19
Sand, medium; contains layer of coarse gravel	10	29
Sand, fine, and blue clay	22	51
Sand, medium, and gravel; contains fragments of sandstone	3	54
Sand, fine; contains clay	6	60
Sand, fine; contains thin layers of clay and gravel	3	63
Clay, blue; contains layers of gravel	12	75
Sandstone	1	76
Clay, blue, and coarse gravel	10	86
Clay, blue	1	87
Clay, dark-blue	11	98
Clay, gray	12	110
Clay, gray; contains thin layers of fine sand	6	116
Clay, gray	29	145
Clay, sandy, gray; contains fragments of shale	55	200
Shale, hard	2	202
Clay, soft, gray; contains small fragments of shale	12	214
Shale, hard	2	216
Clay, dark-gray; contains fragments of shale	29	245
Shale	35	280

Well 30-11-17da

	Thickness (feet)	Depth (feet)
Glacial drift	70	70
Claggett shale:		
Shale	54	124
Concretions, calcareous	1	125
Shale	145	270
Concretions, calcareous	1	271
Shale	14	285
Concretions, calcareous	1	286
Shale	29	315
Concretions, calcareous	1	316
Shale	99	415
Concretions, calcareous	1	416
Shale, black	48	464
Shale, very hard	2	466
Shale, gray	52	518
Shale, very hard	2	520
Shale, gray	50	570
Eagle sandstone:		
Sandstone, gray; small amount of water	15	585
Shale, brown and gray	15	600
Shale, hard, gray	25	625
Shale, brown	3	628
Shale, gray	38	666
Coal	1	667
Shale, sandy, gray	45	712
Shale, sandy, black	13	725
Sandstone (Virgelle sandstone member); brackish water	15	740
Transition beds (black shale)	2	742

TABLE 2.—*Drillers' logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well 30-12-27dc2					
Glacial drift; clay, sandy, yellow	28	28	Judith River formation—Continued		
Judith River formation:			Sandstone, gray; hard water	17	122
Shale, brown	27	55	Shale, gray	33	155
Shale, gray	17	72	Shale, sandy; water, 1 gpm	5	160
Shale, brown	8	80	Claggett shale; blue shale	42	202
Shale, gray	20	100			
Sandstone, gray	5	105			
Well 30-12-36aa					
Judith River formation:			Claggett shale—Continued		
Sandstone, soft, brown	15	15	Shale, soft, gray	200	565
Shale, sandy, gray	25	40	Shale, sandy, gray	15	580
Sandstone, soft, gray; small supply of water	15	55	Shale, gray	15	595
Sandstone, hard, gray	5	60	Eagle sandstone:		
Shale, sandy, gray	35	95	Shale, sandy, soft	100	695
Claggett shale:			Virgelle sandstone member:		
Shale, soft, gray	60	155	Sandstone, soft; small amount of water	33	728
Shale, sandy, hard	5	160	Shale, gray, and sandstone	10	738
Shale, black	200	360			
Shale, sandy	5	365			
Test hole 30-13-15					
Glacial drift:			Eagle sandstone:		
Clay	32	32	Sandstone, red, and shale	10	615
Quicksand	10	42	Shale, gray	10	625
Clay, gray	17	59	Shale, soft, brown; show of gas	8	633
Sand	2	61	Shale, gray	7	640
Quicksand	4	65	Sandstone, gray	10	650
Clay, sandy	15	80	Limestone, hard	10	660
Sand and gravel	5	85	Shale, hard, gray	30	690
Clay	17	102	Shale, sticky	82	772
Clay and boulders	22	124	Virgelle sandstone member:		
Clay	55	179	Limestone	8	780
Boulders	10	189	Shale, sandy, gray	40	820
Claggett shale:			Sandstone, gray	20	840
Shale	67	256	Shale, dark-gray	15	855
Shale, sandy; water	5	261	Sandstone, hard	9	864
Shale	20	281	Transition beds:		
Shale, sandy	7	288	Shale, sandy	36	900
Sandstone, hard	6	294	Shale, gray	15	915
Shale, gray	56	350	Shale, sandy	15	930
Shale, sandy	10	360	Sandstone	30	960
Shale, gray	90	450	Colorado shale:		
Shale, brown	20	470	Shale dark-gray	25	985
Shale, gray	18	488	Shale, gray	5	990
Shale, sandy, hard; show of gas	2	490	Limestone, hard	5	995
Shale, gray	30	520	Shale, gray	45	1,040
Shale, sandy, brown	15	535	Shale, brown	935	1,975
Shale, hard, gray	20	555			
Shale, sandy	25	580			
Limestone, hard, brown	20	600			
Concretion, calcareous	5	605			
Well 30-13-29dc1					
Glacial drift:			Glacial drift—Continued		
Loam and yellow clay	29	29	Sand, fine	20	140
Clay and gravel	3	32	Sand and gravel; water, yield 15 gpm	1	141
Clay, yellow	14	46			
Clay, soft, blue	74	120			

TABLE 2.—*Drillers' logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Test hole 31-13-26abd					
[Tops of formations interpreted from Schlumberger log]					
Claggett shale	975	975	Madison limestone	97	3,540
Eagle sandstone	95	1,070	Three Forks shale equivalent	650	4,190
Colorado shale	145	1,215	Potlatch anhydrite	220	4,410
Bow Island sand of Canada	1,429	2,644	Jefferson formation	58	4,468
Kootenai formation	161	2,805	Cambrian	842	5,310
Ellis group (upper part)	385	3,190			
Ellis group (basal part)	253	3,443			
Well 31-14-12cb					
Glacial drift:			Glacial drift—Continued		
Loam and yellow clay	50	50	Clay, sandy	25	135
Clay, blue	41	91	Sand, gray; water	15	150
Clay, soft, gray	19	110	Judith River(?) formation:		
			Shale, blue, or clay	5	155
Test hole 31-14-15ca1					
[Depth to water, 17.88 feet, May 21, 1947. Altitude of land surface, 2,605.3 feet]					
Soil	1	1	Clay, sandy, soft, blue-gray; contains pebbles	37	97
Clay, silty, yellow	3	4	Sand, fine, and gravel; some sandy clay	5	102
Sand, fine, and gravel	1	5	Clay, very sandy, gray; contains pebbles and fragments of coal	52	154
Clay, soft, yellow	9	14	Gravel, coarse	11	165
Clay, soft, yellow; intermixed with fine sand	11	25	Shale, black	20	185
Clay, soft, light-gray	29	54			
Sand, compact, white	1	55			
Clay, soft, dark-brown	5	60			
Test hole 31-14-15ca2					
[Altitude of land surface, 2,589.1 feet]					
Soil	1	1	Clay, very sandy, gray; contains pebbles and fragments of coal	14	111
Clay, soft, yellow	3	4	Sandstone, hard	1	112
Sand, fine	1	5	Clay, very sandy, gray; contains pebbles	52	164
Clay, soft, yellow	19	24	Shale	11	175
Clay, soft, gray	35	59	Shale, blue-gray and brown	10	185
Clay, soft, blue-gray	8	67	Shale, blue	10	195
Clay, sandy, blue-gray; contains pebbles	30	97			
Test hole 31-14-15dd2					
[Depth to water, 8.55 feet, May 21, 1947. Altitude of land surface, 2,621.9 feet]					
Soil	4	4	Clay, sandy, gray; contains fragments of sandstone	11	131
Sand, fine	6	10	Clay, gray	9	140
Gravel	22	32	Sandstone cobble	.5	140.5
Clay, sandy, yellow; intermixed with gravel	14	46	Clay, gray	5.5	146
Clay, sandy, yellow; contains cobbles	5	51	Shale, black	29	175
Clay, sandy, blue; intermixed with gravel	39	90	Shale, brown; contains thin layers of betonite	7	182
Clay, sandy, blue; contains thin layers of gravel	16	106	Shale, brown and black	7	189
Clay, sandy, blue; intermixed with gravel and fragments of coal	14	120	Shale, black	8	197
			Shale, brown	3	200

TABLE 2.—*Drillers' logs of wells and test holes*—Continued

Test hole 31-14-16ab

[Depth to water, 9.88 feet, May 21, 1947. Altitude of land surface, 2,567.6 feet]

	Thickness (feet)	Depth (feet)
Soil	3	3
Clay, sandy, yellow	7	10
Sand, fine	9	19
Clay, dark-gray; intermixed with gravel	19	38
Clay, dark-gray; contains fragments of coal	7	45
Clay, sandy, dark-gray; contains cobbles	10	55
Sand	2	57
Clay, sandy, dark-gray; intermixed with gravel	3	60
Sand and clay in alternating layers	6	66
Clay, sandy, dark-gray; intermixed with coarse gravel	4	70
Clay, sandy, dark-gray; contains thin layers of gravel	10	80
Clay, very sandy, dark-gray; contains thin layers of gravel	9	89
Gravel and boulders	7	96
Sandstone, hard, gray (drilling time, 1 hr)	1	97
Sand, compact; some clay	3	100
Boulders	2	102
Clay, sandy, gray; intermixed with gravel	10	112
Clay, very sandy, gray; contains layers of bentonite	6	118
Clay, very sandy, gray; contains cobbles	10	128
Sandstone, hard, gray (drilling time, 30 min)	.5	128.5
Clay, sandy, gray	7.5	136
Clay, sandy, gray and brown	4	140
Shale, brown	10	150
Shale, brown and black; contains limestone cobbles	18	168
Shale, brown; contains limestone cobbles and fragments of black shale	9	177
Shale, brown and blue; intermixed with gray clay; contains limestone cobbles	8	185
Cobble	.5	185.5
Shale, blue, brown, and black; contains limestone cobbles	5.5	191
Shale, blue-black; contains limestone	19	210
Clay, alternating red and gray; contains fragments of coal and shale	4	214
Clay, sandy, gray; contains gravel and fragments of coal	10	224
Sandstone, hard, gray	.5	224.5
Clay, sandy, gray; intermixed with gravel and fragments of coal	17.5	242
Sandstone, hard, gray	.5	242.5
Clay, sandy, gray; intermixed with fragments of coal	9.0	251.5
Sandstone, hard, gray (drilling time, 1 hr 10 min)	1.5	253
Clay, sandy, gray; contains some gravel and fragments of sandstone	3	256
Sandstone, hard	1	257
Clay, sandy, gray; contains fragments of sandstone	3	260

Test hole 31-14-16ad

[Depth to water, 26.95 feet, May 21, 1947. Altitude of land surface, 2,596.5 feet]

	Thickness (feet)	Depth (feet)
Soil	2	2
Silt, fine, sandy	1	3
Clay, soft, yellow	21	24
Sand, fine	12	36
Clay, very sandy, blue, and fine sand; contains fragments of coal	6	42
Gravel and coal	3	45
Clay, very sandy, dark-blue	10	55
Clay, sandy, gray; contains pebbles	25	80
Clay, blue-gray; contains pebbles and fragments of coal and brown sandstone	5	85
Clay, blue-gray; contains pebbles and fragments of coal	12	97
Sand and gravel	5	102
Clay, sandy, blue-gray; intermixed with sand and gravel	3	105
Clay, sandy, blue-gray; contains pebbles	10	115
Clay, sandy, blue-gray; contains pebbles and fragments of coal	27	142
Sand, fine, and gravel; some clay	4	146
Clay, sandy, blue-gray; contains pebbles and fragments of coal	11	157
Shale	18	175

TABLE 2.—*Drillers' logs of wells and test holes*—Continued

Test hole 31-14-23bc3

[Depth to water, 12.9 feet, May 21, 1947. Altitude of land surface, 2,634.2 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	3	3	Gravel	3	93
Clay, silty and sandy, yellow	2	5	Clay, very sandy, light-gray	43	136
Sand, fine, and gravel	1	6	Shale	24	160
Clay, soft, yellow	6	12	Clay, light-gray; contains fragments of brown shale and coal	6	166
Sand, fine, and gravel	3	15	Shale, blue	15	181
Clay, dark-yellow; contains pebbles	20	35	Sandstone, hard; contains calcareous concretions	1	182
Clay, gray; contains pebbles	10	45	Shale, brown; contains fragments of coal	1	183
Clay, sandy, blue-gray; contains pebbles	25	70	Shale, gray	2	185
Boulder	1	71			
Clay, sandy, blue-gray	19	90			

Test hole 31-14-23db

[Altitude of land surface, 2,651.8 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	2	2	Clay, sandy, blue; contains gravel	10	90
Gravel	7	9	Sand, fine; intermixed with clay	14	104
Clay, yellow	2	11	Clay, brown; intermixed with coal	6	110
Gravel	7	18	Clay, sandy, blue	5	115
Clay, yellow; intermixed with gravel	13	31	Clay, sandy, blue; intermixed with gravel	9	124
Clay, blue; contains cobbles	11	42	Clay, brown and blue; intermixed with gravel	5	129
Sandstone	10	52	Boulder	.5	129.5
Sandstone, hard, gray (drilling time, 2 hr 45 min)	2	54	Clay, sandy, blue	26.5	156
Clay, blue, and sandstone	4	58	Clay, blue-gray	16	172
Sandstone, soft, and clay	3	61	Shale, brown and black	28	200
Clay, blue-gray	7	68			
Clay, brown and blue	7	75			
Clay, blue	5	80			

Test hole 31-14-25bb

[Depth to water, 19.37 feet, May 21, 1947. Altitude of land surface, 2,681.7 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	3	3	Clay, sandy, blue-gray	6	90
Clay, very sandy, yellow	7	10	Sandstone, soft, gray	5.5	95.5
Clay, sandy, yellow	10	20	Sandstone, hard, gray (drilling time, 35 min)	1.5	97
Clay, sandy; intermixed with gravel	9	29	Sandstone, soft, gray	6	103
Sand	3	32	Clay, sandy, blue-gray	2	105
Gravel, coarse, and clay	4	36	Clay, blue-gray; contains fragments of shale	4	109
Clay, light-yellow-brown	9	45	Clay, light-blue	2	111
Clay, blue-gray	12	57	Shale, brown	3	114
Clay, sandy, blue-gray	8	65	Shale, hard, blue-green, and light-blue sandy shale	6	120
Clay, gray	5	70			
Clay, sandy, blue-gray	3	73			
Sandstone, soft, gray	5	78			
Clay, sandy, brown and blue-gray	6	84			

Well 32-14-25bb

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Glacial drift and alluvium:			Glacial drift and alluvium—Continued		
Loam and yellow clay	45	45	Clay, silty, blue	15	114
Clay, blue	16	61	Quicksand and fine gravel	4	118
Clay, sticky	5	66	Sand and gravel; water, yield 10 gpm	1	119
Clay, blue	29	95			
Clay, sticky	4	99			

TABLE 2.—*Drillers' logs of wells and test holes*—Continued

Test hole 32-15-8dd

[Altitude of land surface, 2,580.1 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Road fill	2	2	Clay, sandy, blue; interbedded with thin layers of gravel	41	112
Clay, sandy, dark-brown	3	5	Gravel and boulders	26	138
Clay, sandy, brown	4	9	Clay, light-blue	4	142
Clay, sandy, yellow; contains cobbles	37	46	Clay, sandy, light-blue; intermixed with gravel	9	151
Clay, sandy, blue, alternating with brown sandy clay; some gravel	13	59	Sandstone	3	154
Clay, sandy, blue; contains gravel and fragments of coal	12	71	Clay, sandy, light-blue	6	160

Test hole 32-15-17ad

[Altitude of land surface, 2,575.9 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	1	1	Clay, sandy, gray; contains pebbles	43	139
Clay, yellow; contains large cobbles	3	4	Clay, silty and sandy, gray; contains pebbles	22	161
Clay, yellow; contains pebbles	33	37	Clay, gray, and fine sand; some gravel	6	167
Clay, yellow; contains fragments of sandstone	5	42	Gravel, coarse (lost circulation, added jel flake; drilling time, 2 hrs.)	14	181
Clay, sandy, yellow; contains pebbles	16	58	Clay, sandy, gray	29	210
Clay, sandy, blue; contains pebbles	38	96	Clay, sandy, brown	5	215

Well 32-15-17dd

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil, sticky	5	5	Gravel	7	104
Clay, brown; contains pebbles	24	29	Clay, silty, very soft	21	125
Clay, yellow; contains pebbles	10	39	Clay, sandy, blue-gray; contains gravel	9	134
Clay, sandy, yellow; contains pebbles	19	58	Clay, silty and sandy, blue-gray	8	142
Clay, sandy, blue-gray; contains pebbles and fragments of coal	39	97	Gravel and blue-gray clay	4	146
			Gravel, coarse	9	155
			Sandstone, very hard	3	158
			Shale	22	180

Test hole 32-15-21bc

[Depth to water, 20.8 feet, May 27, 1947. Altitude of land surface, 2,585.5 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	1	1	Clay, sandy, brownish-gray; contains fragments of coal	5	90
Clay, yellow; contains cobbles	17	18	Clay, sandy, gray and brown; contains fragments of coal, limestone, and sandstone	7	97
Clay, sandy, yellow; intermixed with gravel	19	37	Clay, sandy, gray-green; contains fragments of limestone and coal	4	101
Clay, sandy, yellow and gray; intermixed with gravel	10	47	Clay, sandy, gray, green, and brown; contains gravel and fragments of limestone	9	110
Clay, sandy, blue-gray; intermixed with gravel	25	72	Clay, sandy, gray; some gravel	2	112
Clay, sandy, gray; intermixed with gravel	2	74	Sandstone, hard, gray	2	114
Clay, sandy, gray; contains cobbles	1	75			
Clay, sandy, gray; contains gravel and fragments of coal	5	80			
Gravel and boulders	2	82			
Clay, sandy, brown and gray; contains gravel and fragments of coal	3	85			

TABLE 2.—*Drillers' logs of wells and test holes*—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Test hole 32-15-28bb					
[Flowed at rate of 15 gallons per minute, May 20, 1947. Altitude of land surface, 2,626.24 feet. Sample of water collected for chemical analysis]					
Soil; contains pebbles	1.5	1.5	Gravel, coarse; water	9	63
Sand; contains pebbles and cobbles	.5	2	Clay, sandy, gray; contains pebbles	21	84
Sand, fine, and gravel	8	10	Clay, sandy, light-green and gray; contains pebbles	43	127
Clay, yellow	18	28	Sandstone, hard	3	130
Clay, sandy, yellow	9	37			
Clay, sandy, gray; contains pebbles	17	54			

TABLE 3.—*Water levels in observation wells, in feet below land surface*

[Measurements subsequent to May 1947 made by U. S. Bureau of Reclamation]

Date	Water level	Date	Water level	Date	Water level
28-10-23cc					
1946		*1946*		*1946*	
July 5	242.0	Aug. 30	242.30	Oct. 24	242.06
Aug. 1	242.25	Oct. 10	242.63	May 5	242.54
28-10-28ab					
1946		*1949*		*1951*	
May 28	4.71	June 9	9.74	Oct. 16	7.55
July 5	6.17	July 13	11.23	Nov. 14	7.78
Aug. 1	8.17	Aug. 9	12.00	Dec. 13	8.10
Aug. 30	10.01	Sept. 13	12.90		
Oct. 10	11.27	Oct. 3	13.15	*1952*	
Oct. 24	11.49	Nov. 9	13.22	Jan. 9	[a] 5.50
		Dec. 5	13.56	Apr. 21	1.00
1947				May 19	1.80
May 5	1.48	*1950*		June 17	3.70
June 6	2.45	Mar. 17	14.51	July 18	6.45
July 8	4.61	Apr. 13	.99	Aug. 11	7.75
Aug. 5	7.16	May 16	1.56	Sept. 15	8.80
Sept. 3	8.92	June 14	2.81	Oct. 16	9.29
Oct. 21	10.12	July 6	4.65	Nov. 13	9.10
Dec. 22	11.16	Aug. 15	5.44	Dec. 16	10.10
		Oct. 6	8.98		
1948		Nov. 16	9.52	*1953*	
Feb. 13	11.82	Dec. 20	9.80	Jan. 14	9.60
Mar. 22	6.00			Feb. 16	10.55
June 9	12.12	*1951*		Mar. 13	9.80
July 9	12.23	Jan. 17	9.33	Apr. 14	9.50
Aug. 11	12.50	Feb. 26	9.35	May 15	10.10
Sept. 10	12.89	Mar. 19	8.90	June 12	5.12
Oct. 11	13.45	Apr. 17	.20	July 10	7.05
Nov. 15	13.96	May 14	2.08	Aug. 21	10.10
Dec. 13	14.36	June 15	4.00	Sept. 11	11.10
		July 15	5.45	Oct. 15	11.70
1949		Aug. 27	7.70	Nov. 17	12.60
Jan. 10	14.66	Sept. 17	7.09	Dec. 11	12.80
Feb. 17	15.32				
Apr. 6	6.75				
May 9	8.99				

See footnotes at end of table.

TABLE 3.—*Water levels in observation wells, in feet below land surface*—Continued

Date	Water level
28-11-2ab	
1946	
May 20	6.97
Aug. 1	9.05
Aug. 30	9.24
Oct. 10	9.54
Oct. 24	9.64
1947	
May 5	4.82
June 6	6.15
July 8	7.47
Aug. 5	8.62
Sept. 3	10.56
Oct. 21	9.90
Dec. 22	10.30
1948	
Feb. 13	Dry
Mar. 22	[a] 9.40
June 9	10.10
July 9	10.05
Aug. 11	8.87
Sept. 10	9.23
Oct. 11	9.48
Nov. 15	9.96
Dec. 13	[a] 9.95
1949	
Apr. 6	4.94
May 9	6.05
June 9	6.75
July 13	8.35
Aug. 9	9.15
Sept. 13	9.92
Oct. 3	10.05
Nov. 9	Dry
Dec. 5	Dry
1950	
Mar. 20	Dry
Apr. 13	3.48
May 16	4.89
June 14	5.48
July 6	6.03
Aug. 15	6.69
Oct. 6	7.80
Nov. 16	8.10
Dec. 20	8.60
1951	
Jan. 17	8.20
Feb. 26	8.13
Mar. 19	6.55
Apr. 17	4.00
May 14	5.52
June 15	6.47
July 15	7.25
Aug. 27	8.50
Sept. 17	7.32
Oct. 16	3.90
Nov. 14	9.15
Dec. 13	8.15
1952	
Jan. 9	[a] 10.20
Feb. 1	[a] 9.90
Mar. 10	[a] 8.80
Apr. 21	2.90
May 19	3.80
June 17	4.90
28-11-10cc	
1946	
May 6	8.37
June 4	10.41
July 5	10.86
Aug. 1	13.21
Aug. 30	14.22
Oct. 10	14.61
Oct. 24	15.74
1947	
May 5	5.77
June 6	8.00
July 8	9.15
Aug. 5	11.22
Sept. 3	13.41
Oct. 21	15.29
1948	
Feb. 13	15.76
Mar. 22	15.32
July 9	13.52
Aug. 11	10.48
Sept. 10	13.27
Oct. 11	14.58
Nov. 15	14.90
Dec. 13	15.08
1949	
Jan. 10	15.29
Feb. 17	15.94
Apr. 6	[b] 15.73
May 9	12.47
June 9	13.38
July 13	14.32
Aug 9	15.70
Sept. 13	[c] 16.15
Oct. 3	18.87
Nov. 9	18.85
Dec. 5	18.95
1950	
Mar. 17	18.90
Apr. 13	10.54
May 16	8.84
June 14	9.97
July 6	11.02
Aug. 15	11.93
Oct. 6	13.52
Nov. 16	14.59
28-12-8dd	
1946	
May 6	5.57
June 4	6.67
July 5	8.14
Aug. 1	10.31
Aug. 30	14.98
Oct. 10	13.56
Oct. 24	[b] 13.99
1947	
May 5	.65
June 6	2.20
July 8	3.34
Aug. 5	[b] 9.21
Sept. 3	9.16
Oct. 21	9.73
Dec. 22	11.77
1948	
Feb. 13	12.75
Mar. 22	12.78
June 9	13.80
July 9	10.28
Aug. 11	7.93
Sept. 10	8.30
Oct. 11	10.91
Nov. 15	12.37
Dec. 13	12.81
1949	
Jan. 10	12.68
Feb. 17	13.39
Apr. 6	0.37
May 9	4.27
June 9	4.80
July 13	8.40
Aug. 9	11.08
Sept. 13	14.01
Oct. 3	14.21
Nov. 9	13.99
Dec. 5	14.63
1950	
Mar. 17	[a] 7.85
Apr. 13	[d] .45
May 16	1.38
June 4	7.77
July 6	5.47
Aug. 15	7.80
Oct. 6	9.97
Nov. 16	8.75
Dec. 20	9.78
1951	
Jan. 17	9.55
Feb. 26	9.47
Mar. 19	8.95
Apr. 17	[d] .20
May 14	.50
June 15	7.40
July 15	9.90
Aug. 27	11.80
Sept. 17	9.35
Oct. 16	11.20
Nov. 14	8.90
Dec. 13	7.10
1952	
Jan. 9	[b] 8.50
Feb. 1	8.80
Mar. 10	7.30
Apr. 21	[d] .70
May 19	.20
June 17	3.55
July 18	4.85
Aug. 11	8.35
Sept. 15	7.60
Oct. 16	11.27
Nov. 13	10.85
Dec. 16	11.45
1953	
Jan. 14	10.50
Feb. 16	10.80
Mar. 13	9.70
Apr. 14	1.10
May 15	4.10
June 12	.09
July 10	2.05
Aug. 21	6.30
Sept. 11	6.80
Oct. 15	9.17
Nov. 17	9.15
Dec. 11	9.00

See footnotes at end of table.

TABLE 3.—*Water levels in observation wells, in feet below land surface*—Continued

Date	Water level	Date	Water level	Date	Water level
		28-13-5dd			
1945		*1948*		*1951*	
Aug. 31	9.88	Dec. 13	[a] 9.63	June 15	8.00
1946		*1949*		July 15	8.50
Apr. 5	5.89	Apr. 6	6.72	Aug. 27	10.05
May 6	6.33	May 9	7.72	Sept. 17	9.90
June 4	6.55	June 9	8.58	Oct. 16	8.28
July 5	7.05	July 13	9.88	Nov. 14	6.40
Aug. 1	8.05	Aug. 9	10.60	Dec. 13	5.80
Aug. 30	9.41	Sept. 13	11.65	*1952*	
Oct. 2	9.83	Oct. 3	11.70	Jan. 9	7.90
Oct. 24	7.46	Nov. 9	11.49	Feb. 1	[a] 7.70
		Dec. 5	11.40	Mar. 10	[a] 8.00
1947				Apr. 21	[a] 4.50
May 5	5.43	*1950*		May 19	4.50
June 6	5.85	Mar. 17	[a] 10.50	June 17	6.50
July 7	6.77	Apr. 13	8.47	July 18	8.30
Aug. 5	8.77	May 16	9.02	Aug. 11	8.90
Sept. 3	9.56	June 14	9.65	Sept. 15	Dry
Oct. 21	9.99	July 6	9.90	Oct. 16	Dry
Dec. 22	6.24	Aug. 15	10.92	Nov. 13	Dry
		Oct. 6	11.67	Dec. 16	Dry
1948		Nov. 16	11.78		
Feb. 13	[a] 4.50	Dec. 20	[a] 11.80	*1953*	
Mar. 22	[a] 6.15			Jan. 14	Dry
June 9	6.59	*1951*		Feb. 16	Dry
July 9	7.36	Jan. 17	11.56	Mar. 13	Dry
Aug. 11	7.92	Feb. 26	[a] 11.15	Apr. 14	Dry
Sept. 10	9.10	Mar. 19	[a] 8.10	May 15	Dry
Oct. 11	9.50	Apr. 17	6.03		
Nov. 15	9.63	May 14	6.44		
		28-13-7bb			
1946		*1948*		*1949*	
May 14	49.08	June 9	48.84	Oct. 3	48.75
July 5	48.42	July 9	48.76	Nov. 9	48.59
Aug. 1	48.44	Aug. 11	49.43	Dec. 5	48.39
Aug. 30	48.34	Sept. 10	48.70		
Oct. 10	48.68	Oct. 11	48.80	*1950*	
Oct. 24	48.52	Nov. 15	48.75	Mar. 17	48.69
		Dec. 13	49.07	Apr. 13	48.67
1947				May 16	48.30
May 5	48.73	*1949*		June 14	48.68
June 8	48.70	Jan. 10	48.74	July 6	47.32
July 8	48.57	Feb. 17	48.85	Aug. 15	48.70
Aug. 5	48.60	Apr. 6	48.83	Oct. 6	48.78
Sept. 3	49.45	May 9	48.87	Nov. 16	48.56
Oct. 21	48.75	June 9	48.86	Dec. 20	48.67
Dec. 22	48.68	July 13	48.90	*1951*	
1948		Aug. 9	48.95	Jan. 17	48.38
Feb. 13	48.55	Sept. 13	48.71	Feb. 26	48.34
Mar. 22	48.53			Mar. 19	48.58
		29-11-3cc			
1945		*1947*		*1949*	
Sept. 1	8.95	July 8	5.72	Jan. 10	9.30
1946		Aug. 5	[b] 6.73	Feb 17	9.74
Apr. 5	6.94	Sept. 4	8.62	Apr. 6	7.35
May 6	6.96	Oct. 21	[b] 7.25	May 9	9.37
June 4	6.10			June 9	9.73
July 5	[e] 5.22	*1948*		July 13	[b] 10.24
Aug. 1	[b] 10.41	Feb. 13	[b] 8.10	Aug. 9	9.35
Aug. 30	6.55	Mar. 22	6.80	Sept. 13	9.81
Oct. 10	6.61	July 9	8.10	Oct. 3	9.38
Nov. 24	6.62	Aug. 11	8.70	Nov. 9	9.40
1947		Sept. 10	8.87	*1950*	
May 5	4.81	Oct. 11	10.02	Apr. 13	4.03
June 6	5.30	Nov. 15	9.05		
		Dec. 13	9.25		

See footnotes at end of table.

TABLE 3.—*Water levels in observation wells, in feet below land surface*—Continued

Date	Water level	Date	Water level	Date	Water level
		29-11-16cc2			
1946		*1948*		*1949*	
May 22	13.06	June 9	[b] 12.70	Nov. 9	14.10
July 5	12.64	July 9	13.71	Dec. 5	13.32
Aug. 1	12.71	Aug. 11	12.39	*1950*	
Aug. 30	12.78	Sept. 10	12.39	Mar. 20	13.28
Oct. 10	12.84	Oct. 11	12.53	Apr. 13	10.37
Oct. 24	12.93	Nov. 15	12.42	May 16	11.06
1947		Dec. 13	[b] 14.44	June 14	10.90
May 5	10.99	*1949*		July 6	10.94
June 6	11.00	Jan. 10	13.08	Aug. 15	11.24
July 8	11.31	Feb. 17	14.55	Oct. 6	11.15
Aug. 5	11.41	Apr. 6	14.06	Nov. 16	11.30
Sept. 4	11.53	May 9	13.54	*1951*	
Oct. 21	11.69	June 9	13.60	Jan. 17	13.07
Dec. 22	14.03	July 13	12.45	Feb. 26	13.05
1948		Aug. 9	12.78	Mar. 19	13.12
Feb. 13	[b] 13.93	Sept. 13	12.69		
Mar. 22	12.32	Oct. 3	13.42		
		29-11-32bb			
1946		*1949*		*1951*	
May 22	4.79	May 9	9.04	Nov. 14	1.92
July 5	6.55	June 9	9.34	Dec. 13	2.41
Aug. 1	7.87	July 13	9.92	*1952*	
Aug. 30	8.62	Aug. 9	10.25	Jan. 9	[a] 3.20
Oct. 10	8.76	Sept. 13	10.67	Feb. 1	[a] 3.00
Oct. 24	8.78	Oct. 3	10.82	Mar. 10	[a] [d] .50
1947		Nov. 9	10.93	Apr. 21	[d] 1.80
May 5	2.40	Dec. 5	10.96	May 19	[a] 2.00
June 6	4.30	*1950*		June 17	[d] 1.00
July 8	6.22	Mar. 20	[a] 9.70	July 18	[d] .20
Aug. 5	7.70	May 16	[d] [e] 1.20	Aug. 11	3.20
Sept. 3	8.42	June 14	[d] .57	Sept. 15	4.50
Oct. 21	8.60	July 6	[d] .14	Oct. 16	5.18
Dec. 22	8.80	Aug. 15	1.36	Nov. 13	5.15
1948		Oct. 6	5.09	Dec. 16	5.60
Feb. 13	[a] 8.50	Nov. 16	5.72	*1953*	
Mar. 22	[a] 8.80	Dec. 20	6.20	Jan. 14	[a] 5.00
June 9	8.63	*1951*		Feb. 16	[a] 5.55
July 9	8.77	Jan. 17	[a] 6.25	Mar. 13	[a] 4.90
Aug. 11	8.49	Feb. 26	[a] 6.23	Apr. 14	[a] 5.00
Sept. 10	9.04	Mar. 19	[a] .10	May 15	5.20
Oct. 11	9.27	Apr. 17	[d] 2.00	June 12	2.53
Nov. 15	9.39	May 14	[d] 1.71	July 10	4.40
Dec. 13	9.45	June 15	.15	Aug. 12	6.75
1949		July 15	[d] .45	Sept. 11	7.25
Jan. 10	[a] 9.56	Aug. 27	1.80	Oct. 15	6.84
Feb. 17	[a] 9.57	Sept. 17	1.40	Nov. 17	6.90
Apr. 6	[a] 8.65	Oct. 16	5.39	Dec. 11	6.85
		29-13-22ab1			
1946		*1946*		*1947*	
May 14	31.54	Aug. 30	31.66	Apr. 27	31.42
June 4	31.46	Oct. 2	31.50	June 6	31.50
July 5	32.47	Oct. 24	31.46	July 7	[b] 32.12
Aug. 1	31.59				

See footnotes at end of table.

TABLE 3.—*Water levels in observation wells, in feet below land surface*—Continued

Date	Water level	Date	Water level	Date	Water level
		30-11-27db			
1945		*1948*		*1949*	
Sept. 1	18.85	Feb. 13	19.00	Oct. 3	19.58
		Mar. 22	19.00	Nov. 9	19.50
1946		June 9	19.02	Dec. 5	19.42
May 6	18.30	July 9	19.08		
June 4	18.39	Aug. 11	19.19	*1950*	
July 5	18.58	Sept. 10	19.24	Mar. 20	19.55
Aug. 1	18.75	Oct. 11	19.52	May 16	18.94
Aug. 30	18.84	Nov. 15	19.14	June 14	18.95
Oct. 10	18.86	Dec. 13	19.10	July 6	18.87
Oct. 24	18.87			Aug. 15	18.99
		1949		Oct. 6	19.02
1947		Jan. 10	19.12	Nov. 16	19.10
May 5	18.56	Feb. 17	19.15	Dec. 20	18.99
June 6	18.50	Apr. 6	19.09		
July 8	18.83	May 9	19.10	*1951*	
Aug. 5	18.96	July 13	19.50	Jan. 17	19.30
Sept. 4	19.12	Aug. 9	19.48	Feb. 26	18.85
Oct. 21	20.95	Sept. 13	19.50	Mar. 19	19.00
		30-11-32cb			
1945		*1948*		*1949*	
Sept. 1	12.60	July 9	13.37	Nov. 9	10.15
		Aug. 11	12.33	Dec. 5	9.53
1946		Sept. 10	12.08		
Apr. 5	7.36	Oct. 11	13.14	*1950*	
May 6	9.48	Nov. 15	10.86	Mar. 20	[a] 9.25
June 4	[b] 10.89	Dec. 13	11.00	Apr. 13	2.72
July 5	[e] 4.74			May 16	4.55
Aug. 1	6.85	*1949*		June 14	5.19
Aug. 30	9.11	Jan. 10	[b] 12.36	July 6	5.69
Oct. 12	9.74	Feb. 17	13.53	Aug. 15	7.16
Oct. 24	11.10	Apr. 6	9.40	Oct. 6	7.18
		May 9	9.94	Nov. 6	7.66
1947		June 9	11.69	Dec. 20	7.60
May 5	5.66	July 13	10.97		
June 6	8.40	Aug. 9	12.65	*1951*	
July 8	9.54	Sept. 13	10.68	Jan. 17	[a] 6.50
Aug. 5	9.24	Oct. 3	12.18	Feb. 26	[a] 6.50
Sept. 4	11.43			Mar. 19	[a] 7.70
Oct. 21	9.58				
		30-11-36dd2			
1946		*1946*		*1946*	
May 15	9.95	Aug. 1	11.34	Oct. 10	11.44
July 5	9.87	Aug. 30	11.94	Oct. 24	11.46
		30-12-36aa			
1946		*1947*		*1948*	
May 6	28.00	June 6	26.80	June 9	27.40
June 4	27.91	July 8	27.72	July 9	27.67
July 5	28.31	Aug. 6	28.61	Aug. 11	27.53
Aug. 30	[b] 39.77	Sept. 4	28.08	Sept. 10	28.07
Oct. 10	28.39			Oct. 11	28.98
		1948			
1947		Feb. 13	27.55		
May 5	27.66	Mar. 22	27.20		

See footnotes at end of table.

TABLE 3.—*Water levels in observation wells, in feet below land surface*—Continued

Date	Water level	Date	Water level	Date	Water level
		30-13-26dc			
1946		*1949*		*1951*	
May 10	8.86	June 6	8.45	Nov. 14	4.90
July 5	9.25	July 13	9.03	Dec. 13	7.60
Aug. 1	9.18	Aug. 9	9.26		
Aug. 30	9.28	Sept. 13	9.40	*1952*	
Oct. 2	9.43	Oct. 3	9.48	Jan. 9	[a] 7.70
Oct. 24	9.53	Nov. 9	9.65	Feb. 1	[a] 8.00
		Dec. 5	9.78	Mar. 10	[a] 7.50
1947				Apr. 21	7.35
Apr. 27	9.84	*1950*		May 19	5.15
June 6	9.95	Mar. 17	[a] 8.53	June 17	6.50
July 7	9.86	Apr. 13	8.19	July 8	7.65
Aug. 5	10.15	May 16	8.80	Aug. 11	7.60
Sept. 3	9.73	June 14	8.30	Sept. 15	8.00
Oct. 21	9.47	July 6	7.29	Oct. 16	8.40
Dec. 22	9.70	Aug. 15	6.39	Nov. 13	8.70
		Oct. 6	8.40	Dec. 16	8.70
1948		Nov. 16	9.15		
Feb. 12	[a] 9.00	Dec. 20	9.40	*1953*	
Mar. 22	[a] 9.50			Jan. 14	8.50
June 9	8.49	*1951*		Feb. 16	[a] 9.00
July 9	7.54	Jan. 17	9.50	Mar. 13	[a] 7.50
Aug. 11	6.59	Feb. 26	[a] 8.75	Apr. 14	[a] 8.80
Sept. 10	7.23	Mar. 19	[a] 7.80	May 15	8.90
Oct. 11	7.78	Apr. 17	5.86	June 12	2.09
Nov. 15	8.12	May 14	7.20	July 10	4.10
Dec. 13	[a] 8.33	June 15	7.90	Aug. 21	5.45
		July 15	5.15	Sept. 11	6.05
1949		Aug. 27	5.00	Oct. 15	6.78
Jan. 10	[a] 8.37	Sept. 17	5.20	Nov. 17	7.40
Feb. 17	[a] 8.35	Oct. 16	6.20	Dec. 11	7.80
Apr. 6	10.05				
May 9	9.94				
		30-13-29dc2			
1945		*1948*		*1949*	
Sept. 1	18.40	Feb. 13	14.30	Oct. 3	17.52
		Mar. 22	14.44	Nov. 9	17.79
1946		June 9	14.81	Dec. 5	18.03
Apr. 5	19.03	July 9	14.95	*1950*	
May 6	17.33	Aug. 11	15.13	Mar. 20	18.48
June 4	16.88	Sept. 10	15.28	Apr. 13	18.48
July 5	18.68	Oct. 11	15.55	May 16	17.14
Aug. 1	18.61	Nov. 15	15.74	June 14	16.49
Aug. 30	17.95	Dec. 13	16.05	July 6	16.10
Oct. 10	17.55	*1949*		Aug. 15	16.20
		Jan. 10	16.30	Oct. 6	16.98
1947		Feb. 17	16.43	Nov. 16	17.34
May 5	12.52	Apr. 6	16.72	Dec. 20	17.00
June 6	11.25	May 9	16.64	*1951*	
July 8	11.72	June 9	16.86	Jan. 17	17.86
Aug. 6	12.40	July 13	16.90	Feb. 26	18.32
Sept. 4	12.84	Aug. 9	17.44	Mar. 19	18.10
Oct. 21	13.38	Sept. 13	17.40		

See footnotes at end of table.

TABLE 3—*Water level in observation wells, in feet below land surfoce*—Continued

Date	Water level	Date	Water level	Date	Water level
			30-13-35bc1		
1945		*1949*		*1951*	
Aug. 31	16.90	Jan. 10	15.78	Sept. 17	15.10
		Feb. 17	16.08	Oct. 16	16.15
1946		Apr. 6	16.53	Nov. 14	16.80
Apr. 5	17.92	May 9	17.10	Dec. 13	17.50
May 6	18.15	June 9	15.37		
June 4	18.13	July 13	14.08	*1952*	
July 5	16.36	Aug. 9	14.74	Jan. 9	16.80
Aug. 1	15.46	Sept. 13	15.50	Feb. 1	16.60
Aug. 30	15.59	Oct. 3	15.85	Mar. 10	16.50
Oct. 2	16.03	Nov. 9	16.30	Apr. 21	16.95
Oct. 24	16.22	Dec. 5	16.75	May 19	17.25
				June 17	16.90
1947		*1950*		July 8	17.15
Jan. 4	16.90	Mar. 17	18.23	Aug. 11	16.40
Apr. 27	17.49	Apr. 13	18.49	Sept. 15	15.90
June 6	17.55	May 16	19.10	Oct. 16	15.73
July 7	15.75	June 14	17.70	Nov. 13	16.10
Aug. 5	14.55	July 6	17.10	Dec. 16	16.25
Sept. 3	14.09	Aug. 15	17.30		
Oct. 21	14.78	Oct. 6	17.30	*1953*	
Dec. 22	15.30	Nov. 16	17.77	Jan. 14	17.10
		Dec. 20	17.00	Feb. 16	16.30
1948				Mar. 13	16.70
Feb. 12	16.30	*1951*		Apr. 13	16.90
Mar. 22	16.73	Jan. 17	17.68	May 15	16.90
June 9	15.58	Feb. 26	17.56	June 12	15.57
July 9	14.79	Mar. 19	18.42	July 10	15.10
Aug. 11	13.77	Apr. 17	17.67	Aug. 21	15.80
Sept. 10	14.26	May 14	18.40	Sept. 11	15.40
Oct. 11	14.72	June 15	17.30	Oct. 15	15.47
Nov. 15	15.10	July 15	15.80	Nov. 17	15.55
Dec. 13	15.47	Aug. 27	13.60	Dec. 11	16.05
			30-14-8bd		
1945		*1947*		*1948*	
Aug. 31	31.40	Aug. 5	32.31	Nov. 15	32.78
		Sept. 4	32.80	Dec. 13	33.00
1946		Oct. 21	34.74		
Apr. 5	32.35	Dec. 22	34.84	*1949*	
May 6	32.17			Jan. 10	33.12
June 4	32.42	*1948*		Feb. 17	[b] 33.57
July 5	33.88	Feb. 12	31.19	Apr. 6	[b] 33.79
Aug. 1	32.80	Mar. 22	32.70	May 9	32.09
Aug. 30	32.99	June 9	[b] 34.22	June 9	[b] 33.18
Oct. 2	32.84	July 9	[c] 32.60	July 13	32.50
Oct. 24	32.79	Aug. 11	[c] 31.88	Aug. 9	32.80
		Sept. 10	[b] 32.40	Oct. 3	32.60
1947		Oct. 11	31.93	Nov. 9	32.63
May 5	32.88				
June 13	32.30				
July 7	[b] 34.23				
			31-14-23bc2		
1946		*1947*		*1948*	
May 26	18.02	May 5	18.07	Feb. 12	18.16
July 5	18.21	July 7	18.18	Mar. 22	18.18
Aug. 1	18.32	Aug. 5	18.52	June 9	18.45
Aug. 30	18.34	Sept. 4	18.74	July 9	18.50
Oct. 2	18.25	Oct. 21	18.27	Aug. 11	18.54
Oct. 24	18.15	Dec. 22	18.22		

[a] Water surface frozen.
[b] Well pumped recently.
[c] Well being pumped.
[d] Water level above land surface.
[e] Well surrounded by ponded water.

TABLE 4.—*Record of wells in the Lower Marias irrigation project*

Well: See text for explanation of well-numbering system.
Type of well: B, bored; DD, dug and drilled; Dn, driven; Dr, drilled; Du, dug.
Depth of well: Measured depths are given in feet and tenths; reported depths are given in feet.
Type of casing; C, concrete (brick, tile, or pipe); N, none; P, iron or steel pipe; W, wood.
Geologic source: Kcl, Claggett shale; Kel, sandstone of the Ellis group; Keu, upper member of Eagle sandstone; Kev, Virgelle sandstone member of Eagle sandstone; Kjr, Judith River formation; Qd, Quaternary deposits.
Type of pump: Cy, cylinder; HC, horizontal centrifugal; HP, horizontal piston; N, none; P, pitcher pump; R, rotary; RB, rope and bucket; S, submersible turbine.
Kind of power: E, electric; F, natural flow; G, gas engine; H, hand operated; J, jet; N, none; W, windmill.
Use of water: D, domestic; I, irrigation (lawn and garden); N, none; O, observation of water-level fluctuations; P, public supply; S, stock.
Measuring point: Bcu, base of curb; Bp, base of pump; Ls, land surface; Tca, top of casing; Tco, top of cover; Tcp, top of corner post; Tcu, top of curb.
Depth to water: Measured depths are given in feet, tenths, and hundredths; reported depths are given in feet.
Remarks: A, adequate supply (numeral denotes head of stock); Ca, sample collected for chemical analysis; F, foul smelling; I, inadequate supply; L, log in table; M, reported mineralized; Y, reported yield (numeral denotes gallons per minute).

Well	Owner or tenant	Year drilled	Type of well	Depth of well below land surface (feet)	Diameter of well (inches)	Type of casing	Geologic source	Type of pump	Kind of power	Use of water	Measuring point: Description	Measuring point: Height above or below (–) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks
28-10- 2dd	George Miner	1916	Dr	525	4	P	Kev	Cy	W	S			2,886			M
3ab	Joe H. Drew	1916	Dr	500	4	P	Kev	Cy	W	N			2,890			
7bb	H. R. Matthews	1916	Dr	410	4	P	Kev	Cy	W	S			2,912	200		M; Y-15
7da	Kenneth F. Works	1935	Du	14.6	60	C	Qd	HC	G	D, S	Tco	1.5	2,901.5	8.76	5-28-46	
9db	W. M. Finke	1920	Dr	486	3	P	Kev	Cy	W, G	D, S			2,919	180		M; A—20
10ab	Joe H. Drew	1915	Dr	500	2	P	Kev	Cy	W	S			2,910	190		M
10ba	Hilda N. Anderson		Du	33.4	48	W	Qd	Cy	H	S	Bcu	3.0	2,911	28.57	5-29-46	A-20
12da	Fred Pearson	1914	Dr	513	4	P	Kev	Cy	W	S			2,879	180		M
13ba	A. W. Madison	1915	Dr	477	3	P	Kev	Cy	W	D, S			2,889	85	1915	A—30
14ab	F. J. Swanson		Du	11.0	48	W	Qd	N	N	N	Tca	2.5	2,888.5	11.27	5-28-46	F
14cc	T. O. Dillon	1915	Dr		3	P	Kev	Cy	W	S	Tca	.4	2,907.4	237.75	10-18-46	M
14dd	Adolph Swanson	1913	Dr	400+	4	P	Kev	Cy	W	D, S			2,911			Ca
15ad	Leonard Swanson	1916	Dr	450+	3	P	Kev	Cy	N	N			2,899	123		
15cc	Charles Works	1916	Dr	500±	3	P	Kev	Cy	W	S			2,912	200+		M
17aa	Mary Marks		Du	26.2	60	C	Qd	P	H	N	Tco	.0	2,916	12.20	5-28-46	
17dd	William Works	1916	Dr	500	3	P	Kev	Cy	W	D, S			2,926			A-50; Ca
19ba	Archilas Bessette		Dr		4	P	Kev	Cy	W	S			2,926.7			M
20dd	Annette Keith		Dr		3	P	Kev	Cy	W	D, S			2,930			
23bb	George Reichelt		Dr		3	P	Kev	Cy	W	N			2,914			
23cc	Burl Miner	1911	Dr	454	3	P	Kev	N	N	O	Tca	2.5	2,932.9	244.75	8- 1-46	M
25bb	Carl Cristofferson	1916	Dr	450+	3	P	Kev	Cy	G	S				200		M

27bb	Agnes Drew	1934	Du	32	48	W	Qd	Cy	H	D			2,922	8		
28ab	Maynard Johnson		Du	23.1	42	W	Qd	Cy	H	S, O	Tcu	2.5	2,922.5	7.21	5-28-46	
29aa	Annie M. Dixon		Du	16.5	48	W	Qd	RB	H	D	Tco	4.0		15.13	5-28-46	
11— 2ab	Gordon Crofoot		Du	10.2	48	W	Qd	N	N	O	Tcu	1.5	2,849.5	8.47	5-20-46	
3cd	Maurits Monson		Du	29.2	48	N	Qd	N	N	N			2,898	Dry	5-20-46	
6ab	Henry Chauvet		Du	18.2	48	W	Qd	N	N	N	Tcu	−1.0	2,833	9.97	5-20-46	F
6dd	Lloyd Pearson	1945	Dr	600	5.5	P	Kev	Cy	W	S			2,877	113		Ca
10cc	A. J. Cline		Du	30.8	48	W	Qd	Cy	H	D, S, O	Tco	.5	2,906.5	8.87	5- 6-46	
12ad	Clara A. Elverson	1931	Dr	3,120	12, 4¾	P	Kel	N	N	F			2,919.2			M; Y-0.5; L
14dd	Frank V. Holmes	1917	Dr	604	3	P	Kev	Cy	G, W	D, S			2,919	304		Ca
15cd	Frank W. Silka	1917	Dr	600	3	P	Kev	Cy	W	N			2,925	200	1917	M
18cc	Floyd Parr	1917	Dr	485	6	P	Kev	Cy	W	S			2,914	150+		
19cd	Leonard Swanson	1917	Dr	450+	6	P	Kev	Cy	G	S			2,930	200+		
22bb	R. F. Haakensen	1917	Dr	650	4	P	Kev	Cy	W	S						A-50; Ca
12- 1ad	Ernest Picken	1916	Du	53.1	48	C	Kjr	Cy	H	D, S	Tco	2.0	2,877	49.49	5-16-46	Ca
2ac	Raymond Livers	1916	Du	33.2	54	C	Kjr	Cy	H	S	Tco	.5	2,866.5	25.04	5-22-46	A-20
2db	Rose Kivilin Estate	1916	Du	25.5	60	C	Kjr	Cy	H	D, S	Tco	.8	2,867.9	23.62	5-22-46	A-10
3da	Clifford Dyrland		Du	23.9	60	C	Kjr	N	N	N	Tcu	.4	2,864.4	22.03	5-16-46	
8dd	S. M. Dyrland		Du	18.5	48	C	Qd	Cy	G	D, S, O	Tco	1.5	2,873.5	7.07	5- 6-46	
11aa	N. R. Martin	1910	Du	55.6	46.7	C	Kjr	Cy	H	D, S	Tco	1.3		50.12	5-14-46	
12aa	Henry Gerson	1912	Du	54	36	C	Kjr	Cy	H	D, S				46		A-26
13bd	William Finke		Du	44.2	48	W	Qd	Cy	H	N				Dry	5- 6-46	
16aa			Dr	100+	5	P		N	N	N				100+	5-16-46	
24ca	Jessie A. Marcinko		Du	29.0	30	W	Qd	RB	H	D	Tcu	1.0		26.72	5-14-46	
24db	do		Du	44.2	48	W	Qd	Cy	W	D, S	Tco	.2		31.76	5-14-46	
13- 5dd	Christopher Jensen		Du		48	W	Qd	Cy	H	O	Tco	1.0		7.33	5- 6-46	
6cd	Max Gerson	1912	Du	54.4	42	N	Kjr	Cy	H	N	Tcu	1.3		50.59	5-14-46	
7bb	Robert W. Martin	1916	Dr	60.1	5	P	Kjr	Cy	H	O	Bp	.1		49.18	5-14-46	
18ac	Henry Chevette	1888	Dr	78.0	8	P	Qd	Cy	W	S	Tca	−6.0		38.68	5-23.46	M; A-125
19ba1	Mrs. L. Walters		Dr	63.9	6	P		Cy	H	N	Tca	1.0		21.81	5-23-46	
19ba2	Martin Bakke		Dr	64.9	6	P		Cy	H	N	Tca	.0		21.44	5-23-46	
19ba3	Otis Misfeldt	1916	Dr	58.9	5	P		N	N	N	Tcu	.0		22.50	5-23-46	
19ba4		1916	Dr	79.4	6	P		Cy	H	N	Tca	.0		24.89	5-23-46	
19ba5			Dr	56.3	4	P		Cy	H	N	Tca	.4		23.23	5-23-46	
19bb	C. McNamarra	1916	Dr	39.5	4	P		Cy	H	N	Bp	2.0		24.8	5-23-46	
19bd	Town of Big Sandy	1930	Dr	90	6	P		S	E	P	Tca			25-30		Y-45
20bb	do	1941	Dr	109	8	P		S	E	P				12.5		Y-60
29- 7- 1da	Donald Fraser	1916	Dr	160	6	P		Cy	G	D, S			2,919	110		M; Y-159
2cb	Stanley Kantorowiez	1926	Dr	180	6	P		Cy	G	D, S			2,923			M
3cd	Carl Borys	1930	Dr	200	6	P		Cy	G, W	S			2,922			M; A-50
11ad	John C. Brickman		Dr	130.1	5	P		N	N	N			2,916	Dry		
12ab	Carl Kantorowiez		Dr	200						N			2,918			
8- 4aa	Pete Siemens	1916	Dr	220	6	P	Qd	Cy	G	D, S			2,916.8	190		M; A-100; Ca
6bb	L. B. Han	1916	Dr	185	6	P		Cy	G	D, S			2,931			A-140
9- 5aa	A. J. Wilson	1916	Dr	250	6	P	Qd	Cy	G	D, S			2,884	70		Y-15; Ca
6aa	Howard Tracht	1916	Dr	350	6	P		Cy	G, W	S			2,894			
7bb	D. E. Black	1926	Du	17.5	48	W	Qd	N	N	N	Tcu	3.5	2,885.5	11.47	6-11-46	
8cc	Herbert Boehm	1930	Dr	245	6	P		Cy	G	D, S			2,876	110		
14ad	Albert Bold	1914	Dr	422	2.5	P		Cy	W	N			2,887.7	272	1915	Y-3
17da	Frank O'Neil	1944	Dr	320	5	P		Cy	G	D, S			2,875	125		M; Y-1
18cb1	Albert Hansen	1916	Dr	129	5	P		N	N	N			2,890			
18cb2	do	1943	Dr	318	6	P		Cy	W, G	S			2,890			

See footnotes at end of table.

TABLE 4.—*Record of wells in the Lower Marias irrigation project*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well below land surface (feet)	Diameter of well (inches)	Type of casing	Geologic source	Type of pump	Kind of power	Use of water	Measuring point: Description	Measuring point: Height above or below (–) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks
29-10- 1cd	U. S. Dept. Interior		Du	13.0	84	W	Qd	Cy	H	D, S	Bp	3.9		10.25	5-24-36	
2ad	George Cook	1946	Dr	319	7, 4	P	Qd	Cy	W	D, S	Tca	.2		153.87	7-18-46	A-100; Ca
18cc1	Reinhard Bold	1916	Dr	450	5	P	Kev	Cy	W	D, S			2,878	200		M; A-200; Ca
18cc2	do	1941	Dr	435	4	P	Kev	Cy	W, G	D, S			2,876	200		M; A-200
20aa	Walter Buchholz	1918	Dr	393	5, 3	P	Kev	Cy	W, G	D, S			2,870	150		A-50
22bc	Dave Stroup	1916	Dr	580	5	P	Kev	Cy	W	D, S			2,867			Ca
22dd	Raymond Reichelt		Dr	350	4	P	Keu	Cy	W				2,870			I
23aa	Willis Kulbeck	1917	Dr	495	6	P	Kev	Cy	W, G	D, S			2,860	180		Y-15; Ca
25cc	Christ Larson	1916	Dr	500	3	P	Kev	Cy	W	S			2,875			M
26ba	Peter Paulson	1931	Dr	400	6	P	Keu	Cy	W	D, S			2,874			I; Ca
26cc	M. L. Peterson	1916	Dr	450	4	P	Kev	Cy	W	S			2,888			M; A-40
28cb	Edward Bucholz	1916	Dr	456	4	P	Kev	Cy	W, G	D, S			2,887	180		A-75
29ac	Alvin Jenkins	1916	Dr	460	4	P	Kev	Cy	W	D, S			2,882	180		A-60
31da1	A. G. Jennings	1941	Dr	470	6, 4	P	Kev	Cy	W	S			2,896			Y-15; Ca
31da2	do	1941	Dr	375	6	P	Kcl	N	N	N	Tca	.6	2,896	168.10	7-18-46	
36dd	State of Montana		Dr		3	P		Cy	W	N			2,862			
11- 3cc	George Dielman		Du	11.2	72	C	Qd	Cy	G	D, S, O	Tcu	.5		7.46	5- 6-46	
7aa	Clara Linn		Du	23.0	48	W	Qd	Cy	W	D, S	Tco	2.0		20.12	5-17-46	
7bc	W. E. Parker		Du	18.4	60	W	Qd	HC	G	D, S	Tcu	3.8		7.80	5-22-46	A-200
16cc1	Peter Christofferson		Du	16.5	60	W	Qd	Cy	W	S	Bp	3.5		15.98	5-22-46	
16cc2	do		Du	23.5	72	W	Qd	HP	G	D, S, O	Tco	3.5		16.56	5-22-46	Y-25; Ca
17dd	Albert Archibald		Du	22.4	(1)	W	Qd	Cy	G	D, S	Tco	1.0		5.64	5-22-46	
29ca	James Morrison		Du	11.8	60	W	Qd	Cy	H	D, S	Tcp	4.0	2,816	6.44	5-22-46	
32bb	Peter Christofferson		Du	15.9	60	W	Qd	N	N	O	Tcu	3.5	2,821.5	8.29	5-22-46	M
35ca	Roy Crofoot		Du	19.4	60	C	Qd	Cy	H	D, S	Bp	3.8	2,842	15.98	5-20-46	
36cd	State of Montana		Du	11	36	W	Qd	Cy	H	N	Bp					(2)
12- 5dd1	Heinrich Bitz		DD	90			Qd	Cy	W	S	Bp	1.0	2,789	2.55	5-15-46	
5dd2	do	1945	Dr	629	5.5	P	Kev	Cy	G	S			2,794.6			Ca; L
9ad	do	1917	Dr	412	2	N		Cy	W	N			2,790			
24ad	Western Holding Co.		Du	26.5	48	C	Qd	Cy	H	D, S	Tco	.5	2,710.8	9.36	5-14-46	
25dd	A. O. Cleveland		Dr	93.6	6	P	Kjr	Cy	H	D, S	Tca	.0	2,836	54.11	5-14-46	
26ad	George Campbell		Du	10.0	144	C	Qd	N	N	N	Tcu	.0	2,720	5.95	7-24-46	
32bd	John Russell		Du	17.4	72	W	Qd	HC	G	S	Tco	.6	2,756.6	14.40	5-13-46	
32db	do		Du	18.2	96	W	Qd	Cy	H	D, S	Tcu	1.5	2,757.5	15.70	5-13-46	A-500; Ca
34dd	Elmer Lund		DD	47.1	6	P	Kjr	Cy	W, G	D, S	Tca	2.0	2,858	30.42	5-16-46	
35dc1	Julius Peterson		Du	14.1	48	C	Kjr	N	N	N	Tco	.5	2,840	11.29	5-14-46	I

35dc2	do.	1946	Du	5.2	48	C	Kjr	Cy	H	D, S	Bp	.5	2,830.5	1.75	5-14-46	
13- 5bb	John Grass	1944	Dr	152	6	P	Kjr	Cy	H, E	D, S, I						Y-10
14ac	H. V. Williams	1946	Dr	50	6	P	Qd	Cy	W	D, S						Y-3
21aa1	O. F. Hagan	1910	Du	30	48	C	Qd	Cy	W	D, S, I	Tco	.8		24.10	8-31-45	I
21aa2	U. S. Dept. Interior	1947	Dr	210	2	P	Qd	N	N	N	Tca	.4		16.42	5-21-47	L
21dd	K. W. Hagan		Du	26.6	48	W	Qd	Cy	G	D, S	Tco	.5		24.51	5-14-46	I
22ab1	William Drake		Du	48.8	48	W	Qd	N	N	O	Tco	.6		32.14	5-14-46	I
22ab2	do.	1945	Dr	248	5.5	P	Qd	Cy	W, G	D, S, I				60		Ca; L
26bb			Du	30.2	36	W	Qd	N	N	N				Dry		
27dc	Max W. Clawiter	1946	Dr	235			Qd							40		Y-50
30- 7-34dc	John Dalimator	1940	Dr	180	6	P	Qd	Cy	G	D, S	Tca	.3	2,934.3	7.0	6-12-46	
8-31cc	C. D. Han	1946	Dr	265	6	P	Keu	Cy	J							Y-10; M
32dc	K. M. Han		Dr	157.2	6	P		N	N	N	Tca	.0		156.5		F
9-13dc	Charles Mikluckey		Du	9.5	96	W	Qd	Cy	H	S	Tcu	.0		5.90	5-31-46	A-300; M
23cd	C. E. Klemetson	1936	Du	11.6	48	W	Qd	RB	H	D, S	Tco	1.5	2,906.4	8.60	5-31-46	I
24cb	Adolph Klemetson	1926	Du	17.0	60	W	Qd	Cy	W	D, S	Tco	1.0	2,921	16.21	5-31-46	I
25ba	Joseph Frolik		Du	20.7	42	W	Qd	Cy	H	S	Tco	1.0	2,922	19.21	5-31-46	F
25cc	Russell Jackson	1916	Dr	100.5	6.5	P		N	N	N	Tca	.5	2,902.5	Dry	5-31-46	
26dd	do.	1916	Dr	22.6	5	P		N	N	N	Tca	.0	2,900	Dry	5-31-46	
27da	Hank Luken		Du		48	C	Qd	Cy	G	D			2,890			I
29dd	Lewis E. Mertz		Du	7.7	48	W	Qd	RB	H	D, S	Tca	5.0	2,892	8.04	6-11-46	
32cb	Karl Vaeck		Dr	250				Cy	W				2,903			
34cd	Matt Carr	1926	Dr	111	6	P	Qd	N	N	N	Tca	.2	2,886.8	Dry	6-11-46	
10-25aa	U. S. Dept. Interior		Du	13.3	[3]	W	Qd	N	N	N	Tcu	.5		10.47	5-24-46	
29ab	Charles Mikluckey	1946	Dr	453	5.5	P	Kev	Cy	W, G	S			2,943.6	268	5-30-46	Ca
11-10cc	Harold Pulaski	1946	Dr	77.0	4	N		N	N	N	Ls	.0		50.88	7-14-46	
15cb	Anna Eller		Du	43.3	48	W		N	N	N	Ls	.0		Dry	5-17-46	
17da	J. D. Griffith	1946	Dr	742	4.5	P	Kev	Cy	G	S				60		Ca; L
22cd	Elba Walls	1912	Du	40	60	C		Cy	W	D, S				36		
24dd	Aline O'Conners		Du	24.5	48	N		N	N	N	Tco	.0		22.80	5-15-46	
27db	E. J. Walls		Du	22.6	48	W		Cy	H	D, O	Tco	2.5		20.80	5- 6-46	
30cb	M. G. Hass		Du	10.9	48	W		N	N	N	Tcp	.5		11.10	5-24-46	
32cb	Frank Silvernale		Du	13.7	48	W	Qd	Cy	H	D, S, O	Tco	3.0		12.48	5- 6-46	
36dd1	O. K. Olson		Du	21.8	48	W	Qd	Cy	H	D, S						I
36dd2	do.		B	22.2	12	P	Qd	Cy	H	O	Bp	.6	2,851.6	10.55	5-15-46	
12-17ca	U. S. Dept. Interior	1946	Dr	207	5.5	P	Kjr	Cy	W	S				80		Y-6
19db	A. Renner		Du	14.8	48	W	Qd	RB	H	S	Tcu	3.0		10.07	5-16-46	
19dc	do.	1946	Dr	116	5.5	P	Qd	Cy	G	D, S				60		I
23dc	Albert Bitz	1926	Dr		6	P		Cy	W, G	D, S						
26aa	George Falk		Du	100+		N		Cy	H	N				Dry		
26bb	William McCrum		Du	39.9	72			Cy	H	D, S	Tco	.1		30.25	5-16-46	
27dc1	H. H. Bitz		Du	30				Cy	H	D, S				28		
27dc2	do.	1945	Dr	202	6	P		Cy	W, G	S				150		Y-1; L
31da	Emil Jourgenson	1945	Dr	152	6	N		N	N	N				Dry		
36aa	Fred Schmith	1945	Dr	738	6	P	Kev	Cy	W	S, O	Tco	3.2		31.20	5- 6-46	A-50; Ca; L
13-22dc	U. S. Dept. Interior		Du	11.8	[4]	W		N	N	N	Tcu	.1		10.55	5-10-46	
25aa	do.		Dr	90	6	P		Cy	H	D, S	Tca	.5		44.89	5-10-46	
26dc	Great Northern Ry		Du	13.7	54	W		Cy	H	S, O	Tco	.5		9.36	5-10-46	
27dd	J. J. O'Conner	1941	B	18.8	8	P	Qd	Cy	H	S	Tca	1.0		9.67	5-10-46	
29bd	Fred Schmith	1945	Dr	204	6	P	Kjr	Cy	W, G	S						
29dc1	Anton Nedregger	1945	Dr	141	6	P	Qd	Cy	W	S				4.5		Y-15; L
29dc2	do.		Du	20.2	48	W	Qd	Cy	H	D, O	Tco	.5		17.83	5- 6-46	

See footnotes at end of table.

TABLE 4.—*Record of wells in the Lower Marias irrigation project*—Continued

Well	Owner or tenant	Year drilled	Type of well	Depth of well below land surface (feet)	Diameter of well (inches)	Type of casing	Geologic source	Type of pump	Kind of power	Use of water	Measuring point: Description	Measuring point: Height above or below (−) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks
30-12-35ba1	Nolan	1946	Dr	42	6	P	------	------	------	------	------	------	------	------	------	
35ba2	Edward Kruger	1935	Dr	28	6	P	------	Cy	H	D	------	------	------	18	------	
35ba3	Boxelder Hospital	------	Dr	35	6	------	------	R	E	D	------	------	------	------	------	
35ba4	George Briggs	------	DD	32	7	P	------	------	------	D	------	------	------	------	------	
35bb1	------	1946	Dr	45.7	6	P	Qd	N	N	N	Tca	1.0	------	13.88	7-25-46	
35bb2	Agnes Wick	------	Dr	48	------	------	------	R	E	D	------	------	------	------	------	
35bb3	William Frohwirth	1946	Dr	44.4	5.5	P	Qd	------	------	N	Tca	.7	------	14.75	7-17-46	Y-50
35bb4	Freier	1946	Dr	46.8	4	P	Qd	Cy	H	D, S, I,	Tca	.3	------	15.50	5-10-46	Y-30
35bc1	William Cowan	------	Du	21	48	W	Qd	Cy	H, W	D, I, O	Tco	.3	------	17.20	8-31-45	
35bc2	J. E. Prather	1928	Du	38	(5)	W	------	Cy	E	D	------	------	------	18	------	
35bc3	D. Bitz	------	Dr	42	6	------	------	------	------	D	------	------	------	------	------	
35bc4	Art Cowan	------	Du	40	48	------	------	------	------	------	------	------	------	------	------	
35bc5	Alfred Faechner	------	Du	25	60	W	------	Cy	G	D, S, I	------	------	------	------	------	
35bd1	Webster Briggs	1914	DD	26	6	P	------	R	E	D	------	------	------	18	------	
35bd2	H. C. Goodien	1930	Du	26	36	C	------	Cy	E	D	------	------	------	18	------	
35bd3	Beck	1916	Du	30	36	W	------	Cy	H	D	------	------	------	18	------	
35bd4	Flansburg	1936	Du	25	48	W	------	Cy	H	D	------	------	------	18	------	
35bd5	Nickolas Fouarg	1930	Du	30	42	W	Qd	R	E	D	------	------	------	18	------	
35bd6	Boxelder School	1929	Du	35	36	C	------	R	E	D	------	------	------	------	------	Y-30
14- 8bd	R. Swan	------	Du	37.2	48	W	Qd	Cy	W	D, S, O	Tco	.8	------	32.97	5- 6-46	
17ba	Fred Guenser	------	Du	65	48	------	Qd	Cy	W	D, S	Tco	.3	------	39.53	5-14-46	
31-14- 2ba	L. J. Anderson	------	Dr	100+	5	P	------	Cy	H	N	Tca	.5	------	39.89	5- 7-46	
12cb	Roy Lotton	------	Dr	155	6	P	------	Cy	W	S	Tca	.6	------	33.80	5- 7-46	L
13ad	Steve Waritz	------	DD	10	------	P	------	Cy	H	N	------	------	------	------	------	
13bc	William Brown	1916	Du	24.5	48	W	------	Cy	E	S	Tco	.0	------	20.78	5-10-46	
15ba	F. E. Boyer	1945	B	19.5	6	P	------	Cy	H	D	------	------	------	------	------	
15dd1	William Daniel	------	Du	18.8	36	W	------	N	N	N	Tco	.0	------	16.92	6-26-46	
23ac	Steve Waritz	1936	Du	5.4	18	P	------	RB	H	D	Tca	2.2	------	3.79	5-14-46	
23bc1	Wilfred Tow	1939	Du	24	72	C	Qd	R	E	D, S, I	------	------	------	17	5-27-46	Ca
23bc2	Clint Clark	------	Du	24	48	C	------	Cy	H	D, S, O	Bp	.5	------	18.52	5-26-46	
23cc	do	------	Du	25	48	C	------	Cy	W	D	------	------	------	------	------	
32dc	William Daniel	1917	Du	28	36	W	Qd	Cy	H	D, S	------	------	------	------	------	
33bc	U. S. Dept. Interior	------	Du	29.7	60	W	------	Cy	H	D, S	Tco	.2	------	26.62	6-26-46	
34aa	P. M. Delp	1939	Du	14	60	C	Qd	Cy	H	D, S	------	------	------	9	------	A-100
15-5ab	Gordon Sand	------	Dr	55	6	P	------	Cy	H	N	Tca	.5	------	29.45	6-26-46	

8ad	do		Dr	47.8	6	P		N	N	N	Tca	.0		27.84	6-26-46	
8ab	W. Neuwerth	1917	Dr	69.6	6	P		Cy	G	D	Bp	2.0		51.40	6-26-46	Y-15
32-14-25bb	Simon Jess	1944	Dr	119	4	P	Qd	Cy	W	D, S				40	1944	Y-10; L
25da			Dr	93.3	4	P		N	N	N	Tca	.2		45.67	5- 7-46	
33dd	George Daniel		Du	15	30	W		Cy	H	S		.0		11.35	6-25-46	
35ad	G. A. Hockett	1926	Dr	103	6	P		Cy	W	D, S				40		
15-17dd	U. S. Dept. Interior	1947	Dr	180	2	P	Qd	N	N	N	Tca	.2	2,580.3	44.18	3-23-50	Ca; L
21bb		1917	Dr	92.1	6	P		Cy	H	N	Bp	1.0		Dry	5- 7-46	
30dc	Arnold Johnson		Dr	61.8	6	P										
31cc	G. Jess		Dr	180	6	P	Qd	Cy	W	D, S				80		
32db	W. F. Neuwerth		Du	8	48	W		N	F	S						Y-1

[1] Well is 5 x 6 ft.
[2] Well recently caved in. Water reported very mineralized.
[3] Well is 3.5 x 15 ft.
[4] Well is 2 x 5 ft.
[5] Well is 4 x 5 ft.

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