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GROUND-WATER RESOURCES OF THE LOWER YELLOWSTONE RIVER VALLEY BETWEEN MILES CITY AND GLENDIVE MONTANA

By

Alfred E. Torrey and Frank A. Swenson

With a Section on the

CHEMICAL QUALITY OF THE WATER

By

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ABSTRACT

The geology and ground-water resources of the lower Yellowstone River valley between Miles City and Glendive, Mont., were studied during the summer of 1948. The purpose of the study was to collect data on ground water and to relate its occurrence to present and proposed irrigation in the area. With such data, one may better predict the effects of the proposed application of irrigation water to additional lands in the area.

Most of the area covered by this report consists of flat to gently sloping terraces that border the Yellowstone River on both sides. At the present time extensive areas on the lower terraces are irrigated and much of the remaining surface of these lower terraces is proposed for irrigation. The exposed bedrock consists of shale and sandstone beds of the Fort Union formation, except at the eastern end of the area where the Hell Creek formation, Fox Hills sandstone, and Pierre shale are exposed on the Cedar Creek anticline.

The chief bedrock aquifers in this area are the Fort Union and Hell Creek formations and the Fox Hills sandstone. The terrace deposits and the alluvium are sources of shallow water supplies. In topographically favorable locations west of the Cedar Creek anticline wells ranging in depth from 200 to 600 feet obtain flowing water from the sandstone beds of the bedrock formations.

Ground water in the part of the lower Yellowstone River valley considered in this report is variable in both concentration and chemical composition. The sodium bicarbonate character of the deep, soft waters from the undifferentiated Hell Creek and Fort Union formations is significant and suggests a base-exchange reaction. Other ground waters show increasing amounts of sulfate with increase in dissolved solids. Most of the waters

are satisfactory for drinking but are unsuitable for irrigation because of high percent sodium or high mineral content.

Because of the high water table, serious problems exist on some of the lands now under irrigation. Waterlogging is especially prevalent on the lands in the First Division of the Buffalo Rapids Project. Detailed ground-water investigations designed to determine the most feasible methods of reclaiming the waterlogged lands and of forestalling further occurrence of this condition were started by the United States Geological Survey and the United States Bureau of Reclamation in the spring of 1950. Because drainage problems are to be expected in the areas proposed for irrigation, detailed ground-water investigations should be made before construction of irrigation facilities is begun.

INTRODUCTION

LOCATION AND EXTENT OF AREA

This report describes the geology and ground-water conditions of an area that lies along the Yellowstone River valley between Miles City and Glendive in eastern Montana. (See fig. 1.) The area covered is about 400 square miles in extent, approximately 80 miles long, and 4 to 8 miles wide. Of major interest in this study was the occurrence of ground water in the lower stream terraces and in the alluvial bottom lands, both of which are now irrigated or proposed for irrigation.

SCOPE AND PURPOSE OF INVESTIGATION

The investigation upon which this report is based is one of several being undertaken as part of the program of the Interior Department for development of the Missouri River basin. The study was of a general reconnaissance nature, because the necessity of covering a large area in a short time precluded obtaining many detailed data that might otherwise be included in a ground-water study. The purpose of the investigation was to obtain a general over-all picture of the conditions to show whether more detailed and comprehensive studies are needed. Owing to the fact that waterlogging has resulted from a high water table and has made the land unfit for cultivation, the need for detailed ground-water studies in some areas is indicated. Inasmuch as the waterlogging was caused by irrigation without provision for

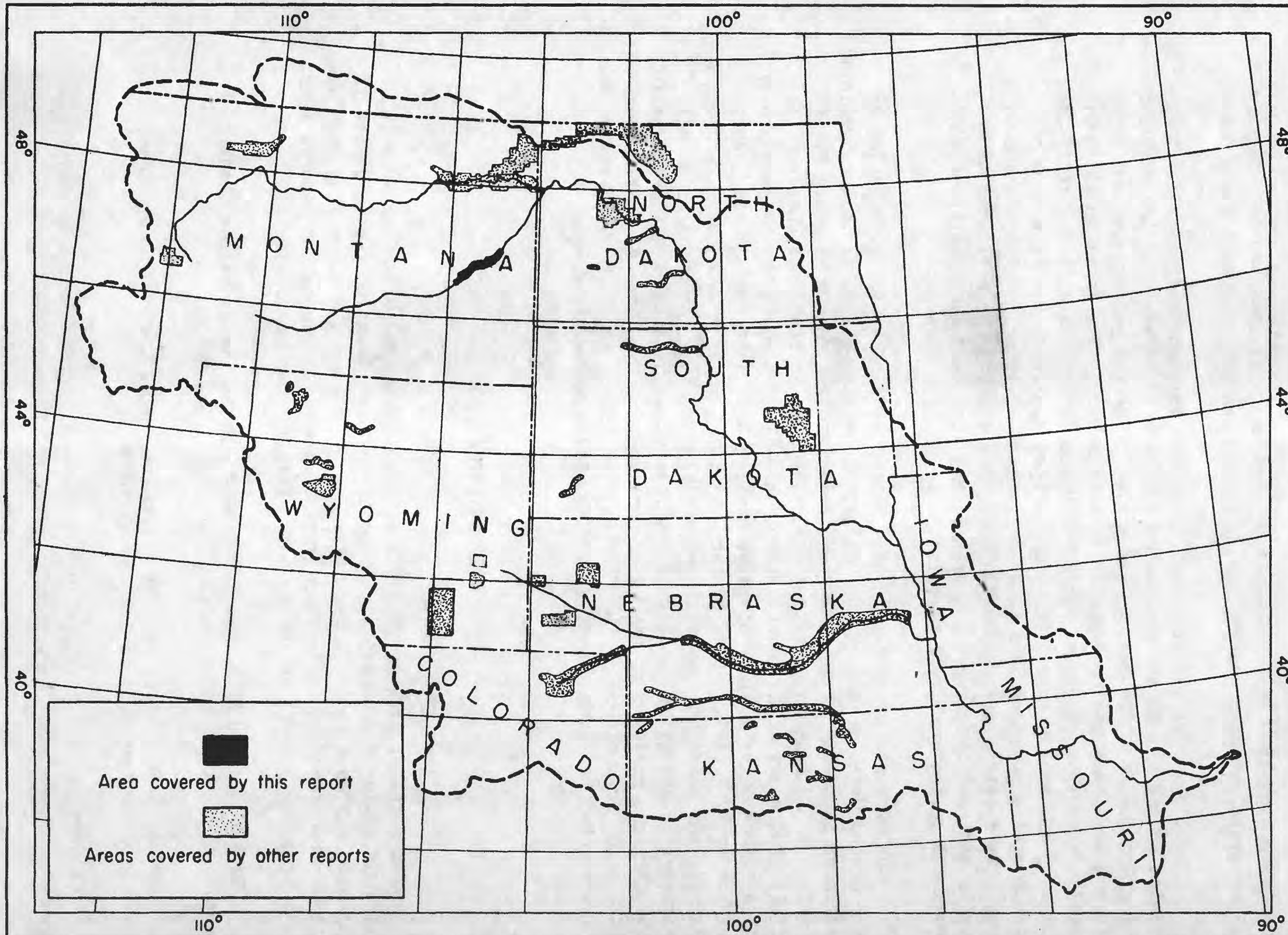

Figure 1 —Map of the Missouri River Basin showing areas in which ground-water studies have been made under Missouri Basin program.

adequate drainage, it is likely that similar conditions may develop in other areas proposed for irrigation unless preventive measures are taken.

The field work was performed from June through November 1948 and consisted of a study of the geology of the area in relation to the occurrence of ground water. The geology was mapped on aerial photographs and transferred to a base map by means of a Sketchmaster. The location and depth of wells, the depth to ground water below the land surface, the quantity and quality of water obtained from the various aquifers, the direction of ground-water movement, and the fluctuations of water levels in observation wells were determined in the course of the study. The altitudes of the wells and test holes were determined, and temporary bench marks to aid future leveling work were set at or near section corners.

The work was under the general supervision of A. N. Sayre, Chief of the Ground Water Branch, U. S. Geological Survey, and G. H. Taylor, regional engineer in charge of ground-water investigations in the Missouri River basin. F. A. Swenson, district geologist, was in immediate charge of the field studies by A. E. Torrey, and both collaborated in the preparation of this report. The quality-of-water studies were under the general supervision of S. K. Love, Chief of the Quality of Water Branch, U. S. Geological Survey, and under the immediate supervision of P. C. Benedict, regional engineer in charge of quality-of-water studies in the Missouri River basin. The chemical analyses of the water were made in the Lincoln, Nebr. laboratory by R. H. Langford, M. B. Florin, W. M. Barr, and F. H. Rainwater. The instrumental leveling was done by F. E. Busch and R. L. Morgan.

PREVIOUS INVESTIGATIONS

The regional geology of southeastern Montana has been discussed in numerous geologic reports, but the only previous detailed geologic work in the area was done by C. E. Erdmann and R. M. Larsen and dealt with the Cedar Creek anticline a short distance west of Glendive. Among the reports that have been most useful in the present study are the following:

Beekly, A. L., 1912, The Culbertson lignite field, Valley County, Mont.: U. S. Geol. Survey Bull. 471-d, pp. 319-358.

Bowen, C. F., 1912, The Baker lignite field, Custer County, Mont.: U. S. Geol. Survey Bull. 471-d, pp. 202-226.

Calvert, W. R., 1912, Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey Bull. 471-d pp. 187-201.

Campbell, M. R., and others, 1915, Guidebook of the western United States, Part A, The Northern Pacific Route, with a side trip to Yellowstone Park: U. S. Geol. Survey Bull. 611, 218 pp.

Collier, A. J., and Smith, C. D., 1907, The Miles City coal field, Mont.: U. S. Geol. Survey Bull. 341-a, pp. 36-62.

Erdmann, C. E., and Larsen, R. M., 1934, Geologic and structure map of the Cedar Creek anticline, Dawson, Prairie, Wibaux, and Fallon Counties, Mont.: U. S. Geol. Survey.

Hance, J. H., 1912, The Glendive lignite field, Dawson County, Mont.: U. S. Geol. Survey Bull. 471-d, pp. 271-283.

Herald, F. A., 1912, The Terry lignite field, Custer County, Mont.: U. S. Geol. Survey Bull. 471-d, pp. 227-270.

Stebinger, E., 1912, The Sidney lignite field, Dawson County, Mont.: U. S. Geol. Survey Bull. 471-d, pp. 284-318.

ACKNOWLEDGMENTS

The writers are grateful to the many persons who contributed information and assistance in the field and to those who aided in the preparation and review of this report. G. Askins, A. Bodine, W. Johnson, and L. W. Edlund furnished logs of wells drilled by them in the area. The Bureau of Reclamation and the Soil Conservation Service made available the logs of their test holes, and they also contributed records of water-level measurements made in the test holes. The field investigation was expedited by the cooperation of many of the residents of the area.

WELL-NUMBERING SYSTEM

Wells are numbered in this report according to their location within the land subdivisions of the Bureau of Land Management survey of the area. The first numeral of a well number indicates the township, the second the range, and the third the section in which a well is located. The lower-case letters after the section number show the location of the well within the section. The first letter denotes the quarter section and the second the quarter-quarter section or 40-acre tract. The letters are assigned in a counterclockwise direction beginning in the northeast quarter of the section and of the quarter-quarter section. If more than one well is located in a 40-acre tract, consecutive numbers beginning with one are added to distinguish the individual wells.

Figure 2 shows a graphical illustration of this method of well numbering.

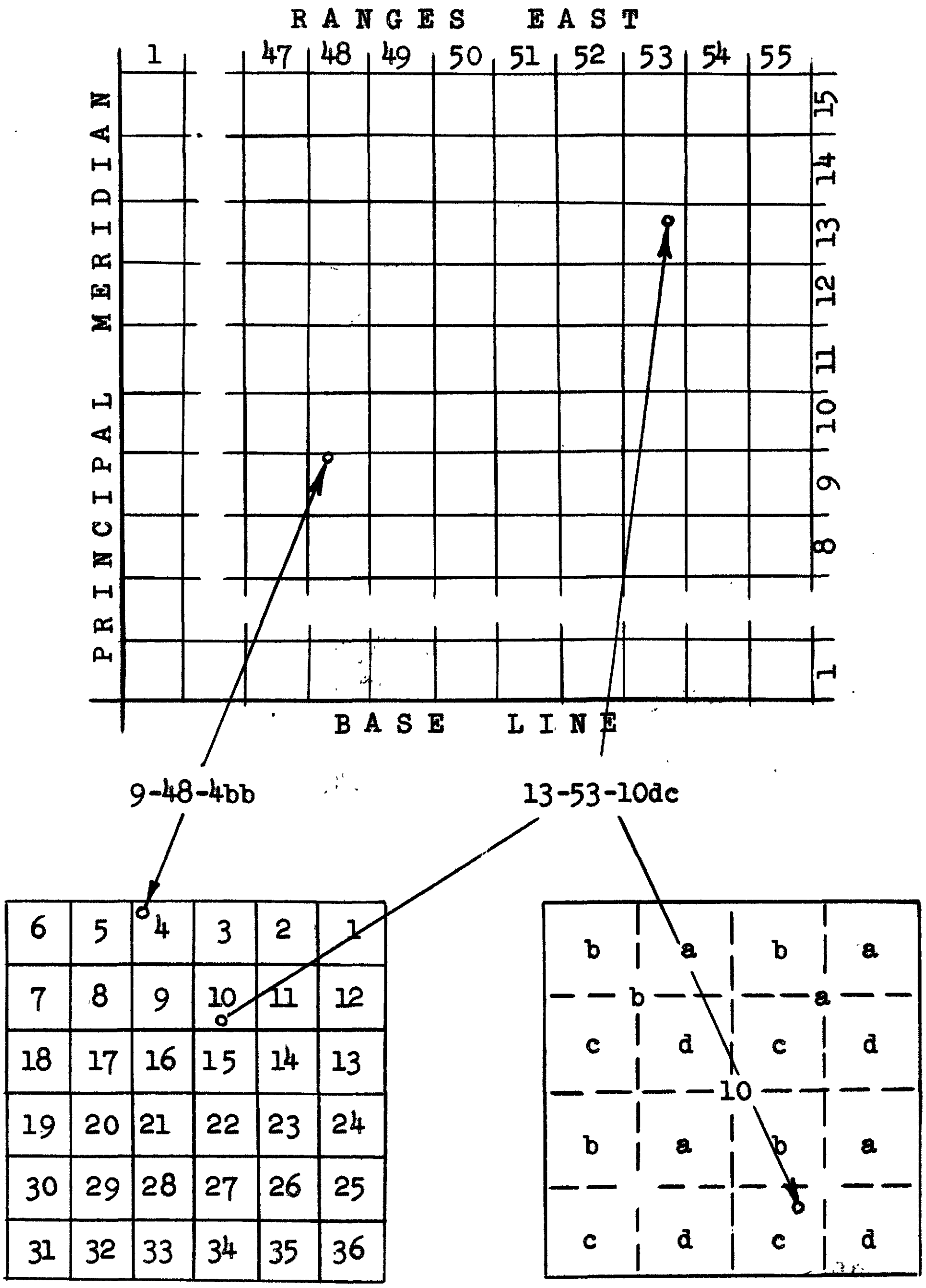

Figure 2.--Sketch showing well-numbering system.

GEOGRAPHY

HISTORY

As far as is known, white men who first visited the area were members of an expedition sent by the Northwest Co. in 1804 to trade with the Sioux and Crow Indians. In the course of their travels these men, under the leadership of Francois Larocque, explored the valleys of the lower Yellowstone, Powder, and Tongue Rivers. Captain William Clark, co-leader of the Lewis and Clark Expedition, descended the Yellowstone River in 1806 with a small party as they returned eastward from the Pacific Ocean. Because Clark was scheduled to meet Lewis and his party who were returning by the Missouri River, the trip down the Yellowstone was rather hurried. The diaries of the expedition[1] provide interesting reading and several physiographic features described in them can be recognized by those familiar with the area. The party was delayed for several hours by a large buffalo herd that was crossing the Yellowstone River at a chain of rapids, which they named Buffalo Rapids. Outcrops of coal and red clinker beds, which resulted from the natural burning of the underlying coal beds, were noted. Game of all kinds, including elk, bear, buffalo, deer, big horn sheep, beaver, and antelope were reported to be very numerous.

Fort Keogh was established in 1877 at the junction of the Tongue and Yellowstone Rivers to protect the early settlers from the Indians. This fort was established the year after the Custer Massacre, which occurred on the Little Bighorn River about 100 miles southwest of Miles City. People settled close to the fort for protection, and in 1878 they established the town of Miles City, which was named in honor of General Nelson A. Miles. When the Indians no longer threatened danger, ranches were established farther from the fort, and the valleys of the Tongue and Yellowstone Rivers were settled. The Northern Pacific Railroad, building west from Minneapolis, reached Miles City in 1881; this ready transportation stimulated settlement of the region. About this time cattle herds, driven overland from Texas, began to arrive in large numbers in this part of Montana. Many ranches were established along the perennial streams. The cattle were pastured on the unfenced open range and soon increased greatly in numbers. However, in the very severe winter of 1886-87 about 60 percent of the cattle died from cold and lack of feed, and thus it became apparent that provision for winter feed was necessary. Large quantities of feed could be raised in the area only by irrigation. The first large-scale irrigation facilities in the area were

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1 Original journals of the Lewis and Clark expedition, 1804-1806, edited by Reuben Gold Thwaites, vol. 5, pt. 2, pp. 310-315, Dodd, Mead & Co., New York, 1904.

constructed by the Miles City Irrigation and Ditch Co., organized in 1886. Water taken from the Tongue River, by means of a diversion dam, was used to irrigate lands near the confluence of the Tongue and Yellowstone Rivers. Large herds, owned by several companies, continued to be pastured on the open range during the summer. After the passage of the enlarged Homestead Act in 1909, the lands owned by the Federal Government were divided into 320-acre tracts; as a result, many farmers moved into the area and many acres of virgin prairie sod were broken.[2] Since that time more and more land has been supplied with irrigation water, and additional lands are now proposed for irrigation.

CLIMATE

East-central Montana has a semiarid climate characterized by wide deviations from average precipitation and by a wide range in temperature. Weather stations have been maintained by the United States Weather Bureau since 1878 at Miles City and since 1890 at Glendive. Much of the following discussion is based on records obtained at these stations.

The average annual precipitation at Miles City is 13.18 inches for 72 years of complete record since 1878. (See fig. 3.) The total annual precipitation has ranged from 5.51 inches (1934) to 22.75 inches (1879). Rains are irregular in occurrence; several excessively dry months are sometimes followed by greater-than-average rainfall, a fact not indicated in annual rainfall totals. In 1879, the wettest year, for example, a total of 17.92 inches of rain fell in the five months of April to August although precipitation was below average for five of the other months in the same year. (See table 1, p. 10.) If the driest months between 1878 and 1949 were to appear in any single year the total annual precipitation at Miles City would be only 0.57 inch; likewise, if the wettest months in this period were to appear in any single year, the total annual precipitation would be 45.19 inches. (See fig. 3.)

The cumulative departure from average precipitation at Miles City is also shown in figure 3. In this graph a period of greater-than-average rainfall is indicated by a rising line and a period of below-average precipitation by a declining line. Thus it may be seen that the total cumulative deficiency amounted to about 19 inches of moisture in the dry cycle that began in 1881 and reached its climax in 1905. The wet cycle that began in

2 Oravetz, G. J., and others, Water resources survey, Custer County, Mont., pt. 1, History of land and water use on irrigated areas: State Engineer's Office, Helena, Mont., pp. 6-14, 1948.

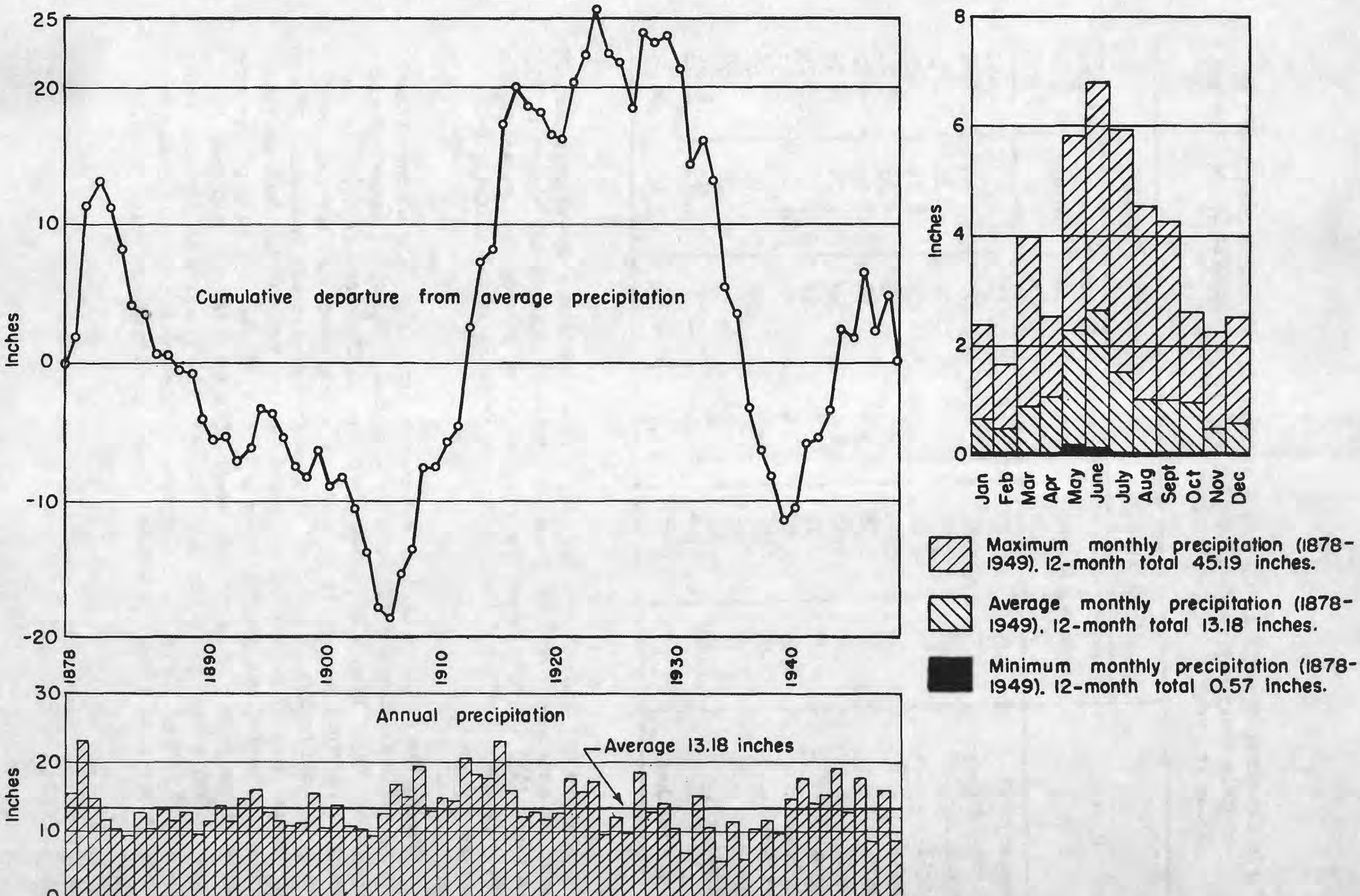

Figure 3.- Precipitation records at Miles City, Mont., 1878-1949
(From records of the U.S. Weather Bureau)

Table 1.--Monthly precipitation data for the driest and wettest years and monthly average precipitation for period of record at Miles City and Glendive, Mont.

Month	Miles City			Glendive		
	Driest year (1934)	Average	Wettest year (1879)	Driest year (1934)	Average	Wettest year (1916)
January.......	0.12	0.64	0.26	0.13	0.52	0.91
February......	.05	.49	.69	.05	.43	.04
March.........	1.05	.82	.28	1.04	.82	.35
April.........	.40	1.06	2.20	.09	1.10	.25
May...........	.34	2.12	2.75	.15	2.13	1.21
June..........	.66	2.55	5.23	1.98	3.30	5.22
July..........	.67	1.48	5.90	.59	1.74	4.96
August........	.42	1.03	1.84	.11	1.29	6.29
September.....	1.04	.99	.44	.32	1.21	4.37
October.......	.03	.84	2.47	.08	.80	.67
November......	.38	.55	.11	.07	.56	.50
December......	.35	.61	.58	.22	.52	1.25
Total (inches)	5.51	13.18	22.75	4.83	14.42	26.02

1906 reached its highest peak in 1923 with a cumulative excess of almost 27 inches of moisture. The dry cycle that followed reached its climax in 1939, and since 1939 the area again has received above-average precipitation except in 1945, 1947, and 1949, during which years it was slightly below average.

During the 60 years of complete record since 1890, the average annual precipitation at Glendive has been 14.42 inches. The total annual precipitation has ranged from 4.83 inches (1934) to 26.02 inches (1916). As the amount of rainfall from month to month is highly variable, several excessively dry months may be followed by greater-than-average rainfall. In 1916, the wettest year of record, 20.84 inches of rain fell in the four months of June to September, but precipitation was below average for five of the other months in the year. If the driest months between 1890 and 1949 were to appear in any single year, the total annual precipitation at Glendive would be only 0.83 inch; likewise, if the wettest months in this period were to appear in any single year, the total annual precipitation would be 45.79 inches.

The graph showing the cumulative departure from average precipitation at Glendive (see fig. 4) is helpful in indicating the long-term deficiencies and excesses of precipitation. It may be seen from this graph that the wet cycle that began in 1891 reached its climax in 1916 when there was a total cumulative excess of about 41 inches of moisture. The dry cycle that began in 1917 reached its climax in 1941 with a cumulative deficiency of about 2.5 inches of moisture. There were several years of below-average precipitation between 1890 and 1916; likewise, there were several wet years in the dry cycle that reached its climax in 1941. Since 1941, the area has received above-average precipitation except in 1945, 1948, and 1949, during which years the precipitation was slightly below average.

AGRICULTURE AND INDUSTRY

The gross value of crops produced in 1948 on the 14,248 acres under cultivation on the First Division, Buffalo Rapids Project, was $748,545. Of this amount the return from the sugar beet crop was $285,301 and the return from the barley and potato crops was approximately $81,000 each. Other crops raised in the area include alfalfa, wheat, corn, oats, and flax. The greatest gross return per acre was $400 for sweet corn; the next greatest returns per acre were $317 for potatoes and $103 for sugar beets. The acreage to be planted with sugar beets by individual farmers is determined by the Holly Sugar Co., at Sidney, which also processes the beets.

The 6,924 acres under cultivation in 1948 on the Second Division, Buffalo Rapids Project (Shirley and Terry Units), produced crops valued at $118,905. These lands have been irrigated only a few years and have not yet reached peak production. The gross returns from the three leading crops were as follows: sugar beets, $44,003; alfalfa, $18,788; and wheat, $13,239. The greatest gross return per acre was $101.40 for potatoes; the next greatest returns were $80 for clover seed and $63 for alfalfa seed.

Similar information was not available for the Kinsey or Tongue and Yellowstone River Irrigation Districts.

Nonirrigated land on the higher terraces is used extensively for the production of small grains, corn, and flax. Summer fallowing and strip cropping are practiced on these lands. The fields are laid out normal to the prevailing wind in strips 200 to 500 feet wide and are planted during alternate years. The blowing of loose soil is held to a minimum by leaving stubble in the field until the windy spring months are passed; the fallow strips are then cultivated to destroy the weeds and to receive and retain

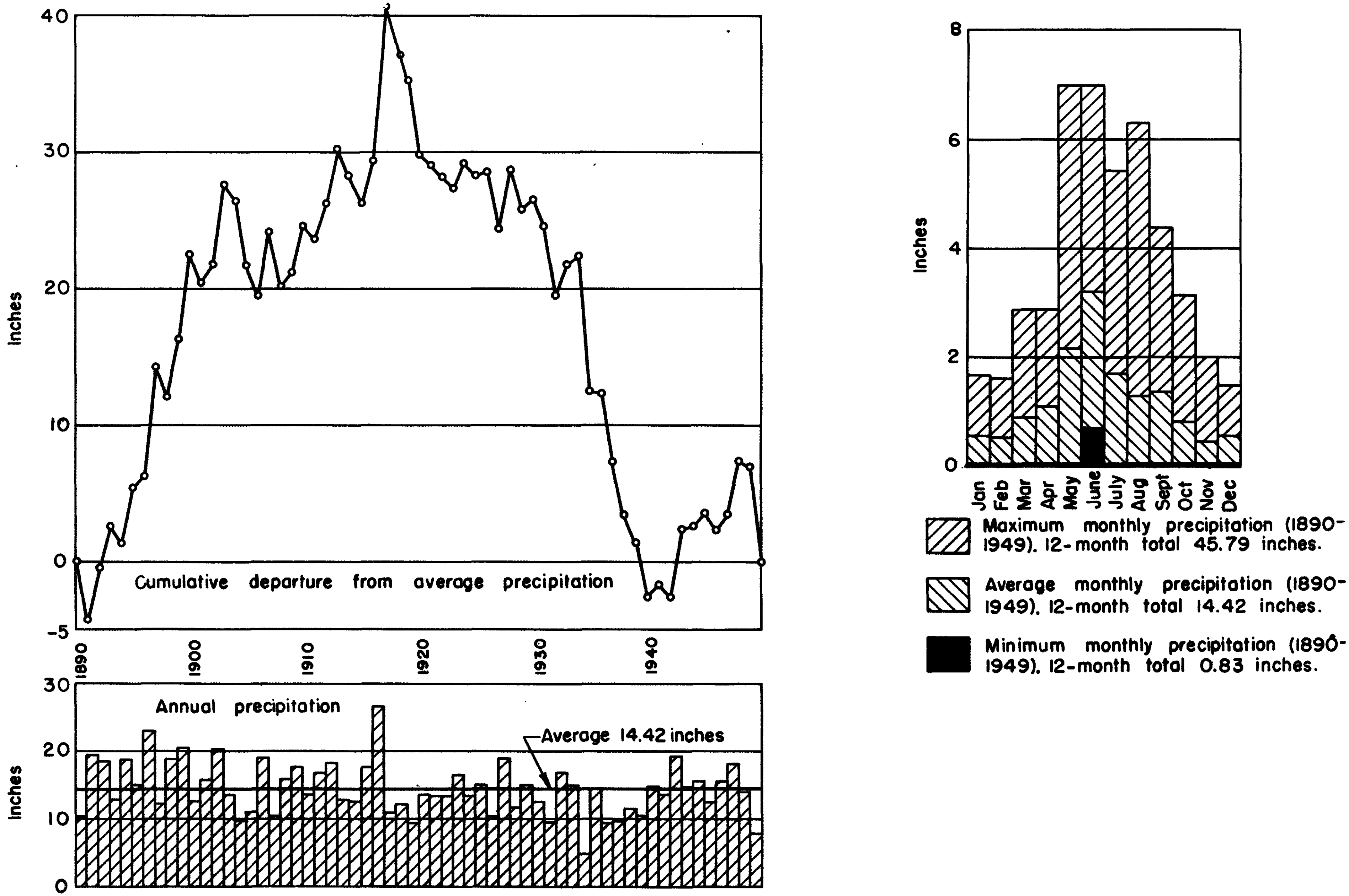

Figure 4.— Precipitation records at Glendive, Mont., 1890-1949. (From records of the U.S. Weather Bureau)

moisture more readily. Wheat is the most important exported crop; in dry years the yield is low, but in moist years the large acreages make it a profitable crop.

The only active commercial lignite mine in the valley is located 12 miles west of Glendive in the SW$\frac{1}{4}$ sec. 15, T. 14 N., R. 54 E. It is an open-pit mine with a 20-foot face, is privately owned, and is operated on demand during the late fall and winter. The total output of the mine is used locally. The better grade of lignite is at the bottom of the seam at this mine. Many other coal seams, most of which are too thin to work or are too impure for commercial use, crop out in this area. Some coal is mined by individual ranchers for their own use.

Gas produced by wells drilled on the Cedar Creek anticline is used for heating and cooking in the towns along the river.

TRANSPORTATION

The area is served by two transcontinental railroads: the Northern Pacific Railway, which follows the course of the Yellowstone River from Glendive to Miles City, and the Chicago, Milwaukee, St. Paul & Pacific Railroad, which enters the valley at Fallon and continues to Miles City. The main thoroughfare through this valley is U. S. Highway 10. The Greyhound Bus Line and the Northwest Airlines also serve the area. Bridges at Miles City, Terry, Fallon, and Glendive plus many graded county roads make all parts of the valley accessible by car throughout the year.

IRRIGATION

A large part of the valley bottom land and much of the lower terrace land along the Yellowstone River between Miles City and Glendive either are irrigated or have been proposed for irrigation. (See fig. 5.)

The Tongue and Yellowstone River Irrigation District irrigates the lower valley of the Tongue River and the south side of the Yellowstone River valley from Miles City eastward for 10 miles. The water used for this irrigation is diverted by gravity from the Tongue River, 12 miles above its confluence with the Yellowstone River. The Tongue and Yellowstone River Irrigation District is a private company that was organized in 1911 under the laws

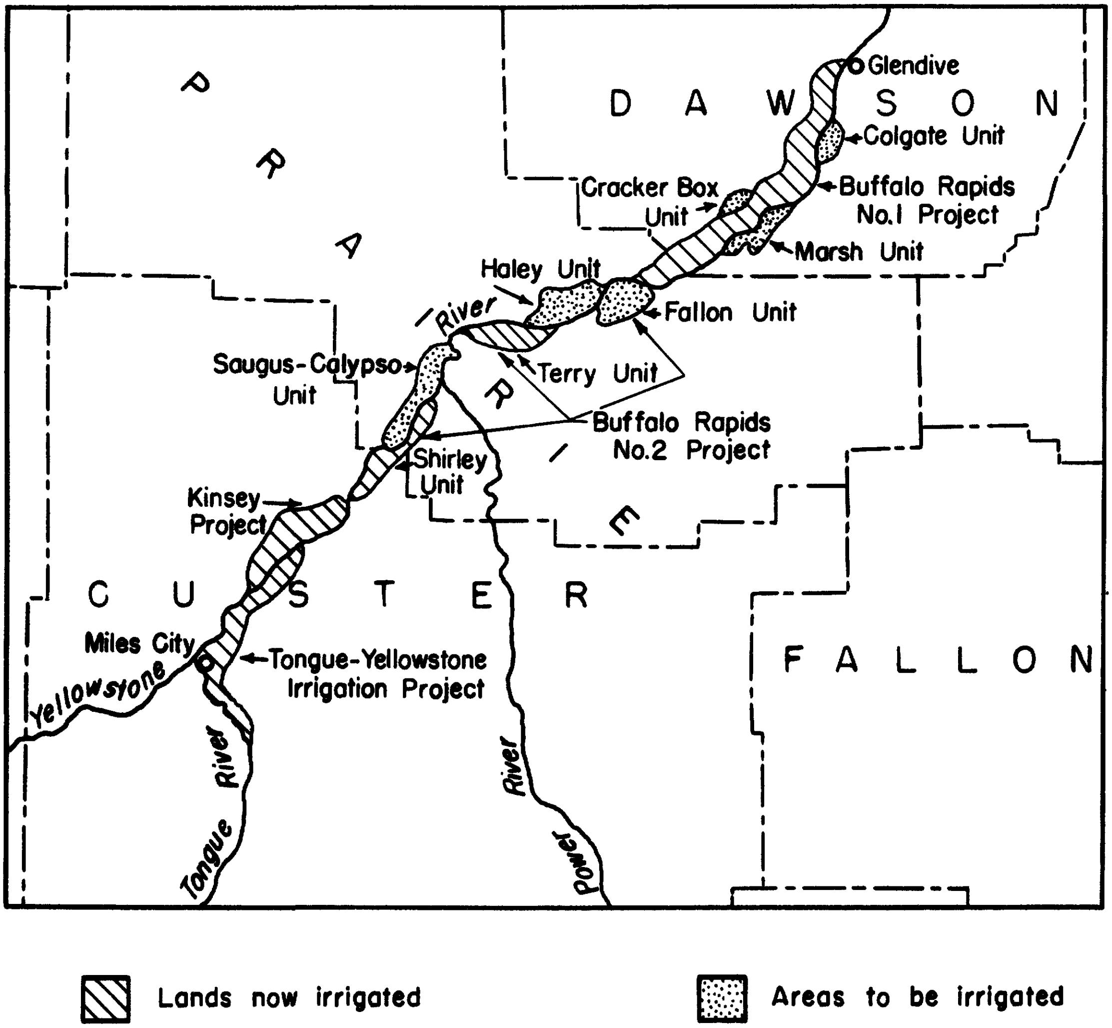

Figure 5.– Irrigated lands and lands proposed for irrigation between Miles City and Glendive, Mont.

of Montana; it succeeded the Miles City Canal and Irrigation Co., which had constructed the facilities to supply water to this land.

The Kinsey Irrigation Co. supplies water to about 6,200 acres on the north side of the Yellowstone River in the stretch of the valley 9 to 17 miles downstream from Miles City. The irrigation water is pumped from the Yellowstone River both to the lowest terrace and, by means of a relift, to the second terrace. These irrigated lands have had a long and discouraging history of financing and refinancing. In 1896 the Buffalo Rapids Ditch Co. was formed to irrigate part of the lands, but after some years it became defunct as a result of lack of capital and of insufficient gravity water during the irrigation season. An irrigation district was formed by the farmers in 1918 but, after an indebtedness of $53 per acre developed, it also ceased to function. In 1935 application was filed with the Works Progress Administration for funds to rehabilitate the project, and funds were advanced for work that continued until May 1938. At that time the project became the Kinsey Farms Resettlement Project under the Department of Agriculture Resettlement Administration. After that date and until its liquidation in 1945 the building and management of the project passed through several other Department of Agriculture bureaus. The Kinsey Irrigation Co. was formed in May 1945 to acquire the irrigation system constructed by the Farm Security Administration. This company continues to operate and manage the project at present.

The Shirley Unit of the Second Division, Buffalo Rapids Project, is supplied with water pumped from the Yellowstone River at a point 18 miles downstream from Miles City. This unit began operation in 1944. The total irrigable acreage of this unit amounts to about 5,300 acres; however, not quite all of this land is under irrigation.

The Terry Unit of the Second Division, Buffalo Rapids Project, is supplied with irrigation water pumped from the Yellowstone River about 2 miles west of Terry. Lands of this unit were first irrigated in 1945. The total irrigable acreage amounts to about 2,800 acres, but some of the lands proposed for irrigation have not yet been irrigated.

Construction of facilities for the irrigation of the Fallon Unit of the Second Division, Buffalo Rapids Project, was essentially completed in 1948, and the first delivery of water is scheduled for the summer of 1950. A pumping plant, located a short distance west of Fallon, is designed to lift water from the Yellowstone River to irrigate about 3,500 acres in this unit.

The irrigated lands of the First Division, Buffalo Rapids Project, are on the west side of the Yellowstone River between Fallon and Glendive. Water is pumped from the Yellowstone River, at a point about a mile downstream from the highway bridge, to irrigate about 14,000 acres of land. These lands are on several terrace levels, of which the highest is more than 100 feet above the river. According to recent surveys made by the Bureau of Reclamation and the Soil Conservation Service, almost 13,000 acres of the irrigated land are either waterlogged at the present time or in danger of becoming waterlogged unless effective drains are constructed.

Present plans call for construction of facilities for the irrigation of additional lands between Miles City and Glendive. The proposed Saugus-Calypso Unit, the Haley Unit, and the Cracker Box Unit are on the west side of the river, and the proposed Marsh and Colgate Units are on the east side of the river near the towns for which they are named. (See fig. 5.)

PHYSIOGRAPHY

The area covered by this report is in the northern part of the Great Plains physiographic province.[3]

The Yellowstone River meanders back and forth across its valley and in places impinges directly against the valley walls to form sheer cliffs rising 200 feet or more above the river. Bordering the river are prominent, well-developed terraces at levels ranging from 15 to more than 300 feet above the river. The higher terraces are undulating and are dissected by streams, and in some places only isolated buttes remain. The lower terraces are broad, flat areas 3 to 5 miles wide, with little dissection. A rugged and picturesque topography is formed by differential erosion of the bedrock, and badlands occur at various locations in the area. The total relief of the area is about 400 feet.

GEOLOGY AND GROUND-WATER SUPPLY

GENERAL FEATURES

Rocks ranging in age from Late Cretaceous to Recent are exposed in the the area covered by this report. The oldest rocks are exposed on the crest

3 Fenneman, N. H., Physiography of western United States: McGraw-Hill Book Co., New York, 1931.

of the Cedar Creek anticline near the northeastern end of the area. Almost all the irrigable land is underlain by Quaternary deposits, which consist of alluvium and stream-terrace deposits. Several distinct stream terraces have been recognized and mapped. (See pl. 1.) The lithology of the formations that crop out in the area is described briefly, and an interpretation of the probable water-bearing properties of each formation is given in table 2.

The bedrock underlying this area has been gently downwarped and forms a large basin, which lies between the Cedar Creek anticline near Glendive, and the Porcupine dome, about 50 miles west of Miles City. This large structure forms an ideal artesian basin in which the sandstone beds furnish the water for the many flowing wells.

The water obtained by deeper wells drilled into the bedrock is soft but considerably mineralized. (See section on chemical quality of water.) The water is potable and is used for domestic and stock needs. Some small garden plots are irrigated with water from flowing wells, but the water is too highly mineralized for this purpose except as an emergency supply. The flows range from 1 to 40 gallons a minute, the larger flows being obtained by deeper wells which draw water from several different artesian aquifers. The pressures are not excessively high, but locally water rises to the second floor of houses.

Water obtained from wells dug or drilled into the terrace gravels or alluvial deposits is hard in contrast to the soft water obtained by deeper wells, but in general these shallow waters are not as highly mineralized as are the deeper waters.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Cretaceous

Upper Cretaceous

Pierre shale.--The Pierre shale is a blue-black to dark-gray marine shale, which on weathering oxidizes to a yellow-brown color. It underlies the entire area but crops out only in Dawson County on the crest of the Cedar Creek anticline about 2 miles west of Glendive. The total thickness of the formation is 4,075 feet in the Montana-Yellowstone Oil Co. No. 1

Table 2.--Generalized section of the geologic formations exposed in the lower Yellowstone River valley between Miles City and Glendive

System	Series	Formation	Thickness (feet)	Lithology	Water supply
Quaternary	Recent	Alluvium	5-40	Sand, silt, clay, and gravel.	Yields plentiful supplies from saturated sands and gravels.
	Pleistocene	Terrace deposits	5-60	Silty and sandy soil underlain by sand and gravel; gravel contains well-rounded quartzite pebbles and cobbles and fragments of extrusive and intrusive igneous rocks.	Yields abundant supplies for domestic and small-scale irrigation use where gravel deposits are thick and recharge is available; discharges as springs in many places. Water is hard but potable.
Tertiary	Paleocene	Fort Union formation	700±	Interbedded yellowish-gray to buff sandstone and shale with thin beds of coal. Coal burned on the outcrop in many places.	Yields small supplies, adequate for needs of ranchers, from sandstone and coal beds; discharges as small springs in many places. Water is hard at shallow depth but is soft at deeper horizons. Generally water is under artesian pressure.
Cretaceous	Upper Cretaceous	Hell Creek formation	580±	Brownish-gray sandstone with interbedded carbonaceous shale and gray mudstone.	Yields moderate supplies from sandstone beds. Water is hard at shallow depths but is soft at deeper horizons. Generally water is under artesian pressure.
		Fox Hills sandstone	150-220	Massive, white to light-gray, fine- to medium-grained friable sandstone in upper part; yellow-banded shaly sandstone with interbedded gray silty sandstone in lower part.	Yields abundant supplies of water for domestic and stock use from sandstone beds. Generally water is under artesian pressure.
		Pierre shale	4,000±	Dark-gray marine shale with interbedded sandy streaks.	Not water bearing.

well[4] in the $SE\frac{1}{4}NE\frac{1}{4}SW\frac{1}{4}$ sec. 4, T. 14 N., R. 55 E.

The Pierre shale is not known to yield appreciable supplies of water to any wells in the area. Available logs of wells drilled into this formation indicate that no water was encountered.

Fox Hills sandstone.--The upper part of the Fox Hills sandstone is a massive, white to light-gray, fine- to medium-grained, friable sandstone. The lower part is yellow, banded, shaly sandstone with interbedded gray silty sandstone. The Fox Hills sandstone overlies the Pierre shale and crops out on the flanks of the Porcupine dome 50 miles west of Miles City and is also on the flanks of the Cedar Creek anticline near Glendive; for this reason it is assumed to underlie the entire area. (See pl. 1.)

The apparent high permeability of the Fox Hills sandstone in surface exposures indicates that this formation, where saturated, should yield water freely to properly constructed wells. The facts that only drillers' logs of wells are available and that no correlations can be made from them prevent accurate determination of the source of water for the many artesian wells in the area. Most wells obtain flows at several horizons, but drillers report that the largest flows are usually obtained within 200 feet of the top of the Pierre shale. This would indicate that the Fox Hills sandstone is probably the best water-bearing bed present.

Hell Creek formation.--The Hell Creek formation consists of brownish-gray sandstone interbedded with carbonaceous shale and silty gray mudstone, and it contains many brown ironstone concretions 1 to 3 inches in diameter. The Hell Creek formation underlies the entire area but crops out only on the flanks of the Cedar Creek anticline.

In exposures of the Hell Creek formation the sandstone beds appear to be quite permeable. It is believed that these beds are the source of some of the water obtained by flowing wells west of the Cedar Creek anticline; but as available drillers' logs do not permit differentiation between the Fox Hills sandstone and the overlying Hell Creek formation, the exact source of the artesian water in most wells has not been ascertained.

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4 Erdmann, C. E., and Larsen, R. M., Geologic and structure map of northern half of the Cedar Creek anticline, Dawson, Prairie, Wibaux, and Fallon Counties, Mont., U. S. Geol. Survey, 1934.

Tertiary

Paleocene

Fort Union formation.--The Lebo shale and Tongue River members of the Fort Union formation are recognized in this area, but a thick transitional zone between them prevents their separation into mappable units. The Tullock member of the Fort Union formation, which underlies the Lebo shale member west of the area of this study, is not recognizable in this area.

The lower part of the Fort Union formation in this area consists mainly of somber-colored shale containing a few interbedded sandy shales. Badlands have formed in places where these lower beds are exposed. Several prominent concretionary zones are present in this part of the formation. Most of the concretions are siliceous but some are calcareous, and on weathering out of the shale they mantle the surface as roundish iron-stained cobbles and boulders. The massive sandstone lenses that are present in some places cannot be traced very far, either in surface exposures or in the subsurface, on the basis of drillers' logs.

The upper part of the Fort Union formation, the Tongue River member, is lighter-colored and is considerably more sandy than the lower part. Beds and lenses of coal are prominent features of this part of the formation. In many places the coal has been ignited on the outcrop, and the overlying shale and sandstone beds have been transformed by the resultant heat into more resistant scoria or clinker. One coal bed in sec. 10, T. 12 N., R. 51 E., on the north side of the Yellowstone River opposite the town of Terry, is burning at the present time (1949); where the coal has been burned out, the overlying beds have slumped down and heat and fumes issue from the cracked and broken surface. Beds overlying the burned coal seams are colored red to purple as a result of the oxidation and local reduction of their iron content, and the color is an aid in the correlation of these beds. Colored clinker beds capping the buttes are prominent features in some areas of badland topography.

The Fort Union formation comprises most of the exposed bedrock of the area. It extends from the west end of the area eastward to the Cedar Creek anticline, but is not found on the crest or eastern flank of the anticline within the area covered by this report.

Water is found under both water-table and artesian conditions in the Fort Union formation but the supplies are meager. In order to assure fairly large flows, most wells are drilled at least 150 to 200 feet into this formation. Supplies adequate for domestic and stock needs are usually encountered in a sandstone or coal bed. Locally the water from the coal beds is brown because of organic compounds in solution. Considerable water from the Fort Union formation is wasted because the wells are not equipped with control valves. Nothing is known about the amount of loss of artesian pressure in the area as no pressure heads have been measured.

Quaternary

Pleistocene

Stream terraces.--The most prominent physiographic features of the area are six well-developed stream terraces which border the flood plain of the Yellowstone River and which range in height from 15 to 275 feet above the river. Higher terraces are recognizable but they lie beyond the area covered by this report. The terraces are not present everywhere in the area studied but where present they are prominent, and each has a characteristic height above the river. They have been designated, for the purpose of this report, as terraces A, B, C, D, E, and F. (See table 3.)

The stream terraces have flat to gently rolling surfaces and are underlain by sandy soil and unconsolidated gravel of variable thickness. The sandy soil permits easy recharge of the underlying gravels. The porosity and permeability of the underlying gravels make them excellent aquifers where sufficient water is available to recharge them adequately. Where an underlying gravel is exposed in the escarpment between two terraces, numerous small springs are found at the base of the gravel bed.

The height of terraces E and F above the river is so great that pumping water from the river to irrigate them may never be feasible, although the good crop yields during moist years indicate that the soil and natural underdrainage is favorable for irrigation. The growing of "dry-farm" grains is practiced extensively on these higher terraces.

The gravels underlying terraces E and F, because of inadequate recharge, contain only small or medium quantities of water. However, if the wells are not too close to the lower escarpment, where underdrainage lowers the local water table, adequate water supplies for domestic and stock needs can generally be obtained from wells dug or drilled to the base of the gravels on the more extensive remnants of the terraces.

Table 3.--Generalized description of stream terraces along Yellowstone River between Miles City and Glendive, Mont.

[See pl. 1 for location of terrace remnants]

Terrace	Height above Yellowstone River (feet)	Thickness of unconsolidated gravel underlying sandy soil (feet)	Availability of ground water in terrace deposits	Location of largest terrace remnants	Source of water used for irrigation
A	15-20	3-5	Adequate supplies for domestic and stock needs from wells 10 to 20 feet deep.	West side of Yellowstone River near Kinsey.	Pumped from Yellowstone River.
B	35-45	5-8	Adequate supplies for domestic and stock needs from wells 10 to 30 feet deep.	East side of Yellowstone River near Miles City.	Diverted by gravity from Tongue River.
C	55-60	10-15	Adequate supplies for domestic and stock needs from wells 20 to 40 feet deep.	West side of Yellowstone River near Glendive.	Pumped from Yellowstone River.
D	80-100	15-20	Abundant supplies from wells 20 to 40 feet deep.	East side of Yellowstone River near Terry.	Pumped from Yellowstone River.
E	155-165	30-40	Adequate supplies for domestic and stock needs from wells 40 to 80 feet deep.	East side of Yellowstone River near Shirley.	Not irrigated.
F	240-275	20-30	Adequate supplies for domestic and stock needs from wells 60 to 100 feet deep.	East side of Yellowstone River near Fallon.	Not irrigated.

Terraces A, B, C, and D are partly or entirely irrigated by water pumped from the Yellowstone River. On these irrigated terraces, alfalfa, sugar beets, corn, barley, and potatoes are grown. The escarpments between these lower terraces are not as high as those between the higher terraces and the permeable gravel deposits are thinner than those under the higher terraces. In general, these terraces have flatter surfaces and abundant recharge from irrigation, two factors contributing to the extensive water-logging of the land. The gravel beds underlying the irrigated terraces are saturated in most places, and moderate to large supplies of water can be developed from wells penetrating the gravel beds. Many of the townspeople of Terry and Fallon obtain their water for domestic use from private shallow sand-point or dug wells, which tap the aquifers underlying the terraces on which the towns are built.

Recent

Alluvium.--The alluvial deposits along the Yellowstone River and the tributary streams are not extensive. They are subject to frequent flooding except where levees have been built, and even the land protected by levees is flooded occasionally when ice jams force the river out of its channel. Most of the alluvium consists of fine silt and sand, but locally it consists of gravel. In general, the gravel pebbles and cobbles were derived from the stream terraces, but in a few places they are angular fragments of purple and red clinker from the Fort Union formation.

Moderate to large supplies of water are available from the alluvium. In the low-lying northern part of Miles City many wells, 10 to 20 feet deep, furnish water for domestic and stock use and for irrigation of gardens and lawns. A thick gravel under the area extends below the river level. Large water supplies for industrial development might be obtained from this gravel if adequate recharge is obtained from the river. Detailed investigation of this possibility seems warranted.

CHEMICAL QUALITY OF THE WATER

By Herbert A. Swenson

GENERAL CONDITIONS

The general study of ground-water resources in the lower Yellowstone River valley between Miles City and Glendive included an evaluation of the chemical quality of these waters. During October 1948 in the course of field work in this area, A. E. Torrey collected 25 water samples for chemical analysis from 11 deep wells (more than 100 feet deep), 6 shallow wells (less than 100 feet deep), 3 drains, 3 seeps, and the Yellowstone River at two places.

As previously stated, it was not possible to correlate the stratigraphic units recognized on the surface with the water-bearing formations because of incomplete information available in well logs. To a limited extent, however, correlation is possible from the chemical analyses on the basis of percent reacting values of acid radicals in the waters--that is, the relative reacting values of bicarbonate (HCO_3), sulfate (SO_4), and chloride (Cl). Hardness and percent sodium of the waters are also helpful in identifying the aquifers.

The waters sampled show wide range in both concentration and character. Maximum and minimum values for certain constituents and properties are shown in the following table:

Constituent or property	Maximum	Minimum
Dissolved solids..p.p.m.	7,520	560
Bicarbonate.......p.p.m.	1,500	213
Sulfate...........p.p.m.	4,860	2.4
Total hardness....p.p.m.	2,690	5
Percent sodium..........	99	30

Sodium and bicarbonate account for most of the mineral content in practically all the artesian waters sampled, whereas sulfate, bicarbonate, calcium, magnesium, and sodium in varying proportions are the principal ions in other waters in the valley.

CORRELATION OF THE WATERS

Inasmuch as geologic correlation based on well drillings or other evidence in the valley is difficult, an attempt has been made to establish the water-bearing formations on the basis of the quality of the contained waters. It is seen in table 4 that all the artesian waters show a remarkable similarity in percent reacting values for bicarbonate, sulfate, and chloride. These waters are very soft, and sodium is practically the only basic ion present. Sodium bicarbonate waters of this type are considered as altered waters and are discussed in more detail under "Origin of the soft waters." Wells yielding these soft, altered waters penetrate the Fort Union formation, and some may reach the underlying Hell Creek formation.

Two seeps or springs, 13-53-11cd and 14-54-28bb (see map, fig. 6), and a well, 13-53-11da, yield waters that are considered to be normal Fort Union formation types. Water from seep 12-51-16ba is probably a mixed water, intermediate between the very soft altered waters and the normal Fort Union type. Both percent reacting values for bicarbonate and sulfate and parts per million of hardness are intermediate between the two extremes.

Wells 10-49-14dd (625 ft. deep) and 14-55-7dc (42 ft. deep) are more difficult to correlate from the available sampling but are thought to be receiving water from the Fort Union formation and the Pierre shale, respectively. The deeper well may also be obtaining water from the Fox Hills sandstone.

The terrace gravels furnish water of somewhat similar chemical properties, whereas the irrigation drainage waters and Yellowstone River water can be conveniently classified in distinctive groups.

Figure 7 is a trilinear graph, showing percent reacting values of acid radicals for the waters sampled.

Studies of ground water in areas of Fort Union and underlying formations show that near the land surface the water is relatively high in calcium and magnesium, but with increasing depth these are exchanged for sodium, the result being a natural softening. This appears to be a general rule, although some exceptions are noted. Furthermore, there seems to be no tendency for the water to acquire more dissolved material with increasing depth, the amount of dissolved solids thus being determined relatively near the surface.

The following are brief descriptions of the chemical character of waters contained in the water-bearing materials in the valley. Results of chemical analysis of these waters appear in table 5.

Table 4.--Chemical properties of waters in the lower Yellowstone River valley

Location	Source of sample	Depth (feet)	Percent reacting values			Hardness (p.p.m.)	Percent sodium	Possible water-bearing formation	Remarks
			HCO_3	SO_4	Cl				
8-47-28ba	Well.....	35	93.6	1.2	5.2	15	98	Hell Creek and Fort Union undifferentiated	Altered water--artesian.
10-49-31bb	...do....	250	89.0	2.6	8.4	11	98		Do.
10-49-15aa	...do....	340	87.0	7.9	5.1	16	97		Do.
14-54-33cc	...do....	412	97.9	.1	2.0	19	98	.....do........	Do.
9-48-18db	...do....	420	91.2	.6	8.2	10	98	.....do........	Do.
13-53-10dc1	...do....	540	96.1	.7	3.2	9	99	.....do........	Do.
9-48-3cd1	...do....	543	90.7	.5	8.8	16	97	.....do........	Do.
9-48-4bb	...do....	612	89.0	.8	10.2	8	99	.....do........	Do.
14-54-13db	...do....	703	90.1	5.0	4.9	17	98	.....do........	Do.
12-51-16cd1	...do....	708	91.8	1.3	6.9	11	98	.....do........	Do.
13-53-11ca	...do....	772	93.8	1.6	4.6	5	99	.....do........	Do.
13-53-11cd	Seep.....	2	18.1	78.8	3.1	1,630	43	Fort Union.....	Normal water.
14-54-28bb	...do....	2	9.1	90.3	.6	1,650	70	.....do........	Do.
13-53-11da	Well.....	41	8.4	88.0	3.6	2,690	30	.....do........	Do.
12-51-16ba	Seep.....	2	78.9	17.8	3.3	312	43	.....do........	Mixed-type water.
10-49-14dd	Well.....	625	50.0	49.1	.9	263	74	.....do........	Fox Hills (?).
14-55-7dc	...do....	42	59.8	36.7	3.5	102	85	Pierre shale...	Shale from 24 to 42 ft.
13-52-34ca2	...do....	17	75.9	22.1	2.0	152	67	Terrace gravels	Terrace F.
11-49-36da	...do....	18	53.1	35.7	11.2	70	94	.....do........	Terrace E.
12-51-16ac	...do....	26	58.3	39.2	2.5	470	40	.....do........	Terrace D.
9-48-2dc	Drain....	1	32.6	65.0	2.4	450	72	Return flows...	From ditch.
10-48-36dc	...do....	7	21.9	75.5	2.6	458	79	.....do........	Do.
14-54-1aa	...do....	5	32.5	65.1	2.4	462	71	.....do........	Do.
Yellowstone River.....	River....	...	41.3	56.5	2.2	316	29	....	At Miles City.
Do.......	...do....	...	40.0	56.3	3.7	290	31	....	Near Fallon.

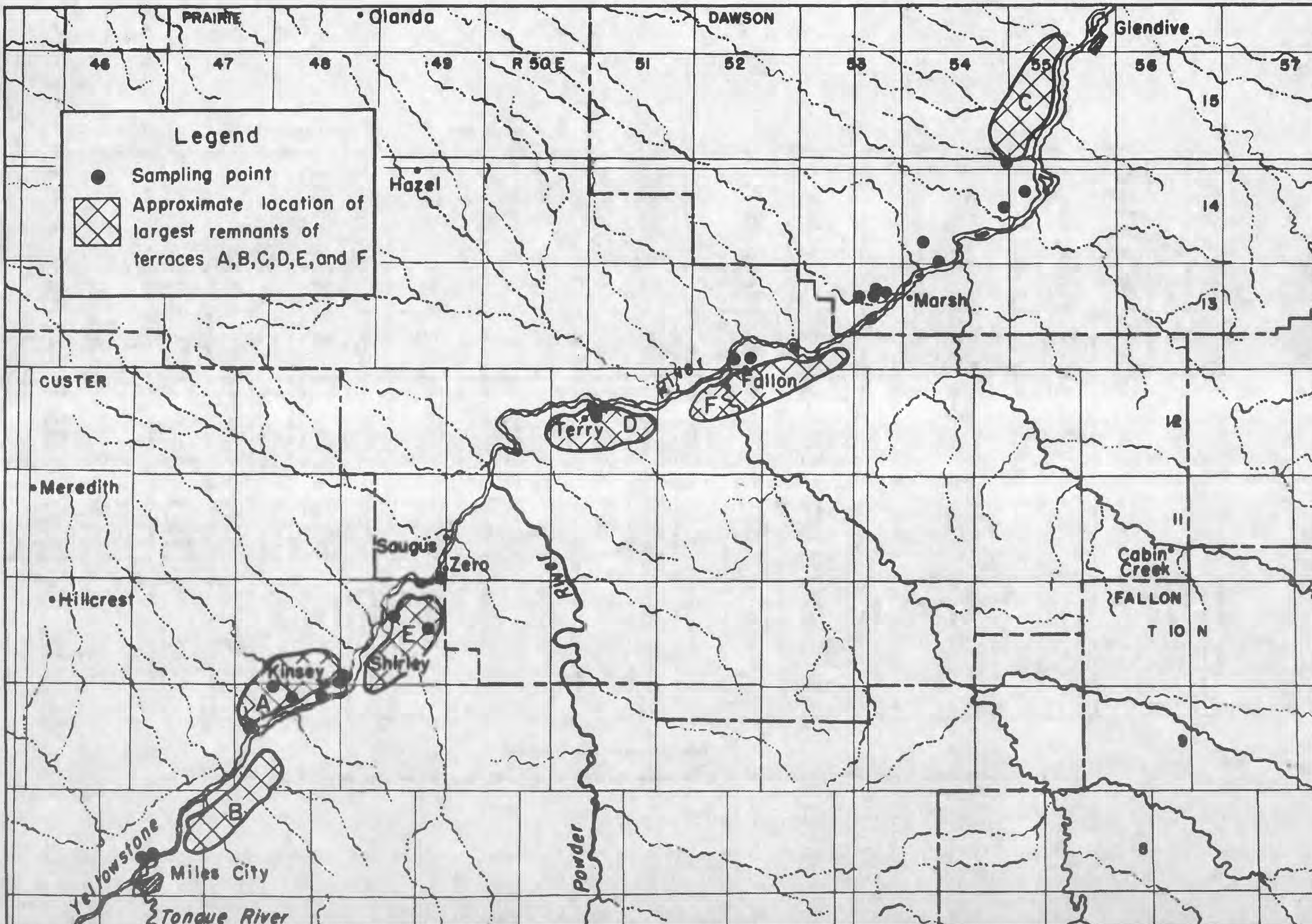

Figure 6.- Map of Lower Yellowstone River valley showing sampling points.

Table 5.--Chemical analyses, in parts per million, and related physical measurements of waters in the lower Yellowstone River valley, Mont.

[Samples collected October 1948]

Location	Source of sample	Depth of well (feet)	pH	Specific conductance (micromhos at 25° C.)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Noncarbonate	Percent sodium
Yellowstone River 1/	River	...	7.8	888	12	0.20	64	38	61	2.4	....	231	250	7.0	0.4	1.0	0.15	584	316	127	29
8-47-28ba........	Well	35	8.6	1,440	12	.30	5.7	.3	391		36	898	10	31	6.0	.1	.96	919	15	0	98
9-48-2dc.........	Drain	1	7.9	2,760	19	.30	106	45	545	4.0	....	660	1,040	27	.8	2.3	.48	2,120	450	0	72
-3cd1........	Well	543	8.9	1,290	15	.10	6.0	.3	313	2.4	53	670	3.2	43	1.5	.0	.68	780	16	0	97
-4bb.........	..do..	612	8.8	1,300	13	.10	3.2	.1	328	1.2	49	708	5.6	53	1.6	.5	.78	818	8	0	99
-18db........	..do..	420	8.5	1,310	11	.02	3.0	.5	343	2.8	30	795	4.0	44	2.4	.5	.48	860	10	0	98
10-48-36dc.......	Drain	7	8.0	3,760	20	2/ .05	98	52	833	10	....	619	1,680	41	1.0	9.6	.71	3,050	458	0	79
10-49-14dd.......	Well	625	8.1	1,730	11	4.0	46	36	347	2.8	12	596	480	6.1	.4	.8	.30	1,240	263	0	74
-15aa.......	..do..	340	9.0	1,310	15	.10	6.0	.4	318	3.6	55	642	54	26	2.4	.0	.76	806	16	0	97
-31bb.......	..do..	250	8.9	1,220	13	.10	4.0	.2	325	1.2	57	651	18	41	1.6	2.0	.84	772	11	0	98
11-49-36da.......	..do..	18	8.0	2,410	22	.16	16	7.4	544	3.6	....	780	414	96	1.0	64	.77	1,560	70	0	94
12-51-16ac.......	..do..	26	7.6	1,380	29	6.0	98	55	146	5.6	....	576	302	13	.4	1.7	.22	934	470	0	40
-16ba.......	Seep	2	7.4	1,070	35	.60	74	31	113	6.0	....	568	99	13	.4	1.1	.08	656	312	0	43
-16cd1......	Well	708	8.7	1,350	14	.06	4.0	.3	319	1.2	39	704	8.8	34	1.2	1.9	.65	820	11	0	98
Yellowstone River 3/	River	...	8.4	920	14	1.0	70	28	59		9.8	193	214	12	.5	2.4	.20	604	290	115	31
13-52-34ca2......	Well	17	7.9	914	26	2/ .06	33	17	149	4.4	....	440	102	8.0	.4	2.2	.17	560	152	0	67
13-53-10dc1......	..do..	540	8.3	2,190	12	1.5	3.0	.4	585		27	1,440	8.0	28	2.0	2.5	.56	1,390	9	0	99
-11cd.......	Seep	2	7.7	4,410	15	.20	233	255	576	6.4	....	646	2,220	63	.9	22	.46	3,710	1,630	1,100	43
-11ca.......	Well	772	8.8	1,330	14	.20	2.0	.0	310		43	681	10	22	2.2	2.5	.64	824	5	0	99
-11da.......	..do..	41	8.0	5,410	28	.20	305	470	547	14	....	376	3,140	94	.9	115	.57	4,900	2,690	2,380	30
14-54-1aa........	Drain	5	8.1	2,710	19	.30	68	71	532	6.8	6.5	589	1,030	40	.8	19	.59	2,090	462	0	71
-13db.......	Well	703	9.0	1,460	15	.14	6.0	.5	356	2.0	65	734	38	27	2.8	2.5	.78	878	17	0	98
-28bb.......	Seep	2	8.1	8,610	9.8	.20	214	272	1,790	23	7.9	625	4,860	26	.6	2.1	1.3	7,520	1,650	1,124	70
-33cc.......	Well	412	7.9	2,580	11	.02	4.5	2.0	733	4.8	....	1,950	2.4	24	1.4	.9	.0	1,760	19	0	98
14-55-7dc........	..do..	42	7.4	1,360	26	.20	18	14	266	2.8	....	506	244	16	1.1	5.0	.37	876	102	0	85

1/ At Miles City. 2/ Dissolved iron. 3/ Near Fallon.

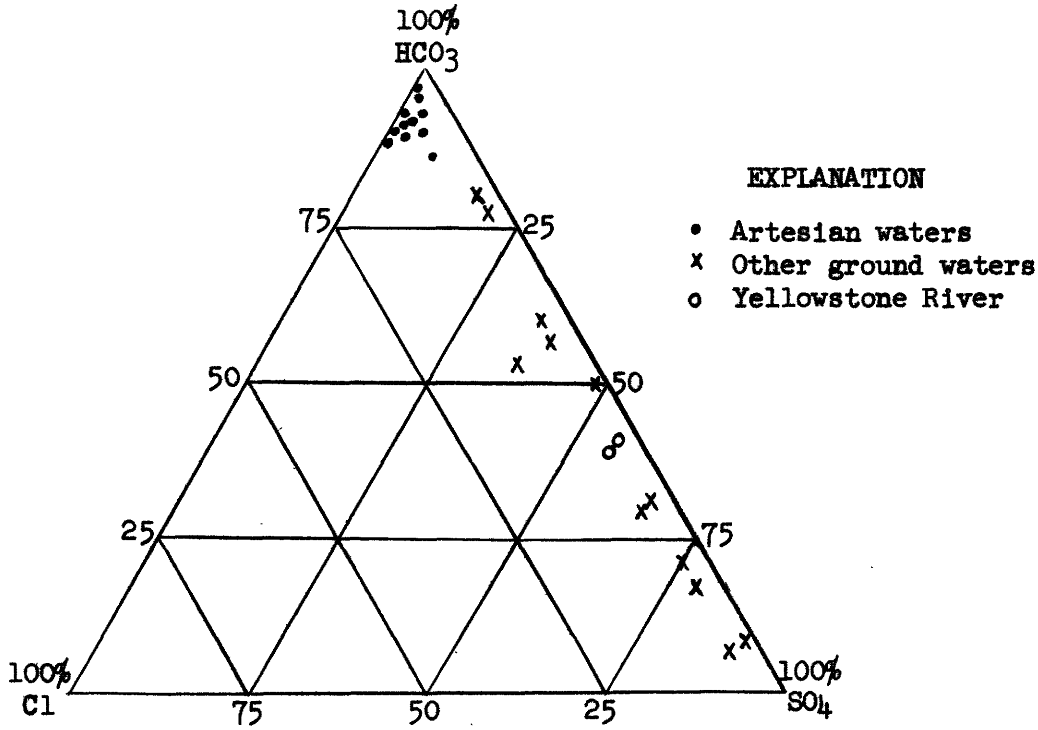

Figure 7.--Percent reacting values of acid radicals in valley waters

Waters in the Terrace Deposits

Ground waters from the stream-terrace deposits show, on the basis of three samples, a range from 560 to 1,560 parts per million of dissolved solids. Hardness as calcium carbonate ranges from 70 to 470 parts per million. The waters contain more bicarbonate than sulfate but not in the same proportions as found in the deeper artesian waters. The waters beneath the lower terraces are expected to vary in chemical properties as a result of varying surface recharge and varying permeability of the aquifers.

Waters in the Hell Creek and Fort Union Formations Undifferentiated

As previously stated, most water in the Hell Creek and Fort Union formations is very soft sodium-bicarbonate water. Many of these water samples contained appreciable quantities of carbonate as well as bicarbonate. Large quantities of calcium and magnesium cannot remain in solution in the presence of carbonate. Sulfate in the water samples is practically negligible, and reduction of sulfate to form bicarbonate may be the explanation of the high bicarbonate values that characterize them. The amounts of chloride are low. Dissolved solids and total hardness for the water samples range from 806 to 1,760 parts per million and from 5 to 19 parts per million, respectively.

Water in the Pierre Shale

No water samples analyzed are definitely known to be derived solely from the Pierre shale. Well 14-55-7dc (42 ft. deep) is thought to be tapping the Pierre shale, as shale was encountered from 24 to 42 feet during drilling. The water has a moderate hardness of 102 parts per million, and a concentration of dissolved solids of 876 parts per million. The sulfate content is less than the bicarbonate.

Drainage Water

The drainage water is typical of return irrigation flows in the valley in that the amount of sulfate exceeds that of bicarbonate. The water is also highly mineralized and very hard. In three samples, dissolved solids ranged from 2,090 to 3,050 parts per million; hardness, as calcium carbonate, ranged from 450 to 462 parts per million.

Spring and Seepage Water

No general statements can be made for the spring and seepage water, as the character of the water varies with its origin, which is not always definitely known. Three samples show ranges of 656 to 7,520 parts per million of dissolved solids and 312 to 1,650 parts per million hardness. Sulfate may exceed or be less than the amount of bicarbonate present in the water. Analyses of water from springs or seeps are shown in table 5 identified by numbers 12-51-16ba, 13-53-11cd, and 14-54-28bb.

River Water

Samples of Yellowstone River water that were collected at Miles City and near Fallon are similar in properties. The water is hard and moderately mineralized. Sulfate and bicarbonate are present in about equal quantities, and the amount of chloride is low.

Sulfate-Dissolved Solids Ratio

It was noted in the study of the chemical quality of the ground water that for samples other than the soft artesian waters, a linear relationship exists between the dissolved solids and the sulfate content. This is apparent in figure 8, where results for 12 samples have been plotted. It is seen that as the concentrations of dissolved solids in the water increases, the sulfate content increases correspondingly.

ORIGIN OF THE SOFT WATER

Renick[5] believes that the difference in the composition of water in deep and shallow wells in the Fort Union formation can be explained as the result of natural softening. He states that the exchange of calcium and magnesium in the water for sodium can be accounted for by the minerals of the leverrierite group, which exchange their bases easily, and which are plentiful in the Fort Union formation. Although leverrierite may be the principal mineral that causes the softening, it is recognized that other hydrated aluminum silicates, such as kaolin, feldspars, and mica, are also capable of exchanging wholly or in part their sodium and potassium for other bases.

The dissolved solids in the upper hard water are derived from the soluble materials resulting from the decomposition of minerals in the sedimentary beds and also, as Renick points out, to some extent from soluble salts deposited in the interstices between mineral grains. The hard water, before becoming softened, must percolate a certain distance, depending upon

5 Renick, B. C., Base exchange in ground water by silicates as illustrated in Montana: U. S. Geol. Survey Water-Supply Paper 520-d, pp. 68-71, 1924.

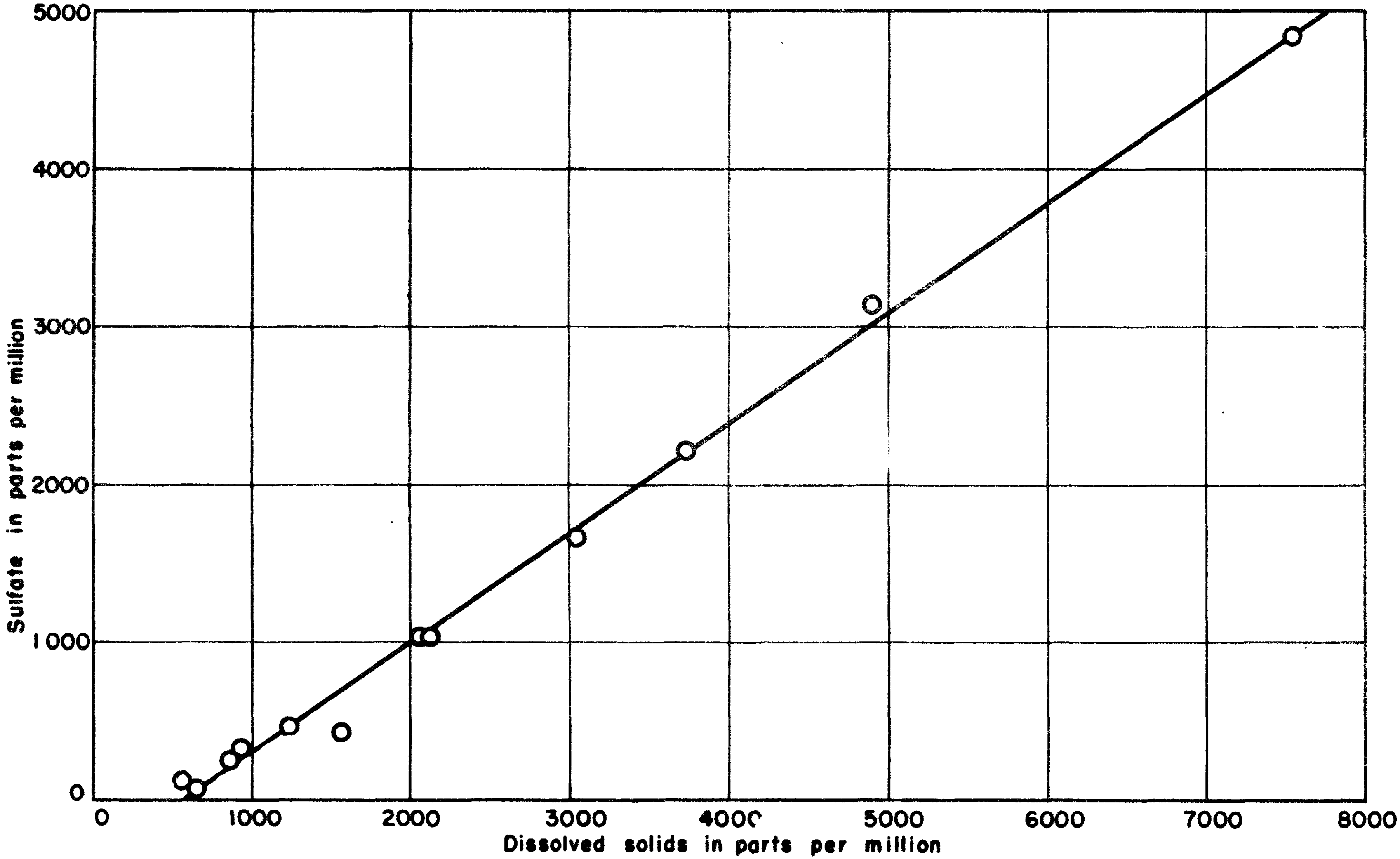

Figure 8. —— Relation of sulfate to dissolved solids in nonartesian water, Lower Yellowstone River valley.

the quantity of leverrierite and related mineral species in the rocks. It is also probable that the distance the hard water must percolate before becoming softened may depend on the character of the material, that is, whether it is rock in place or alluvium. Aggregates of leverrierite swell and go to pieces when wet, and this will happen if the Fort Union formation was converted into soil and alluvium.

Figures 9 and 10 show the distinctive differences in composition between the soft artesian water and other water in the lower Yellowstone River valley.

RELATION OF THE CHEMICAL QUALITY TO USE

Ground water in the valley is used for domestic and stock purposes, whereas the river water is used largely for irrigation. Wells drilled in the Fort Union formation and in the lower terrace gravels usually furnish water satisfactory for drinking and other domestic uses. The soft sodium bicarbonate water in deep wells reaching the undifferentiated Fort Union and Hell Creek formations often contain fluoride in objectionable amounts. Ground water samples analyzed for this study, with few exceptions, would be considered unsuitable for irrigation because of high percentages of sodium and high mineral content. As a result of irrigated tracts along the Yellowstone River becoming waterlogged, changes may occur in the quality of the ground water in nearby wells; such changes would probably affect the suitability of the water for domestic, stock, or other uses.

SUMMARY

An inventory of the present chemical quality of the ground water in the lower Yellowstone River valley from Miles City to Glendive shows wide variability in composition and appreciable differences in concentration. The deep, soft water from the undifferentiated Hell Creek and Fort Union formations is distinctive in character and unlike other ground water sampled.

The sodium bicarbonate content of the deeper Fort Union formation water results from the action of leverrierite and other minerals in this region capable of entering into base-exchange reactions. Water not of this type shows increasing amounts of sulfate, with increase in total mineralization.

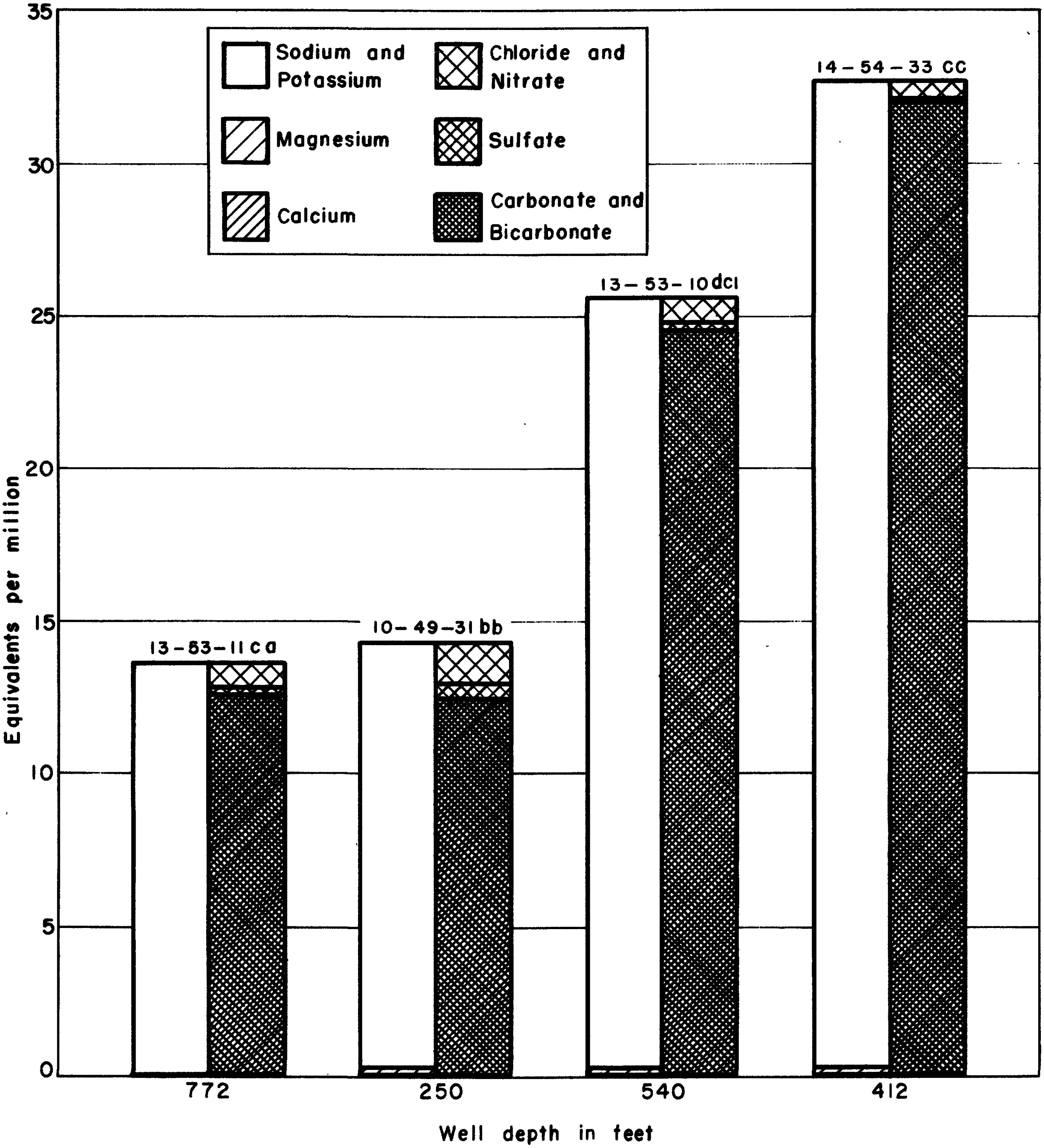

Figure 9.- Composition of artesian water, Hell Creek and Fort Union formations, undifferentiated.

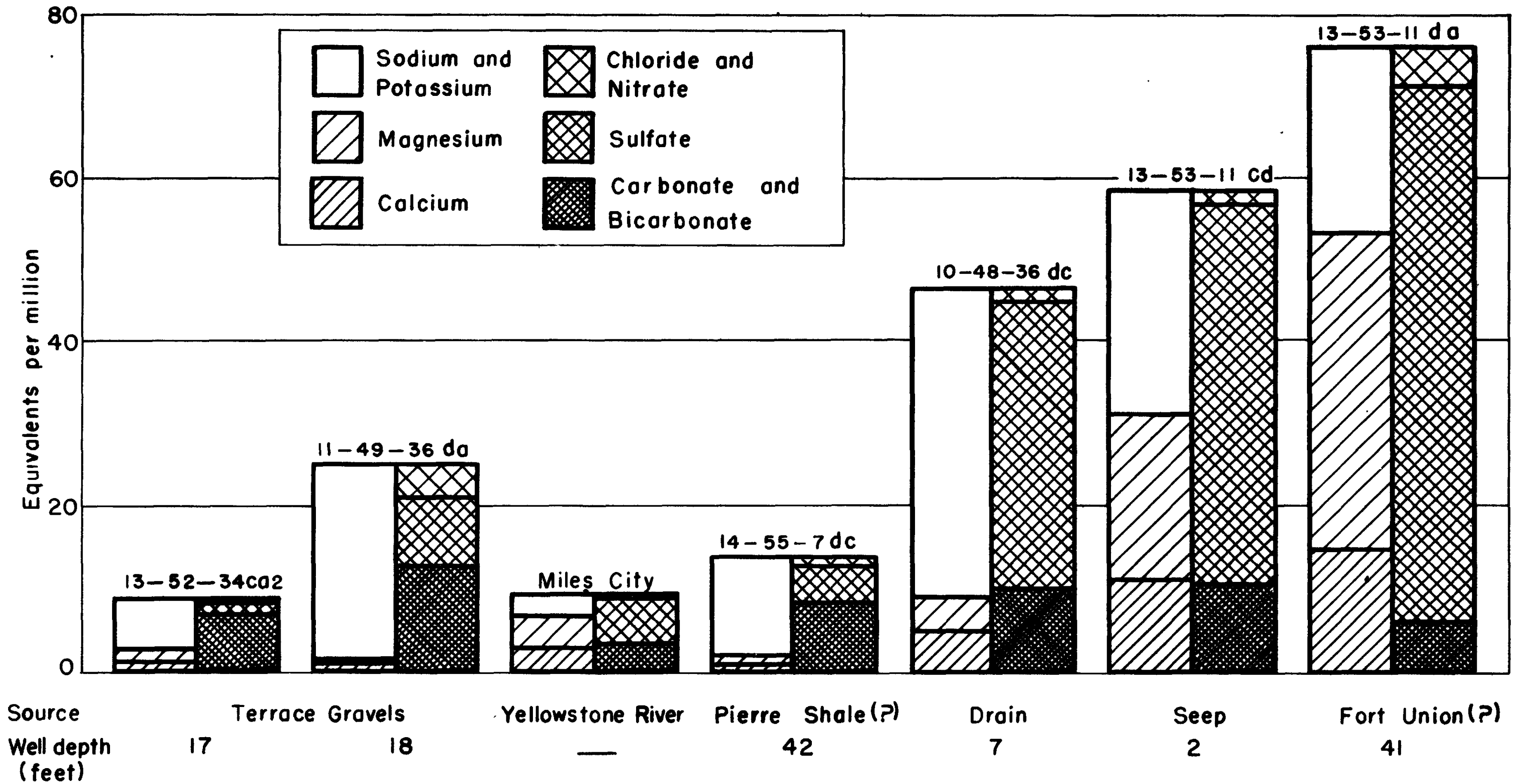

Figure 10.- Composition of water in Lower Yellowstone River valley.

Ground water is used almost exclusively for domestic and stock purposes and most of it is satisfactory for drinking. Fluoride is present in objectionable amounts in some of the water of the Fort Union and Hell Creek formations. Most of the ground water samples analyzed for this study would be classified as unsuitable for irrigation because of a high percentage of sodium or high mineral content. To what extent the chemical character of the ground water has been modified as a result of past irrigation practices is not known. The quality of ground water in irrigated tracts that are now waterlogged will probably be impaired as a result of salt deposition on these lands after the water is evaporated.

FLUCTUATIONS OF WATER LEVEL IN WELLS

Monthly measurement of the water level in about 125 wells was begun early in the investigation, but to date the period of measurement has not been long enough for significant interpretation. Measurements made through December 1949 are listed in table 6, and records of all observation wells, in addition to records of all other wells inventoried in the area, appear in table 7.

A few observation wells have been installed in the past by several government agencies, including the Farm Security Administration, the Soil Conservation Service, and the Bureau of Reclamation, but the water-level measurements that were made have not been published and are unavailable to date. It is also unfortunate that no records of the materials penetrated or the probable sources of water are available for study as part of this investigation. As far as the writers know, little or no interpretation was made of the information obtained by drilling the holes or from the measurements of the water level in them. Some of the abandoned observation wells have been located and are now being measured at monthly intervals.

In the spring of 1948 about 25 holes were drilled with a continuous flight auger on the First Division, Buffalo Rapids Project, by the Soil Conservation Service. These holes were drilled to gravel or to a maximum depth of 30 feet. Each hole was logged but the accuracy of the logs was limited by the unavoidable mixing of materials obtained by this means of sampling. Each hole reached the water table and was cased with downspouting. In the early and latter parts of May 1948, measurements were made of the water level in each well, and records of these measurements were given to the Geological Survey. Monthly measurements of the water level in these test holes have been made since August 1948 by the Geological Survey. Hydrographs showing the fluctuation of the water level in 12 of the test holes in sec. 33,

T. 14 N., R. 54 E., are presented in figures 11 and 12. The period of record is too short, however, for definite interpretations to be made from them. It may be seen that the water table in 7 of the 12 holes was somewhat higher in the spring of 1949 than when the test holes were drilled in 1948. This may be due, at least in part, to greater recharge from the melting of a snow cover which was somewhat heavier than that of the previous winter.

DIRECTION OF GROUND-WATER MOVEMENT

Because of the reconnaissance nature of this study, sufficient data are not available for construction of an accurate contour map of the water table. However, the location of springs and seeps along the edges of the stream terraces indicates that the general ground-water movement is toward the Yellowstone River. Recharge (from rain and snow melt, from springs along the face of the next higher terrace, and from irrigation) seeps into the permeable terrace deposits and then moves laterally through the gravel beds until it emerges in springs at the terrace edge; this process is repeated successively from one terrace to another until the water reaches the river.

The bedrock underlying this area has been gently downwarped between the Cedar Creek anticline near Glendive, and the Porcupine dome, about 50 miles west of Miles City. This large structure forms an artesian basin in which the sandstone beds of the Fox Hills sandstone and the Hell Creek and Fort Union formations furnish the water for the many flowing wells in the area west of Cedar Creek anticline. Because the steeply dipping beds on the western flank of the Cedar Creek anticline do not present a very large area of intake for the Fox Hills sandstone and the Hell Creek formation, it is probable that the greatest recharge to these aquifers is received on the more gently dipping western flanks of the basin.

SUMMARY AND RECOMMENDATIONS

Ample water supplies for domestic and stock needs may be obtained throughout the area except on the crest of the Cedar Creek anticline where the Pierre shale is exposed. On the west side of the Yellowstone River the terrace deposits are thick enough over the shale to provide ample supplies of shallow unconfined water. Water may be obtained elsewhere throughout the area either from terrace deposits or from the underlying bedrock aquifers.

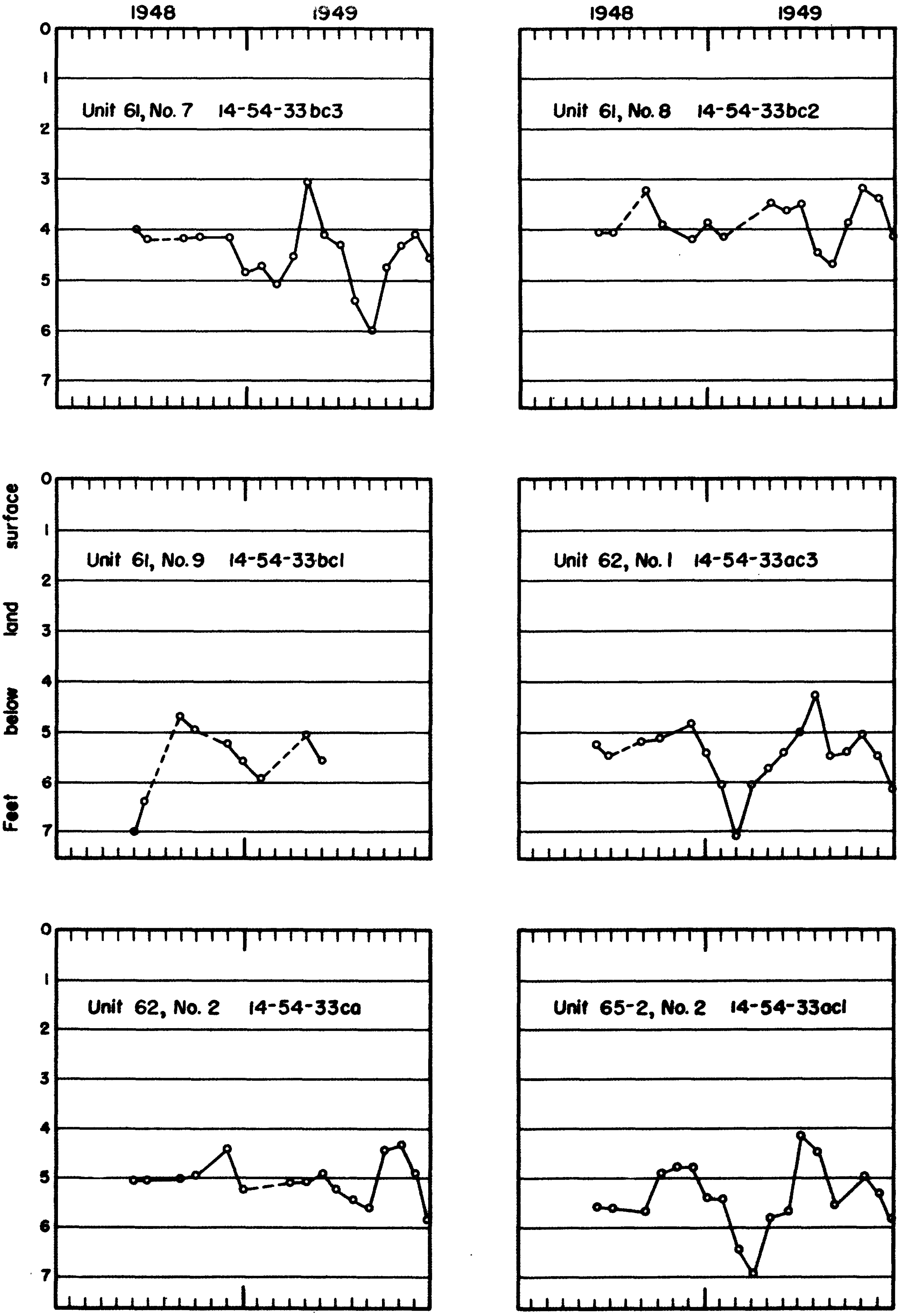

Figure 11.— Hydrographs showing fluctuations of the water level in observation wells on farm units 61 (nos. 7-9), 62 (nos. 1,2), and 65-2 (no. 2).

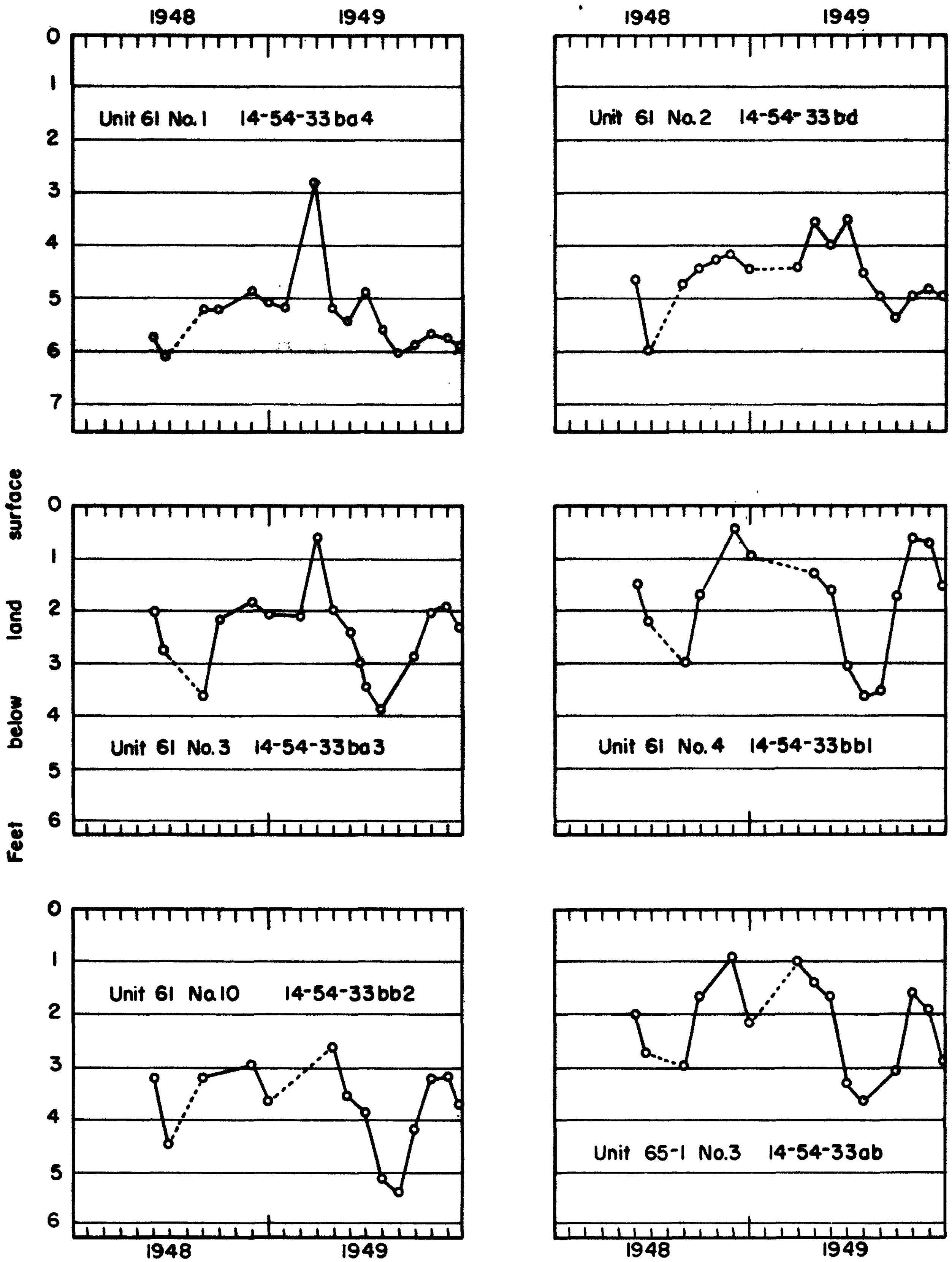

Figure 12.— Hydrographs showing fluctuations of the water level in observation wells on farm units 61 (nos. 1-4, 10) and 65-1 (no. 3).

Ground water is a valuable natural resource; it is not inexhaustible and should not be wasted. Despite this fact, numerous wells in the area are permitted to flow freely. If properly constructed and developed, flowing wells may be provided with control valves which can be used without danger to the wells, and these will prevent undue wastage of ground water and the consequent reduction of artesian pressures. Such conservation practices should be started without further delay.

Waterlogging and the development of saline soils are very serious and obvious ground-water problems that exist or that may exist on many acres of land now irrigated in the Yellowstone River valley; the same problems will probably develop on many tracts in the areas scheduled to be irrigated in the future. Detailed ground-water studies are needed to determine, if possible, means of lowering the water table in waterlogged areas and of forestalling similar conditions in other areas. Available evidence shows that prior to the irrigation of permeable stream terraces the water table was at a considerable depth below the land surface, but after irrigation the water table was recharged from water percolating downward from canals and irrigated fields. If the materials underlying irrigated tracts are permeable enough and if they have sufficiently adequate outlets, the additional recharge drains away without causing the water table to rise appreciably. However, in many places along the Yellowstone River valley, the natural underdrainage is insufficient to transmit additional recharge in large quantities and the water table has risen considerably. In some places the water table has risen close enough to the surface that direct evaporation of the ground water has taken place. Because the water contains dissolved minerals which cannot be evaporated, salts have been left in the soil. This concentration of salts in the upper part of the soil mantle has become so great that vegetation cannot grow, and unless this situation is remedied the land will never again be fit for cultivation. Other areas are likewise threatened. Properly located and designed drainage works will lower the water table under many waterlogged areas, and unless the soils have been permanently damaged by the salts the lands can be made productive again. Adequate drainage systems can be designed and constructed only after detailed geologic and ground-water studies have been made. In some instances adequate ditch or tile drainage may not be economically feasible and other methods (such as pumping from wells or a reduction in applied surface water) will be necessary to lower the water table.

As the several irrigation projects within the area covered by this report differ with regard to their high-water-table problems, each project is discussed separately below.

The Tongue and Yellowstone River Irrigation Project, lying south and east of Miles City, has been in operation since 1886. The drainage problems that have developed on this project have been generally cared for as they appeared, and the present high-water-table problems are not severe. Waterlogged land is out of production in isolated local areas, but these areas are small compared to the total acreage under cultivation. The largest waterlogged areas are near the northeastern end of the project. Some lands lying immediately below the main canal have a very thin mantle of soil over the shaly bedrock; they should not have been irrigated in the first place, and as underdrainage cannot be developed it is unlikely that anything can be done to remedy the situation. Inasmuch as the total acreage of waterlogged land is small, over-all detailed studies of ground-water conditions with respect to drainage are not deemed necessary on this project. However, detailed studies of local areas might prove profitable in alleviating the waterlogging in some of them.

On lands of the Kinsey Irrigation District the water table has risen over extensive areas; severe drainage problems have developed and large acreages have become waterlogged. Somewhat detailed ground-water studies have been made on parts of the project by Department of Agriculture agencies, and the construction of effective drains has resulted in the reclamation of considerable waterlogged land. Other drains have been planned, but difficulties experienced in obtaining the right-of-way for them have prevented their construction. It has been decided that drainage of some large areas of waterlogged land on this project is not economically feasible. Additional detailed study of these lands may be justified, however, as the waterlogged areas appear to be increasing in size. Proper drainage construction may prevent the waterlogging of cultivated lands that surround the existing waterlogged areas. The Federal Government has released the operation and maintenance of this project to the Kinsey Irrigation District.

Irrigation was begun on the Shirley and Terry Units of the Second Division, Buffalo Rapids Project, in 1944 and 1945, respectively, and some lands in both units already have become waterlogged. This condition will become steadily worse unless corrective measures are taken.

Much of the soil mantle on the Shirley Unit is thick and has a low permeability. Underdrainage is poor in parts of this unit because the underlying gravel is thin or no gravel is present. Such areas, located mainly near the upper edges of the terrace, have already become waterlogged and little can be done to remedy this situation. Where the irrigated terrace is underlain by permeable gravel, the rise in the water table has not yet caused waterlogging, but parts of these areas may eventually become waterlogged without adequate and timely remedies. Further detailed study would determine whether drainage structures, pumping from wells, or a reduction in applied surface water would be the most feasible solution of the problem.

Waterlogging has occurred near the upper edge of the lower of the two terraces irrigated on the Terry Unit. This waterlogging is primarily the result of uncontrolled ground-water seepage from the gravel beds exposed in the escarpment marking the boundary between the two irrigated terraces. Other parts of this unit may be expected to become waterlogged unless drainage works are constructed or unless other remedial measures are taken.

A detailed investigation of ground-water conditions should be made before drains are constructed on either the Shirley or Terry Units. A sufficient number of test holes should be drilled and cased, contour maps of the ground-water table should be made, and maps showing the thickness of the unsaturated material should be prepared. Samples should be taken of materials penetrated in drilling the test holes and their hydrologic properties should be determined by laboratory analysis. In some places, pumping tests may be required to make field determinations of those properties. These and other basic geologic and ground-water data would aid materially in the planning of an effective drainage system or in the determination of other remedial measures. The study should be continued after the remedial facilities are completed so that data regarding their effectiveness could be obtained.

The Fallon, Marsh, Colgate, Cracker Box, Haley, and Saugus-Calypso Units have not yet been irrigated. Some serious ground-water problems may be expected to develop when these lands are irrigated, and it is not too early to begin the collection of preliminary water-level data on these units. On the Fallon Unit, which will be irrigated in 1950, a number of problems can be foreseen. The residents of Fallon depend on shallow wells for their water supply. The water table under the town ranged from 15 to 18 feet below the land surface in 1949. Although many homes are provided with outdoor privies or with septic tanks buried 8 to 10 feet deep, the water supplies reportedly were not contaminated by sewage because water reaching the wells had been filtered naturally in its passage through several feet of material. Seepage from the proposed irrigation, however, will cause the water table to rise, and the shallow wells in the town may become dangerously contaminated. Aside from the shallow wells in the town of Fallon, there are now virtually no wells where water-table fluctuations can be observed on any of the units proposed for irrigation. Cased test holes extending below the seasonal low water table or to the bedrock should be installed on all units, and periodic measurements of the water level should be made in them. These measurements should be carefully studied and analyzed. Preirrigation studies of the depth, shape, and extent of the water table and of underlying aquifers will be of considerable benefit to the operation and maintenance of the project.

Serious ground-water problems exist on many of the 14,200 acres of irrigated land on the First Division of the Buffalo Rapids Project. After inspection and as a result of discussion with farmers and personnel of the Soil Conservation Service, the Bureau of Reclamation has mapped 12,978 acres of land as either waterlogged now or in immediate danger of becoming waterlogged. Although it is questionable that areas of future waterlogging can be determined without a detailed ground-water study, the situation is definitely critical and will become increasingly worse until remedial measures are taken. Much of the waterlogged land is no longer productive, and owners of that land are not making their payments to the Federal Government for the construction costs of the irrigation project. The increasing size of the waterlogged areas will further imperil the large investments made by the Federal Government, by private capital, and by the land owners themselves. If these investments are to be saved (that is, if these lands are to remain under cultivation), drainage facilities or other remedial measures are necessary. Attempts to drain the excess ground water should not be made prior to detailed investigations of the geologic and ground-water conditions; the solution of any high-water-table problem involves careful consideration of these factors.

In the early spring of 1949 the Bureau of Reclamation and the Geological Survey agreed to undertake the detailed drainage investigations needed on the First Division of the Buffalo Rapids Project. The duties and responsibilities of each agency in this cooperative investigation were carefully determined. However, because of difficulties in financing the study, it could not be undertaken at that time. Arrangements were later completed, however, to start the work in the spring of 1950. This investigation is designed to give detailed information on the depth, the source, the direction of movement, the areas of discharge, and the quantity and quality of ground water, on the surface configuration and slope of the water table, on the location, thickness, and permeability of beds carrying water under hydrostatic pressure, and on all other pertinent factors that must be considered in the proper design and construction of drainage or other remedial facilities.

Table 6.--Water-level measurements in observation wells, in feet below land surface

Custer County

8-47-11ad.

Date	Water level	Date	Water level	Date	Water level
July 10, 1948	8.40	Feb. 22, 1949	9.33	Aug. 31, 1949	7.51
Aug. 2	8.09	Mar. 28	9.10	Sept.28	7.23
Sept.24	7.71	Apr. 25	9.25	Oct. 27	7.42
Nov. 26	8.53	May 23	8.87	Nov. 30	8.00
Dec. 22	8.85	June 27	6.94	Dec. 28	8.36
Jan. 19, 1949	9.08	July 26	6.05		

8-47-13ad2.

Date	Water level	Date	Water level	Date	Water level
July 7, 1948	15.75	Feb. 22, 1949	16.65	Aug. 31, 1949	15.43
Aug. 2	15.58	Mar. 28	16.48	Sept.28	15.40
Sept.24	15.39	Apr. 25	16.66	Oct. 27	15.73
Nov. 26	16.33	May 23	16.57	Nov. 30	16.27
Dec. 22	16.64	June 27	15.85	Dec. 28	16.75
Jan. 19, 1949	17.01	July 26	15.57		

8-47-13bc.

Date	Water level	Date	Water level	Date	Water level
July 6, 1948	8.93	Feb. 22, 1949	9.66	Aug. 21, 1949	8.73
Aug. 2	8.29	Mar. 28	8.53	Sept.28	8.41
Sept.24	8.94	Apr. 25	9.65	Oct. 27	8.95
Nov. 26	9.54	May 23	9.53	Nov. 30	9.42
Dec. 22	9.89	June 27	7.88	Dec. 28	9.50
Jan. 19, 1949	10.17	July 26	8.55		

8-47-13da2.

Date	Water level	Date	Water level	Date	Water level
July 1, 1948	7.85	Jan. 19, 1949	9.61	Aug. 31, 1949	8.46
Aug. 2	7.45	Apr. 25	9.20	Sept.28	8.13
Sept.24	7.80	May 23	9.16	Oct. 27	8.11
Nov. 26	8.72	June 27	8.70	Nov. 30	8.60
Dec. 22	9.28	July 26	8.37	Dec. 28	8.78

8-47-27aa.

Date	Water level	Date	Water level	Date	Water level
Sept.10, 1948	9.15	Jan. 19, 1949	10.64	Apr. 25, 1949	10.09
Nov. 26	9.56	Feb. 22	9.70	May 23	10.02
Dec. 22	10.07	Mar. 28	9.09	June 27	9.68

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Custer County--Continued

8-47-27aa--Continued.

Date	Water level	Date	Water level	Date	Water level
July 26, 1949	9.18	Sept.28, 1949	8.75	Nov. 30, 1949	9.53
Aug. 31	9.10	Oct. 27	9.13	Dec. 28	9.78

8-47-27ba.

July 6, 1948	10.33	Feb. 22, 1949	12.70	Aug. 31, 1949	12.91
Aug. 2	7.91	Mar. 28	12.25	Sept.28	12.75
Sept.24	11.68	Apr. 25	12.75	Oct. 27	12.59
Nov. 26	12.72	May 23	12.59	Nov. 30	12.62
Dec. 22	12.87	June 27	11.96	Dec. 28	12.68
Jan. 19, 1949	13.11	July 26	12.68		

8-47-27bb.

July 2, 1948	15.98	Feb. 22, 1949	12.65	July 26, 1949	15.10
Aug. 2	15.93	Mar. 28	14.45	Aug. 31	15.18
Sept.24	14.63	Apr. 25	14.54	Sept.28	15.10
Nov. 26	11.82	May 23	14.44	Oct. 27	12.68
Dec. 22	11.82	June 27	14.46	Nov. 30	11.70
Jan. 19, 1949	12.11				

8-47-27cb.

July 8, 1948	8.90	Feb. 22, 1949	9.20	Aug. 31, 1949	7.96
Aug. 2	7.06	Mar. 28	8.50	Sept.28	7.43
Sept.24	7.76	Apr. 25	8.73	Oct. 27	7.63
Nov. 26	8.30	May 23	8.55	Nov. 30	8.05
Dec. 22	8.67	June 27	8.40	Dec. 28	8.34
Jan. 19, 1949	9.00	July 26	8.16		

8-47-27dc.

July 3, 1948	14.75	Sept.24, 1948	12.87	Nov. 26, 1948	13.33
Aug. 2	13.52				

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Custer County--Continued

8-47-27dd.

Date	Water level	Date	Water level	Date	Water level
July 1, 1948	5.01	Nov. 26, 1948	5.41	Feb. 22, 1949	7.22
Aug. 2	3.22	Dec. 22	6.57	Mar. 28	6.35
Sept. 24	3.56	Jan. 19, 1949	6.94		

8-47-28dd1.

Date	Water level	Date	Water level	Date	Water level
July 2, 1948	10.21	Sept. 24, 1948	11.23	Mar. 28, 1949	10.25
Aug. 2	10.25	Feb. 22, 1949	11.20		

8-47-28dd2.

Date	Water level	Date	Water level	Date	Water level
July 2, 1948	9.08	Feb. 22, 1949	Frozen	Aug. 31, 1949	10.56
Aug. 2	9.09	Mar. 28	8.92	Sept. 28	10.60
Sept. 24	9.99	Apr. 25	8.96	Oct. 27	9.78
Nov. 26	9.62	May 23	8.98	Nov. 30	9.82
Dec. 22	9.68	June 27	9.72	Dec. 28	9.72
Jan. 19, 1949	9.72	July 26	10.15		

8-48-8ab.

Date	Water level	Date	Water level	Date	Water level
July 9, 1948	26.15	Sept. 24, 1948	25.51	Dec. 22, 1948	26.50
Aug. 2	26.16	Nov. 26	26.22		

9-48-2ca2.

Date	Water level	Date	Water level	Date	Water level
Aug. 3, 1948	9.43	Mar. 28, 1949	8.77	Aug. 31, 1949	4.34
Nov. 26	9.47	Apr. 25	Dry	Sept. 28	6.54
Dec. 22	9.56	May 23	Dry	Oct. 27	7.85
Jan. 19, 1949	9.64	June 25	7.87	Nov. 30	8.94
Feb. 22	Frozen	July 27	7.79	Dec. 28	Dry

9-48-2cc.

Date	Water level	Date	Water level	Date	Water level
Aug. 3, 1948	7.79	Mar. 29, 1949	3.70	Aug. 31, 1949	4.92
Sept. 23	3.77	Apr. 25	4.67	Sept. 28	4.72
Nov. 26	4.50	May 23	4.66	Oct. 27	4.52
Dec. 22	4.65	June 25	5.17	Nov. 30	4.93
Jan. 19, 1949	Frozen	July 27	5.17	Dec. 28	4.92
Feb. 22	Frozen				

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Custer County--Continued

9-48-2dd.

Date	Water level	Date	Water level	Date	Water level
Aug. 3, 1948	Dry	Jan. 19, 1949	3.15	Apr. 25, 1949	3.96
Sept. 23	2.05	Feb. 22	Frozen	May 23	3.40
Nov. 26	2.89	Mar. 28	1.68	Well destroyed	
Dec. 22	2.95				

9-48-3cc1.

Date	Water level	Date	Water level	Date	Water level
Aug. 3, 1948	10.71	Feb. 22, 1949	Frozen	Aug. 31, 1949	9.01
Sept. 29	9.15	Apr. 25	11.05	Sept. 28	8.89
Nov. 26	10.79	May 23	10.80	Oct. 27	9.40
Dec. 22	10.94	June 25	9.37	Nov. 30	10.24
Jan. 19, 1949	11.01	July 27	9.43	Dec. 28	10.59

9-48-3cd2.

Date	Water level	Date	Water level	Date	Water level
Aug. 3, 1948	4.93	Mar. 28, 1949	2.92	Aug. 31, 1949	1.96
Sept. 23	2.27	Apr. 25	Dry	Sept. 28	1.71
Nov. 25	3.41	May 23	Dry	Oct. 27	1.98
Dec. 22	3.56	June 25	2.51	Nov. 30	2.65
Jan. 19, 1949	3.63	July 27	2.41	Dec. 28	Dry
Feb. 22	Frozen				

9-48-3dc.

Date	Water level	Date	Water level	Date	Water level
Aug. 3, 1948	3.30	Feb. 22, 1949	Frozen	July 27, 1949	2.87
Sept. 23	2.02	Mar. 28	3.46	Aug. 31	2.67
Nov. 26	3.70	Apr. 25	3.98	Sept. 28	2.30
Dec. 22	4.19	May 23	3.12	Oct. 27	2.27
Jan. 19, 1949	4.33	June 25	2.16	Well destroyed	

9-48-3dd.

Date	Water level	Date	Water level	Date	Water level
Aug. 3, 1948	8.97	Mar. 28, 1949	9.10	Aug. 31, 1949	8.45
Sept. 23	1.40	Apr. 25	Dry	Sept. 28	8.20
Nov. 26	9.13	May 23	9.20	Oct. 27	8.60
Dec. 22	9.65	June 25	8.70	Nov. 30	8.87
Jan. 19, 1949	Frozen	July 27	8.53	Well destroyed	
Feb. 22	Frozen				

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Custer County--Continued

9-48-8cd1.

Date	Water level	Date	Water level	Date	Water level
Aug. 3, 1948	5.62	Mar. 28, 1949	3.70	Aug. 31, 1949	1.17
Sept.23	5.09	Apr. 25	4.41	Sept.28	2.08
Nov. 26	5.39	May 23	3.73	Oct. 27	2.55
Dec. 22	4.48	June 25	3.64	Nov. 30	3.36
Jan. 19, 1949	4.77	July 27	Dry	Dec. 28	4.01
Feb. 22	Frozen				

9-48-8da1.

Aug. 3, 1948	6.39	Mar. 28, 1949	5.45	Aug. 31, 1949	4.55
Sept.23	4.48	Apr. 25	5.61	Sept.28	4.98
Nov. 26	5.62	May 23	5.55	Oct. 27	4.84
Dec. 22	5.85	June 25	5.59	Nov. 30	5.38
Jan. 19, 1949	Frozen	July 27	5.16	Dec. 28	5.75
Feb. 22	Frozen				

9-48-8dd.

Aug. 3, 1948	7.95	Dec. 22, 1948	7.21	Feb. 22, 1949	Frozen
Sept.23	5.05	Jan. 19, 1949	Frozen	Well destroyed	
Nov. 26	7.32				

9-48-9aa1.

Aug. 3, 1948	2.53	Dec. 22, 1948	2.76	Mar. 28, 1949	0.00
Sept.23	.38	Jan. 19, 1949	Frozen	Well destroyed	
Nov. 26	2.65	Feb. 22	Frozen		

9-48-9aa2.

Aug. 3, 1948	3.61	Dec. 22, 1948	3.16	Mar. 28, 1949	1.73
Sept.23	1.84	Jan. 19, 1949	Frozen	Well destroyed	
Nov. 26	2.70	Feb. 22	Frozen		

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Custer County--Continued

9-48-9ad.

Date	Water level	Date	Water level	Date	Water level
Aug. 3, 1948	3.87	Mar. 28, 1949	2.31	Aug. 31, 1949	3.96
Sept.23	4.50	Apr. 25	3.81	Sept.28	3.51
Nov. 26	4.51	May 23	3.61	Oct. 27	2.79
Dec. 22	4.55	June 25	4.16	Nov. 30	3.53
Jan. 19, 1949	4.68	July 27	4.41	Dec. 28	Dry
Feb. 22	Frozen				

9-48-9db.

Date	Water level	Date	Water level	Date	Water level
Aug. 3, 1948	3.85	Mar. 28, 1949	2.21	Aug. 31, 1949	2.47
Sept.23	2.72	Apr. 25	3.46	Sept.28	2.44
Nov. 26	3.59	May 23	3.31	Oct. 27	2.01
Dec. 22	3.66	June 25	4.06	Nov. 30	2.81
Jan. 19, 1949	3.77	July 27	Dry	Dec. 28	3.56
Feb. 22	Frozen				

9-48-10aa.

Date	Water level	Date	Water level	Date	Water level
Aug. 3, 1948	5.38	Mar. 28, 1949	5.45	Aug. 31, 1949	4.85
Sept.23	4.63	Apr. 25	5.25	Sept.28	4.85
Nov. 26	5.14	May 23	5.45	Oct. 27	4.40
Dec. 22	5.56	June 25	5.00	Nov. 30	4.85
Jan. 19, 1949	5.74	July 27	4.85	Well destroyed	
Feb. 22	Frozen				

9-48-10bb.

Date	Water level	Date	Water level	Date	Water level
Aug. 3, 1948	5.73	Mar. 28, 1949	4.59	Aug. 31, 1949	4.39
Sept.23	5.14	Apr. 25	4.57	Sept.28	4.32
Nov. 26	5.59	May 23	5.25	Oct. 27	3.57
Dec. 22	5.64	June 25	4.70	Nov. 30	4.31
Jan. 19, 1949	5.77	July 27	4.58	Dec. 28	7.39
Feb. 22	Frozen				

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Custer County--Continued

9-48-10ca.

Date	Water level	Date	Water level	Date	Water level
Aug. 3, 1948	4.75	Mar. 28, 1949	4.05	Aug. 31, 1949	2.25
Sept. 23	4.37	Apr. 25	4.19	Sept. 28	2.60
Nov. 26	4.56	May 23	4.50	Oct. 27	2.68
Dec. 22	4.90	June 25	3.00	Nov. 30	3.32
Jan. 19, 1949	5.07	July 27	2.86	Dec. 28	4.04
Feb. 22	Frozen				

9-48-17aa.

Aug. 3, 1948	5.66	Mar. 28, 1949	6.73	Aug. 31, 1949	4.45
Sept. 23	5.52	Apr. 25	6.58	Sept. 28	4.93
Nov. 26	6.20	May 23	5.73	Oct. 27	4.60
Dec. 22	6.30	June 25	5.88	Nov. 30	5.24
Jan. 19, 1949	Frozen	July 27	5.43	Dec. 28	5.36
Feb. 22	Frozen				

9-48-17ba.

Aug. 3, 1948	7.27	Mar. 29, 1949	Dry	Aug. 31, 1949	4.19
Sept. 23	4.52	Apr. 25	Dry	Sept. 28	4.59
Nov. 26	6.90	May 23	Dry	Oct. 27	5.75
Dec. 22	6.92	June 25	Dry	Nov. 30	6.34
Jan. 19, 1949	7.03	July 27	5.35	Dec. 28	8.83
Feb. 22	Frozen				

10-49-3cb.

Aug. 23, 1948	18.23	Mar. 29, 1949	18.54	Aug. 31, 1949	17.58
Sept. 24	17.75	Apr. 26	18.66	Sept. 28	17.47
Nov. 26	17.58	May 23	18.85	Oct. 27	17.64
Dec. 22	17.85	June 27	18.24	Nov. 30	17.88
Jan. 20, 1949	18.10	July 26	18.05	Dec. 28	18.05
Feb. 23	18.34				

10-49-3dd.

Aug. 23, 1948	18.60	Nov. 26, 1948	18.94	Jan. 20, 1949	18.80
Sept. 24	17.78	Dec. 22	18.95	Well destroyed	

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Custer County--Continued

10-49-20dd.

Date	Water level	Date	Water level	Date	Water level
Aug. 24, 1948	12.72	Mar. 29, 1949	11.85	Aug. 31, 1949	Dry
Sept.27	12.66	Apr. 25	12.01	Sept.28	Dry
Nov. 27	12.47	May 13	11.97	Oct. 27	Dry
Dec. 24	12.42	June 26	Dry	Nov. 30	Dry
Jan. 20, 1949	12.37	July 27	Dry	Dec. 28	Dry
Feb. 23	12.04				

Dawson County

13-53-10dc2.

May 5, 1948	8.35	Aug. 19, 1948	9.00		Filled in
28	8.50	Sept.27	8.12		

13-53-10dd.

May 5, 1948	5.00	Jan. 21, 1949	Frozen	July 24, 1949	5.06
28	4.75	Feb. 23	Frozen	Aug. 31	5.76
Aug. 19	5.70	Mar. 30	4.05	Sept.28	3.10
Sept.27	5.16	Apr. 25	4.16	Oct. 30	2.96
Nov. 27	4.55	May 23	3.78	Dec. 2	3.63
Dec. 27	5.05	June 27	5.10	29	4.40

13-53-11cb.

May 5, 1948	5.00	Jan. 21, 1949	5.67	July 24, 1949	6.19
28	5.00	Feb. 23	6.05	Aug. 31	6.97
Aug. 19	6.00	Mar. 30	4.85	Sept.28	5.87
Sept.27	6.49	Apr. 25	4.50	Oct. 30	5.03
Nov. 27	5.29	May 23	4.57	Dec. 2	4.96
Dec. 24	5.61	June 27	5.85		

13-53-11cc.

May 5, 1948	1.90	Sept.27, 1948	1.92	Jan. 21, 1949	Frozen
28	2.00	Nov. 27	1.84	Feb. 23	Frozen
Aug. 19	2.30	Dec. 24	2.09	Mar. 30	0.00

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Dawson County--Continued

13-53-11cc--Continued.

Date	Water level	Date	Water level	Date	Water level
Apr. 25, 1949	0.97	July 24, 1949	3.32	Oct. 30, 1949	1.97
May 23	2.02	Aug. 31	3.63	Dec. 2	1.81
June 27	30.2	Sept.28	2.55	29	2.52

13-53-11cd.

May 5, 1948	1.40	Nov. 27, 1948	1.53	Feb. 23, 1949	Frozen
28	1.50	Dec. 24	1.82	Mar. 30	0.00
Aug. 19	1.30	Jan. 21, 1949	Frozen	Well destroyed	
Sept.27	1.42				

13-53-11dc.

May 5, 1948	3.85	Jan. 21, 1949	6.03	July 24, 1949	4.26
28	3.90	Feb. 23	Frozen	Aug. 31	4.54
Aug. 19	4.20	Mar. 30	.00	Sept.28	4.80
Sept.27	4.52	Apr. 25	3.49	Oct. 30	4.65
Nov. 27	4.87	May 23	3.97	Dec. 2	4.74
Dec. 24	4.77	June 27	3.88	29	4.48

13-53-14bb.

May 5, 1948	3.10	Jan. 21, 1949	3.78	July 24, 1949	4.68
28	2.80	Feb. 23	Frozen	Aug. 31	5.10
Aug. 19	3.90	Mar. 30	.00	Sept.28	3.36
Sept.27	4.43	Apr. 25	2.95	Oct. 30	3.20
Nov. 27	3.45	May 23	2.65	Dec. 2	3.31
Dec. 27	3.86	June 27	4.25	29	3.69

13-53-15aa1.

May 5, 1948	4.85	Jan. 21, 1949	5.27	July 24, 1949	5.83
28	2.80	Feb. 23	Frozen	Aug. 31	3.23
Aug. 19	5.10	Mar. 30	4.47	Sept.28	1.63
Sept.27	2.22	Apr. 25	4.21	Oct. 30	2.87
Nov. 27	4.35	May 23	4.38	Dec. 2	3.66
Dec. 27	4.95	June 27	5.26	29	4.56

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Dawson County--Continued

13-53-15aa2.

Date	Water level	Date	Water level	Date	Water level
May 5, 1948	2.10	Jan. 21, 1949	1.51	July 24, 1949	4.05
28	.80	Feb. 23	2.51	Aug. 31	.00
Aug. 19	3.00	Mar. 30	.00	Sept.28	.00
Sept.27	.00	Apr. 25	1.74	Oct. 30	.73
Nov. 27	1.87	May 23	2.32	Dec. 2	1.40
Dec. 27	2.71	June 27	.00	29	2.33

14-54-1ad1.

Sept.27, 1948	17.97	May 23, 1949	19.59	Sept.28, 1949	16.97
Nov. 26	18.36	June 29	17.33	Oct. 30	17.15
Dec. 24	18.52	July 27	17.91	Dec. 1	17.82
Jan. 21, 1949	18.77	Aug. 31	16.86	29	18.39
Apr. 26	19.75				

14-54-14dd.

Sept.21, 1948	6.16	Apr. 26, 1949	6.63	Sept.28, 1949	6.15
Nov. 26	5.86	May 23	6.68	Oct. 30	6.13
Dec. 24	6.06	June 29	6.56	Dec. 1	6.37
Jan. 21, 1949	6.69	July 27	6.44	29	5.95
Mar. 30	6.03	Aug. 31	6.28		

14-54-33ab1.

May 5, 1948	0.80	Jan. 21, 1949	5.01	July 27, 1949	6.49
28	3.40	Feb. 23	Frozen	Aug. 31	Dry
Aug. 19	4.10	Mar. 30	.00	Sept.30	Dry
Sept.24	3.94	Apr. 25	1.76	Oct. 30	Dry
Nov. 27	3.73	May 23	3.04	Dec. 2	5.29
Dec. 24	4.82	June 27	6.49	29	Dry

14-54-33ab2.

May 5, 1948	2.00	Jan. 21, 1949	Frozen	July 27, 1949	3.70
28	2.75	Feb. 23	Frozen	Aug. 31	Dry
Aug. 19	3.00	Mar. 30	1.02	Sept.30	3.10
Sept.28	1.72	Apr. 25	1.39	Oct. 30	1.62
Nov. 27	.95	May 23	1.70	Dec. 2	1.90
Dec. 27	2.24	June 27	3.30	29	2.95

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Dawson County--Continued

14-54-33ac1.

Date	Water level	Date	Water level	Date	Water level
May 5, 1948	5.65	Jan. 21, 1949	5.42	July 27, 1949	4.48
28	5.60	Feb. 23	6.43	Aug. 31	5.58
Aug. 24	5.70	Mar. 30	6.96	Sept. 30	5.25
Sept. 27	4.93	Apr. 25	5.80	Oct. 30	4.94
Nov. 27	4.79	May 23	5.71	Dec. 2	5.30
Dec. 27	5.36	June 27	4.18	29	5.98

14-54-33ac2.

May 5, 1948	5.00	Jan. 21, 1949	Frozen	July 27, 1949	4.60
28	5.20	Feb. 23	Frozen	Aug. 31	Dry
Aug. 24	5.60	Mar. 30	7.20	Sept. 30	5.35
Sept. 27	4.41	Apr. 25	7.12	Oct. 30	4.85
Nov. 27	4.60	May 23	4.95	Dec. 2	4.91
Dec. 27	5.20	June 29	5.07	29	Dry

14-54-33ac3.

May 5, 1948	5.25	Jan. 21, 1949	6.05	July 27, 1949	4.25
28	5.40	Feb. 24	7.05	Aug. 31	5.45
Aug. 20	5.20	Mar. 30	6.01	Sept. 30	5.40
Sept. 27	5.10	Apr. 25	5.72	Oct. 30	5.08
Nov. 27	4.77	May 23	5.37	Dec. 2	5.48
Dec. 27	5.39	June 27	4.98	29	6.10

14-54-33ba1.

May 5, 1948	1.75	Jan. 21, 1949	Frozen	July 27, 1949	1.17
28	1.65	Feb. 24	Frozen	Aug. 31	2.78
Aug. 20	1.00	Mar. 30	0.00	Sept. 30	1.94
Sept. 27	.52	Apr. 25	.80	Oct. 30	.91
Nov. 27	.95	May 23	.54	Dec. 2	1.51
Dec. 27	2.24	June 27	1.00	29	2.75

14-54-33ba2.

May 5, 1948	6.65	Sept. 27, 1948	1.82	Jan. 21, 1949	4.26
28	4.80	Nov. 27	3.24	Feb. 24	6.07
Aug. 20	2.20	Dec. 27	4.12	Mar. 30	5.52

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Dawson County--Continued

14-54-33ba2--Continued.

Date	Water level	Date	Water level	Date	Water level
Apr. 25, 1949	3.82	July 24, 1949	1.17	Oct. 30, 1949	3.82
May 23	3.45	Aug. 31	3.31	Dec. 2	4.52
June 27	1.95	Sept.30	3.72	29	5.57

14-54-33ba3.

May 5, 1948	2.00	Jan. 21, 1949	Frozen	July 27, 1949	3.82
28	2.75	Feb. 24	2.11	Aug. 31	Dry
Aug. 24	3.60	Mar. 30	.67	Sept.30	2.77
Sept.27	2.10	Apr. 25	1.98	Oct. 30	2.02
Nov. 27	1.82	May 23	2.37	Dec. 2	1.89
Dec. 27	2.02	June 27	3.47	29	2.43

14-54-33ba4.

May 5, 1948	5.75	Jan. 21, 1949	5.13	July 24, 1949	5.54
28	6.10	Feb. 24	Frozen	Aug. 31	6.00
Aug. 24	5.20	Mar. 30	2.77	Sept.30	5.83
Sept.27	5.23	Apr. 25	5.13	Oct. 30	5.70
Nov. 27	4.76	May 23	5.36	Dec. 2	5.73
Dec. 27	5.06	June 27	4.79	29	5.88

14-54-33ba5.

May 5, 1948	2.00	Jan. 21, 1949	3.36	July 27, 1949	2.59
28	2.50	Feb. 24	3.99	Aug. 31	4.39
Aug. 24	3.30	Mar. 30	2.56	Sept.30	4.14
Sept.27	2.85	Apr. 25	1.92	Oct. 30	2.83
Nov. 27	2.27	May 23	1.89	Dec. 2	2.95
Dec. 27	3.06	June 27	3.26	29	3.76

14-54-33bb1.

May 5, 1948	1.50	Jan. 21, 1949	Frozen	July 27, 1949	3.69
28	2.20	Feb. 24	Frozen	Aug. 31	3.51
Aug. 19	2.90	Mar. 30	0.00	Sept.30	1.75
Sept.27	1.67	Apr. 25	1.28	Oct. 30	.65
Nov. 27	.42	May 23	1.61	Dec. 2	.70
Dec. 27	1.05	June 27	3.08	29	1.62

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Dawson County--Continued

14-54-33bb2.

Date	Water level	Date	Water level	Date	Water level
May 5, 1948	3.20	Jan. 21, 1949	Frozen	July 27, 1949	5.11
28	4.50	Feb. 24	Frozen	Aug. 31	5.39
Aug. 19	3.20	Mar. 30	0.00	Sept. 30	4.19
Sept. 27	3.15	Apr. 25	2.66	Oct. 30	3.21
Nov. 27	2.96	May 23	3.51	Dec. 2	3.20
Dec. 27	3.63	June 27	3.83	29	3.79

14-54-33bc1.

May 5, 1948	7.00	Nov. 27, 1948	5.24	Mar. 30, 1949	Frozen
28	6.30	Dec. 27	5.68	Apr. 25	5.08
Aug. 19	4.70	Jan. 21, 1949	5.86	May 23	5.57
Sept. 27	4.97	Feb. 24	Frozen	Well destroyed	

14-54-33bc2.

May 5, 1948	4.10	Jan. 21, 1949	4.12	July 27, 1949	4.45
28	4.00	Feb. 24	Frozen	Aug. 31	4.65
Aug. 19	3.20	Mar. 25	Frozen	Sept. 30	3.85
Sept. 27	3.86	Apr. 25	3.41	Oct. 30	3.12
Nov. 27	4.16	May 23	3.60	Dec. 2	3.34
Dec. 27	3.80	June 27	3.45	29	4.17

14-54-33bc3.

May 5, 1948	4.00	Jan. 21, 1949	4.70	July 27, 1949	5.40
28	4.20	Feb. 24	5.08	Aug. 31	6.04
Aug. 19	4.20	Mar. 30	4.60	Sept. 30	4.75
Sept. 27	4.15	Apr. 25	3.03	Oct. 30	4.26
Nov. 27	4.13	May 23	4.10	Dec. 2	4.16
Dec. 27	4.27	June 27	4.26	29	4.65

14-54-33bd1.

May 5, 1948	4.60	Jan. 21, 1949	Frozen	July 27, 1949	4.49
28	6.00	Feb. 24	Frozen	Aug. 31	4.93
Aug. 20	4.70	Mar. 30	4.44	Sept. 30	5.26
Sept. 27	4.32	Apr. 25	3.50	Oct. 30	4.90
Nov. 27	4.27	May 23	3.96	Dec. 2	4.76
Dec. 24	4.41	June 27	3.47	29	4.94

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Dawson County--Continued

14-54-33bd2.

Date	Water level	Date	Water level	Date	Water level
May 5, 1948	1.90	Jan. 21, 1949	Frozen	July 27, 1949	3.80
28	2.50	Feb. 24	Frozen	Aug. 31	4.80
Aug. 19	3.50	Mar. 30	2.09	Sept.30	3.67
Sept.27	2.52	Apr. 25	1.48	Oct. 30	2.75
Nov. 27	2.94	May 23	2.08	Dec. 2	2.57
Dec. 27	2.75	June 27	3.12	29	3.20

14-54-33bd3.

Date	Water level	Date	Water level	Date	Water level
May 5, 1948	2.65	Jan. 21, 1949	3.84	July 27, 1949	4.59
28	3.20	Feb. 24	3.93	Aug. 31	5.19
Aug. 24	4.10	Mar. 30	3.46	Sept.30	4.90
Sept.27	2.91	Apr. 25	2.70	Oct. 30	4.11
Nov. 27	3.74	May 23	3.21	Dec. 2	3.79
Dec. 27	3.79	June 27	3.95	29	4.82

14-54-33ca.

Date	Water level	Date	Water level	Date	Water level
May 5, 1948	5.00	Jan. 21, 1949	Frozen	July 27, 1949	5.36
28	5.00	Feb. 24	Frozen	Aug. 31	5.55
Aug. 24	5.10	Mar. 30	5.09	Sept.30	4.41
Sept.27	4.93	Apr. 25	5.06	Oct. 30	4.31
Nov. 27	4.44	May 23	4.87	Dec. 2	4.83
Dec. 27	5.16	June 27	5.22	29	5.84

14-54-33cb.

Date	Water level	Date	Water level	Date	Water level
May 5, 1948	6.50	Jan. 21, 1949	Frozen	July 27, 1949	5.31
28	6.25	Feb. 24	Frozen	Aug. 31	4.67
Aug. 19	5.50	Mar. 30	0.00	Sept.30	4.45
Sept.27	5.15	Apr. 25	5.68	Oct. 30	4.51
Nov. 27	5.04	May 23	4.51	Dec. 2	5.19
Dec. 27	5.68	June 27	4.16	29	6.02

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Dawson County--Continued

14-55-6dd.

Sept.25, 1948	22.71	Mar. 30, 1949	22.13	Aug. 31, 1949	23.02
Nov. 26	21.84	Apr. 26	23.32	Sept.28	22.98
Dec. 24	22.61	May 23	23.43	Oct. 30	22.95
Jan. 21, 1949	22.83	June 27	23.21	Measurements	
Feb. 24	22.44	July 27	23.15	discontinued	

14-55-16bb.

Sept.27, 1948	5.91	Mar. 30, 1949	8.35	Aug. 31, 1949	5.58
Nov. 27	7.57	Apr. 26	8.15	Sept.30	5.58
Dec. 24	5.83	May 23	7.12	Oct. 30	5.85
Jan. 21, 1949	5.85	June 29	7.10	Dec. 1	6.47
Feb. 24	7.70	July 27	6.96	29	6.02

15-55-16cb.

Sept.27, 1948	7.92	Mar. 30, 1949	7.45	Aug. 31, 1949	5.36
Nov. 27	7.26	Apr. 26	8.34	Sept.28	5.63
Dec. 24	7.68	May 23	7.65	Oct. 30	6.00
Jan. 21, 1949	7.82	June 29	6.80	Dec. 1	6.38
Feb. 24	8.52	July 27	6.57	29	8.82

15-55-19dc.

Sept.27, 1948	12.69	Dec. 24, 1948	13.56	Measurements
Nov. 26	13.43			discontinued

Prairie County

11-50-17ac.

Aug. 26, 1948	10.05	Mar. 29, 1949	10.82	Aug. 31, 1949	9.93
Sept.24	10.11	Apr. 26	11.09	Sept.28	9.98
Nov. 26	10.20	May 23	10.78	Oct. 27	10.27
Dec. 22	10.52	June 28	10.27	Nov. 30	10.37
Jan. 20, 1949	10.79	July 26	10.17	Dec. 28	10.41
Feb. 23	10.75				

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Prairie County--Continued

11-50-30aa.

Date	Water level	Date	Water level	Date	Water level
Aug. 2, 1948	9.13	Mar. 29, 1949	7.93	Aug. 31, 1949	7.12
Sept.24	9.25	Apr. 25	8.25	Sept.28	7.61
Nov. 26	7.46	May 23	5.76	Oct. 27	7.85
Dec. 22	7.90	June 27	6.01	Nov. 30	7.99
Jan. 20, 1949	Frozen	July 26	6.08	Dec. 28	8.09
Feb. 23	Frozen				

12-51-3dc.

Sept. 1, 1948	7.57	Apr. 26, 1949	6.71	Sept.28	5.45
Nov. 26	8.43	May 23	7.22	Oct. 30	5.75
Dec. 22	8.50	June 28	6.43	Nov. 30	6.29
Jan. 20, 1949	8.75	July 26	5.32	Dec. 28	6.49
Feb. 23	7.71	Aug. 31	5.31	Measurements discontinued	
Mar. 29	7.49				

12-51-16ac.

Aug. 2, 1948	20.49	Nov. 26, 1948	20.75	Measurements discontinued	
Sept.24	19.70	Dec. 22	19.15		

12-51-16cb2.

Aug. 26, 1948	10.93	Dec. 22, 1948	11.02	Feb. 23, 1949	11.02
Sept.24	10.95	Jan. 20, 1949	10.94	Mar. 29	10.87
Nov. 26	10.92				

12-51-16cd2.

Aug. 26, 1948	20.57	Dec. 22, 1948	20.05	Mar. 29, 1949	20.05
Sept.24	20.31	Jan. 20, 1949	20.10	Measurements discontinued	
Nov. 26	20.13	Feb. 23	20.14		

12-51-16dc.

July 28, 1948	20.20	Nov. 26, 1948	19.82	Feb. 23, 1949	19.79
Aug. 26	20.15	Dec. 2	19.80	Mar. 29	19.73
Sept.24	19.98	Jan. 20, 1949	19.76	Apr. 26	20.00

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Prairie County--Continued

12-51-16dc--Continued.

Date	Water level	Date	Water level	Date	Water level
May 23, 1949	20.20	Aug. 31, 1949	19.68	Nov. 30, 1949	19.03
June 28	19.82	Sept.28	19.46	Dec. 28	19.20
July 26	19.81	Oct. 27	19.26		

12-51-21ab.

Aug. 26, 1948	22.78	Dec. 22, 1948	23.79	Feb. 23, 1949	22.18
Sept.24	22.54	Jan. 20, 1949	24.73	Measurements discontinued	
Nov. 26	22.36				

12-52-1ad.

Aug. 31, 1948	31.12	Mar. 29, 1949	30.84	Aug. 31, 1949	30.87
Sept.24	31.09	Apr. 26	30.78	Sept.28	30.83
Nov. 26	31.03	May 23	30.72	Oct. 30	30.82
Dec. 22	31.22	June 28	30.89	Nov. 30	30.82
Jan. 20, 1949	31.25	July 26	30.91	Dec. 29	30.83
Feb. 23	29.37				

12-52-2aa.

Aug. 2, 1948	19.14	Feb. 23, 1949	19.00	July 26, 1949	19.58
Sept.24	19.18	Mar. 29	19.33	Aug. 31	19.15
Nov. 26	19.15	Apr. 26	19.27	Sept.28	19.18
Dec. 22	19.25	May 23	19.25	Oct. 30	19.28
Jan. 20, 1949	19.41	June 28	19.62	Nov. 30	19.33

13-52-34ac2.

Aug. 2, 1948	18.93	Mar. 29, 1949	18.88	Aug. 31, 1949	19.33
Sept.24	18.89	Apr. 26	18.98	Sept.28	18.92
Nov. 26	18.86	May 23	19.29	Oct. 30	18.80
Dec. 22	18.89	June 26	20.61	Nov. 30	18.81
Jan. 20, 1949	18.87	July 26	20.29	Dec. 29	18.80
Feb. 23	19.47				

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Prairie County--Continued

13-52-34ac4.

Date	Water level	Date	Water level	Date	Water level
Aug. 27, 1948	16.54	Mar. 29, 1949	16.35	Aug. 31, 1949	16.59
Sept. 24	16.66	Apr. 26	16.33	Sept. 28	16.48
Nov. 26	16.38	May 23	16.40	Oct. 30	16.42
Dec. 22	16.34	June 28	16.44	Nov. 30	16.32
Jan. 20, 1949	16.38	July 26	16.60	Dec. 29	16.27

13-52-34ad1.

Aug. 31, 1948	15.92	Dec. 22, 1948	15.69	Mar. 29, 1949	15.59
Sept. 24	15.79	Jan. 20, 1949	15.75	Measurements discontinued	
Nov. 26	15.69	Feb. 23	15.74		

13-52-34ad2.

Aug. 28, 1948	15.81	Mar. 29, 1949	15.74	Aug. 31, 1949	15.80
Sept. 24	15.79	Apr. 26	15.89	Sept. 28	15.74
Nov. 26	15.77	May 23	15.94	Oct. 30	15.64
Dec. 22	15.79	June 28	15.68	Nov. 30	15.60
Jan. 20, 1949	15.70	July 26	15.80	Dec. 29	15.59
Feb. 23	15.84				

13-52-34bd.

Aug. 27, 1948	18.24	Mar. 29, 1949	19.05	Aug. 31, 1949	18.15
Sept. 24	18.17	Apr. 26	18.86	Sept. 28	18.10
Nov. 26	18.10	May 23	18.50	Oct. 30	18.06
Dec. 22	18.05	June 28	18.04	Nov. 30	18.02
Jan. 20, 1949	18.25	July 26	18.15	Dec. 29	18.04
Feb. 23	18.96				

13-52-34ca1.

Aug. 27, 1948	18.29	Mar. 29, 1949	18.15	Aug. 31, 1949	18.40
Sept. 24	18.23	Apr. 26	18.16	Sept. 28	18.02
Nov. 26	18.17	May 23	18.18	Oct. 30	18.20
Dec. 22	18.19	June 28	18.25	Nov. 30	18.14
Jan. 20, 1949	18.75	July 26	18.63	Dec. 29	18.10
Feb. 23	18.21				

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Prairie County--Continued

13-52-34ca2.

Date	Water level	Date	Water level	Date	Water level
Aug. 27, 1948	15.13	Mar. 29, 1949	15.04	Aug. 31, 1949	15.16
Sept.24	14.98	Apr. 26	15.21	Sept.28	15.91
Nov. 26	14.87	May 23	15.49	Oct. 30	15.08
Dec. 22	14.94	June 28	16.55	Nov. 30	14.98
Jan. 20, 1949	15.12	July 26	16.24	Dec. 29	14.97
Feb. 23	15.09				

13-52-34cb.

Aug. 27, 1948	17.74	Mar. 29, 1949	17.83	Aug. 31, 1949	17.98
Sept.24	17.71	Apr. 26	17.85	Sept.28	17.88
Nov. 26	17.89	May 23	18.00	Oct. 30	17.83
Dec. 22	17.80	June 28	18.10	Nov. 30	17.75
Jan. 20, 1949	18.04	July 26	18.22	Dec. 29	17.90
Feb. 23	18.07				

13-52-34da.

Aug. 28, 1948	17.00	Mar. 29, 1949	16.93	Aug. 31, 1949	16.90
Sept.24	17.09	Apr. 26	16.91	Sept.28	17.10
Nov. 26	16.92	May 23	16.93	Oct. 30	17.06
Dec. 22	17.03	June 28	17.01	Nov. 30	17.00
Jan. 20, 1949	17.00	July 27	17.12	Dec. 29	16.94
Feb. 23	17.26				

13-52-34db1.

Aug. 31, 1948	19.25	Dec. 22, 1948	19.02	Mar. 29, 1949	19.14
Sept.24	19.21	Jan. 20, 1949	19.07	Measurements discontinued	
Nov. 26	19.18				

13-52-34db2.

Aug. 31, 1948	19.73	Mar. 29, 1949	19.97	Aug. 31, 1949	20.12
Sept.24	19.75	Apr. 26	19.94	Sept.28	19.74
Nov. 26	19.65	May 23	19.96	Oct. 30	20.01
Dec. 22	19.68	June 28	20.07	Nov. 30	19.67
Jan. 20, 1949	19.70	July 27	20.18	Dec. 29	19.92

Table 6.--Water-level measurements in observation wells, in feet below land surface--Continued

Prairie County--Continued

13-53-7db2.

Date	Water level	Date	Water level	Date	Water level
Sept. 3, 1948	30.65	Apr. 26, 1949	30.07	Sept.28, 1949	27.48
Nov. 26	29.02	May 23	29.91	Oct. 30	27.60
Dec. 22	29.15	June 28	28.77	Dec. 1	27.95
Jan. 20, 1949	29.96	July 27	28.36	28	28.55
Mar. 29	20.43	Aug. 31	27.64		

13-53-30ab.

Sept.20, 1948	22.46	Dec. 22, 1948	22.86	Measurements discontinued
Nov. 26	22.42	Jan. 20, 1949	23.07	

Table 7.--Records of wells in lower Yellowstone River valley between Miles City and Glendive, Mont.

Well number: See description of well-numbering system in text.
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 below measuring points; reported depths are given in feet below land surface.
Type of casing: C, concrete (brick, tile, or pipe); N, none; P, iron or steel pipe; W, wood.
Geologic source: G, Quaternary gravel; Tfu, Fort Union formation.
Method of lift: Cy, cylinder; F, natural flow (gallons per minute); N, none; P, pitcher pump.
Type of power: E, electric; H, hand-operated; W, wind.
Use of water: D, domestic, I, irrigation; In, industrial; N, none; O, observation; PS, public supply; S, stock.
Measuring point: Bp, base of pump; Ls, land surface; Tca, top of casing; Tco, top of cover. Altitude of land surface is given for wells in which water level was not measured.
Depth to water: Measured depths to water level are given in feet, tenths, and hundredths below measuring point; reported depths to water level are given in feet.
Remarks: Ca, water sample collected for chemical analysis.

Well number	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Geologic source	Method of lift and type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks
					Custer County										
8-47-11ad	Ray Torgenson........	....	Dr	20.4	4	P	G	P,H	D,S,O	Tca	2.65	2,341.07	11.05	7-10-48	..
-11dd	Ray Allen............	1918	Dr	.....	4	P	Tfu	F	D,S	...	....	2,348.6	......	....	..
-13aa	Clem Adamson.........	....	Dr	180	2	P	Tfu	Cy,H	D,S	...	....	2,360.21	......	....	..
-13ad	Ed Geist.............	1947	Dr	.....	4	P	Tfu	Cy,H	D,S	Tca	.8	2,355.99	18.00	7- 8-48	..
-13ad1	John Fancher.........	1944	Dr	185	4	P	Tfu	Cy,H	D	...	....	2,354.00	......	....	..
-13ad2	A. C. Door...........	....	Dr	29.9	4	P	Tfu	Cy,H	D,O	Tca	.25	2,353.68	16.00	7- 7-48	..
-13ad3	J. G. Milroy.........	....	Dr	150	4	P	Tfu	Cy,H	D	...	....	....	......	....	..
-13bc	....	....	Dr	49.5	4	P	Tfu	N	O	Tca	.65	2,348.82	9.58	7- 6-48	..
-13da1	W. Dyba..............	1938	Dr	90	3	P	Tfu	Cy,E	.....	...	....	2,354.35	......	....	..
-13da2	.....do..............	....	Dr	13.6	2	P	...	Cy,H	D,O	Tca	.3	2,352.63	8.15	7- 1-48	..
-13db	E. L. Hubbs..........	....	Dr	160	3	P	Tfu	Cy,E	D,S	...	....	2,352.7	......	....	..
-13dd	Fred M. Lane.........	1930	Dr	125	2	P	Tfu	Cy,E	D,S	...	....	2,352.00	......	....	..
-23ad	Ed Luff..............	1938	Dr	50	6	P	Tfu	Cy,E	D	...	....	2,346.65	......	....	..
-23cb	John Kistof..........	....	Dr	75	4	P	Tfu	Cy,H	D	...	....	....	......	....	..
-23cd	Cross Roads Inn......	1941	Dr	125	4	P	Tfu	Cy,E	D	...	....	2,348.84	......	....	..
-25bc	Carl Herzog..........	1925	B	276	2.5	P	Tfu	Cy,E	D,S	...	....	2,369.2	......	....	..
-25cc	Fred Herzog..........	....	Dr	300	6	P	Tfu	Cy,E	D,S	...	....	2,355.7	......	....	..

-26ad	George Spranden......	1928	Dr	300	4	P	Tfu	Cy,E	D,S	...	....	2,363.4	......	....	..
-27aa	State Port of Entry..	....	Dr	58.0	2.5	P	Tfu	P,H	PS,O	...	1.67	2,351.02	10.82	9-10-48	..
-27ba	Ted Matzen..........	1922	Du	14.4	48	C	...	Cy,E	D,O	Tco	1.67	....	12.00	7- 6-48	..
-27bb	....	....	Dr	50.3	4	P	Tfu	Cy,H	D,O	Tca	.5	2,351.06	16.48	7- 2-48	..
-27cb	C. E. Hough..........	....	Du	13.4	36	C	...	Cy,H	O	Tca	1.9	2,353.20	10.8	7- 8-48	..
-27dc	....	....	Dr	25.5	3	P	...	Cy,E	D,O	Tca	.3	2,353.64	15.05	7- 3-48	..
-27dd	Carl May............	1934	Du	10.0	48	W	...	N	O	Tca	.1	2,353.71	5.11	7- 1-48	..
-28ba	....	1948	Dr	35	2	P	...	Cy,H	D	...	....	....	......	....	Ca
-28dd1	....	....	B	15.9	1.6	P	...	Cy,E	D,O	Tca	.2	2,348.43	10.41	7- 2-48	..
-28dd2	Paul Blueher.........	....	Du	7.7	.96	W	...	Cy,E	D	Tca	-5.8	2,349.18	3.28	7- 2-48	..
8-48-6cd	Don Muggli...........	1908	Dr	.....	3	P	Tfu	F	D,S	...	....	....	......	....	..
-7ab	P. J. Wittmayer......	1928	Dr	750	3	P	...	F	D,S	...	....	....	......	....	..
-7ac	Agusta Henn..........	1928	Dr	312	3	P	Tfu	Cy,H	D	...	....	....	......	....	..
-7bc	Joe Muggli...........	....	Dr	204	4	P	Tfu	Cy,E	D,S	...	....	....	......	....	..
-7cc	John Roberts.........	....	Dr	200	6	P	Tfu	F	D,S	...	....	....	......	....	..
-7dc	C. E. Retallick......	1932	Dr	250	4	P	Tfu	Cy,E	D,S	...	....	....	......	....	..
-8ab	Ray Olson............	1939	Du	29.00	36	N	...	N	O	Tco	.6	....	26.75	7- 9-48	..
-18bb	August Birkholz......	1927	Dr	138	4	P	Tfu	Cy,E	D,S	...	....	2,360.7	......	....	..
-18bc	P. Smelser...........	....	Dr	120	3	P	Tfu	Cy,H	D	...	....	2,359.5	......	....	..
-18cb	Ben Toennis..........	....	Dr	150	6	P	Tfu	Cy,E	D,S	...	....	2,355.5	......	....	..
9-47-24cc	C. W. Hall...........	1902	Dr	380	4	P	...	Cy,H	D	...	....	2,342.24	......	....	..
-33cc	A. E. Taylor.........	....	Dr	35.0	6	P	Tfu	Cy,H	D	Tca	.7	....	8.35	9-29-48	..
-35ab	Carl Wohlgenant......	1943	Dr	220	4	P	Tfu	F	D,S	...	....	....	......	....	..
9-48-1bd1	Zable............	....	Dr	536	3	P	...	F	D,S	...	....	2,293.91	......	....	..
-1bd2	Frank Cleveland......	....	Dr	......	4	P	Tfu	F	D,S	...	....	2,295.09	......	....	..
-1cb	M. Scheid............	....	Dr	......	....	P	Tfu	F	D,S	...	....	2,299.22	......	....	..
-2ba1	W. Myron.............	....	Dr	......	....	P	Tfu	F	D,S	...	....	....	......	....	..
-2ba2	M. Ownes.............	....	Dr	365	2	P	...	F-8	D	...	....	2,300.22	......	7-15-48	..
-2bb	C. L. Martin.........	....	Dr	......	4	P	...	F-5	D,S	...	....	2,300.44	......	7-15-48	..
-2ca1	Alick Beckman........	....	Dr	502	3	P	...	F-5	D,S	...	....	2,301.72	......	7-16-48	..
-2ca2	.....do..............	....	B	13.5	3	W	...	N	O	Tca	.95	2,303.87	10.38	8- 3-48	..
-2cc	Carl Astrom..........	....	B	9.5	3	W	...	N	O	Tca	.93	2,297.48	8.72	8- 3-48	..
-2da	Benard Hanson........	1940	Dr	......	4	P	...	F	D,S	...	....	2,299.20	......	....	..
-2dd	Alick Beckman........	....	B	5.6	3	W	...	N	O	Tca	1.4	2,297.45	Dry	8- 3-48	..
-3cb	Carl Astrom..........	....	Dr	506	3	P	...	F-25	D,S	...	....	2,311.12	......	7-12-48	..
-3cc1	Laurids Lund.........	....	B	13.2	3	W	...	N	O	Tca	.85	2,309.44	11.56	8- 3-48	..
-3cc2	.....do..............	....	Dr	373	3	P	...	F-15	D,S	...	....	2,308.24	......	7-20-48	..
-3cd1	Otto Schmitt.........	....	Dr	543	3	P	...	F-40	D,S	...	....	2,314.00	......	7-16-48	Ca
-3cd2	.....do..............	....	B	7.0	3	W	...	N	O	Tca	1.09	2,301.22	6.02	8- 3-48	..
-3dc	George Robhahn.......	....	B	8.1	3	W	...	N	O	Tca	.58	2,303.81	3.88	8- 3-48	..
-3dd	Carl Astrom..........	....	B	12.0	3	W	...	N	O	Tca	1.10	2,305.86	10.07	8- 3-48	..

Table 7.--Records of wells in lower Yellowstone River valley between Miles City and Glendive, Mont.--Continued

Well number	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Geologic source	Method of lift and type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks
	Custer County--Continued														
9-48-4bb	Walter Zable	....	Dr	612	3	P	...	F-3	D,S	...	....	2,352.21	......	7-16-48	Ca
-4bd1	Hillier	....	Dr	596	4	P	...	F-20	D,S	...	....	2,346.74	......	7-14-48	..
-4bd2	Irvine	....	Dr	......	3	P	...	F-3	D,S	...	....	2,346.12	......	7-12-48	..
-5da	George Ingerham	....	Dr	648	3	P	...	F-17	D,S	...	....	2,334.65	......	7-14-48	..
-7ba	....	....	Dr	......	3	P	...	F	D,S	...	....	2,351.62	......	....	..
-7ca	Dan Carter	....	Dr	597	4	P	...	F-17	D,S	...	....	2,348.41	......	7-16-48	..
-7dd	Cecil Nile	....	Dr	609	4	P	...	F-7	D,S	...	....	2,325.35	......	7-16-48	..
-8aa1	H. Shook	....	Dr	......	3	P	...	F-15	D,S	...	....	2,329.51	......	7-16-48	..
-8aa2	Tony Janutes	....	Dr	383	4	P	...	F-25	D,S	...	....	2,317.93	......	7-16-48	..
-8bb	M. Bender	....	Dr	672	4	P	...	F-3	D,S	...	....	2,344.28	......	7-16-48	..
-8ca	Burt Hanson	1940	Dr	459	4	P	...	F-6	D,S	...	....	2,324.70	......	7-15-48	..
-8cb	Burnside	1940	Dr	......	3	P	...	F-8	D,S	...	....	2,331.12	......	7-12-48	..
-8cc	M. G. Grist	1940	Dr	750	3	P	...	F-3	D,S	...	....	2,331.62	......	7-15-48	..
-8cd1	Burt Hanson	....	B	8.40	3	W	...	N	O	Tca	1.62	2,307.94	7.24	8- 3-48	..
-8cd2	Kirkpatrick	....	Dr	358	3	P	...	F-30	D,S	...	....	2,320.67	......	7-12-48	..
-8da1	Tony Janutes	....	B	7.3	3	W	...	N	O	Tca	.59	2,305.69	6.98	8- 3-48	..
-8da2	Burt Hanson	....	B	8.5	2	W	...	N	N	Tca	.67	2,304.32	7.39	8- 3-48	..
-8da3	.....do	....	B	9.2	2	W	...	N	N	Tca	1.27	2,306.56	8.09	8- 3-48	..
-8da4	Tony Janutes	....	B	5.5	2	W	...	N	N	Tca	.97	2,306.39	Dry	8- 3-48	..
-8dc1	Burt Hanson	....	B	6.2	2	W	...	N	N	Tca	1.38	2,306.73	5.59	8- 3-48	..
-8dc2	.....do	....	B	7.9	2	W	...	N	N	Tca	.00	2,307.89	Dry	8- 3-48	..
-8dd	.....do	....	B	8.3	3	W	...	N	O	Tca	.99	2,306.73	8.94	8- 3-48	..
-9aa1	Laurids Lund	....	B	7.6	3	W	...	N	O	Tca	1.12	2,301.30	3.65	8- 3-48	..
-9aa2	.....do	....	B	8.0	3	W	...	N	O	Tca	1.12	2,301.48	4.73	8- 3-48	..
-9ad	Fred Wambolt	....	B	8.4	3	W	...	N	O	Tca	.94	2,301.37	4.81	8- 3-48	..
-9bb	Otto Myran	....	Dr	......	3	P	...	F	D,S	...	....	2,331.02	......	....	..

-9ca	Adam Gresser.........	....	Dr	302	4	P	...	F-3	D,S	...	....	....	......	7-15-48	..
-9db	Fred Wambolt.........	....	B	8.4	3	W	...	N	O	Tca	1.04	2,301.89	4.89	8- 3-48	..
-10aa	George Robhahn.......	....	B	7.3	3	W	...	N	O	Tca	1.05	2,302.46	6.43	8- 3-48	..
-10bb	Henry George.........	....	B	6.7	3	W	...	N	O	Tca	.71	2,302.21	6.44	8- 3-48	..
-10bc	.....do..............	1940	Dr	381	4	P	...	F-4	D,S	...	....	2,301.20	......	7-16-48	..
-10ca	.....do..............	....	B	9.6	3	W	...	N	O	Tca	1.10	2,299.99	5.85	8- 3-48	..
-17aa	Kirkpatrick......	....	B	7.5	3	W	...	N	O	Tca	1.22	2,309.18	6.88	8- 3-48	..
-17ba	.....do..............	....	B	9.5	3	W	...	N	O	Tca	1.08	2,307.45	8.35	8- 3-48	..
-18aa	Dalbey...........	....	Dr	......	3	P	...	F-3	D,S	...	....	2,324.03	......	7-15-48	..
-18bb	F. L. Campbell.......	1940	Dr	......	3	P	...	F-7	D,S	...	....	2,347.61	......	7-16-48	..
-18cb	M. D. Ferris.........	1940	Dr	640	3	P	...	F-8	D,S	...	....	2,334.33	......	7-12-48	..
-18cc	Carl Mathison........	....	Dr	......	3	P	...	F-8	D,S	...	....	2,330.11	......	7-12-48	..
-18db	Edwards..........	....	Dr	420	3	P	...	F-5	D,S	...	....	....	......	7-15-48	Ca
-30db	Northern Pacific R.R.	1947	Dr	195	6	P	Tfu	Cy,H	D	...	....	2,328.31	......	....	..
-36cd	Fred Johnson.........	1937	Dr	564	4	P	...	F	D,S	...	....	2,294.85	......	....	..
10-48-25cb	....	....	Dr	......	4	P	...	F	D,S	...	....	2,303.62	......	....	..
-33dd	H. Watts.............	....	Dr	595	3	P	...	F	D,S	...	....	2,346.28	......	....	..
-34ca	L. Walker............	1941	Dr	500	4	P	...	F-4	D,S	...	....	2,334.31	......	7-12-48	..
-34dc	T. Dalke.............	1940	Dr	605	4	P	...	F-5	D,S	...	....	2,320.06	......	7-12-48	..
-35ac	....	....	Dr	......	4	P	...	F	D,S	...	....	2,311.53	......	....	..
-35ad1	C. Carey.............	....	Dr	......	4	P	...	F-15	D,S	...	....	2,300.75	......	7-14-48	..
-35ad2	Schiba...........	....	Dr	463	3	P	...	F-18	D,S	...	....	2,313.49	......	7-16-48	..
-35bc	G. Price.............	....	Dr	562	3	P	...	F-8	D,S	...	....	2,307.91	......	7-16-48	..
-35cc	M. Mathason..........	1940	Dr	542	4	P	...	F-5	D,S	...	....	2,304.65	......	7-12-48	..
-35dc	A. Christonson.......	1940	Dr	602	3	P	...	F-10	D,S	...	....	2,298.97	......	7-12-48	..
-35dd	V. Carey.............	....	Dr	495	3	P	...	F-5	D,S	...	....	2,303.37	......	7-16-48	..
-36ab	J. Schlenker.........	....	Dr	463	3	P	...	F-8	D,S	...	....	2,295.80	......	7-16-48	..
-36dc	Chas. Nelson.........	....	Dr	422	3	P	...	F-12	D,S	...	....	2,292.75	......	7-12-48	..
10-49-3cb	Homer Watts..........	1947	Du	20.4	24	P	...	Cy,H	D,S,O	Tca	.45	2,247	18.68	8-23-48	..
-3dd	Harold Watts.........	1948	Du	21.4	24	P	...	Cy,H	D,S	Tca	1.3	2,270	19.90	8-23-48	..
-10cb	G. S. Sweet..........	....	Du	23.0	24	P	...	Cy,W	D,S	Tca	.40	....	20.00	7-24-48	..
-14bc	J. Cosgrove..........	1948	Dr	397	6	P	...	F-1	D,S	...	....	2,320	......	7-23-48	..
-14dd	J. Nelson............	1948	Dr	625	6	P	...	Cy,H	D,S	...	....	....	......	....	Ca
-15aa	Custer County........	1948	Dr	340	3	P	...	F-24	D	...	....	....	......	....	Ca
-15cb	H. Lapp..............	1948	Dr	200	4	P	Tfu	F	D,S	...	....	2,300	......	....	..
-20dd	A. Henery............	....	B	14.7	2.5	P	...	N	O	Tca	1.00	2,265	13.72	8-24-48	..
-22ca	F. Lapp..............	1948	Dr	360	4	P	...	F-18	D,S	...	....	2,310	......	7-22-48	..
-28bb	D. R. Salsberry......	1947	Dr	118	6	P	Tfu	Cy,H	D	...	....	2,279	......	....	..
-28bd	W. Birkholz..........	1909	Dr	350	2	P	...	F-1	D,S	...	....	2,315	......	7-22-48	..
-30ca	Albert Rinehart......	....	Dr	......	4	P	...	F-5	D,S	...	....	2,285.21	......	7-12-48	..

Table 7.--Records of wells in lower Yellowstone River valley between Miles City and Glendive, Mont.--Continued

Well number	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Geologic source	Method of lift and type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks
	Custer County--Continued														
10-49-31ba	Alven T. Walker......	....	Dr	......	4	P	...	F	D,S	...	.....	2,284.12	......	....	..
-31bb	Heit............	....	Dr	250	3	P	Tfu	F	D	...	.....	2,288.75	......	....	Ca
-31bd	R. A. Greenfield.....	....	Dr	600	4	P	...	F	D,S	...	.....	2,287.80	......	....	..
-31cb1	....	....	Dr	400	....	P	...	F-20	D,S	...	.....	2,292.09	......	7-12-48	..
-31cb2	....	....	Dr	456	4	P	...	F-3	D	...	.....	2,287.19	......	7-13-48	..
-31cc1	Tindall..........	....	DD	456	4	P	...	F-3	D,S	...	.....	....	......	7-15-48	..
-31cc2	Morton..........	....	Dr	......	4	P	...	F-20	D,S	...	.....	2,285.13	......	7-15-48	..
-32ad	Barrett..........	1910	DD	......	4	P	...	F	D,S	...	.....	2,315	......	....	..
	Dawson County														
13-53-1cc	Jackson..........	....	Dr	650	4	P	...	F	D,S	...	.....	2,208	......	....	..
-10dc1	Edwin Miller.........	1943	Dr	540	7	P	...	F	.....	...	.....	2,210	......	....	Ca
-10dc2	.....do............	1948	Dr	15	2	P	...	....	O	Tca	2.0	2,178.15	10.35	5- 5-48	..
-10dd	....	1948	Dr	15	2	P	...	....	O	Tca	2.0	2,169.11	7.0	5- 5-48	..
-11ca	Wilhelm Siegle.......	....	Dr	772	2	P	...	F	D,S	...	.....	2,194	......	....	Ca
-11cb	....	1948	Dr	15	2	P	...	....	O	Tca	1.73	2,164.31	6.73	5- 5-48	..
-11cc	Wilhelm Siegle.......	1948	Dr	15	2	P	...	....	O	Tca	.48	2,152.25	2.38	5- 5-48	..
-11cd	.....do............	1948	Dr	10	2	P	...	....	O	Tca	1.92	2,148.36	3.32	5- 5-48	..
-11da	John Ginther.........	1943	Dr	41	4	P	Tfu	Cy,E	S	Ls	.....	2,192	8	9-20-48	Ca
-11dc	W. Siegle..........	1948	Dr	15	2	P	...	....	O	Tca	2.05	2,147.70	5.90	5- 5-48	..
-12ab1	....	1943	Dr	40	4	P	Tfu	....	.....	...	.....	2,191	......	....	..
-12ab2	E. Haft............	....	Dr	820	..	P	...	F	D,S	...	.....	2,191	......	....	..
-12ca	Don Bushard.........	....	Du	14	36	P	...	....	.....	...	....	2,192	5.31	9-20-48	..
-14bb	....	1948	Dr	15	2	P	...	....	O	Tca	1.7	2,155.11	4.80	5- 5-48	..
-15aa1	....	1948	Dr	15	2	P	...	....	O	Tca	1.97	2,170.65	6.82	5- 5-48	..
-15aa2	....	1948	Dr	15	2	P	...	....	O	Tca	1.89	2,164.43	3.99	5- 5-48	..

-16ba	....	1943	Dr	61	4	P	Tfu	....	.....	...	....	2,115	......	....	..
-16dc	Jake Roesler.........	....	Dr	56	4	P	Tfu	Cy,H	D,S	Ls	....	2,188	35	9-20-48	..
13-54-6bc	Jake Baxdaum.........	1944	Dr	836	..	P	...	F	D,S	...	....	2,183	......	....	..
14-54-1aa	Mullet...........	1942	Dr	202	4	P	...	Cy,H	D,S	...	....	2,177	20	9-27-48	..
-1ad1	School...............	....	Dr	50	4	P	Tfu	Cy,E	D,S,O	Tca	.6	2,167	18.57	9-27-48	..
-1ad2	B. L. Hansen.........	....	Dr	55	4	P	...	....	D,S	Bp	....	2,174	20	9-27-48	..
-12ab1	....	....	Dr	73	....	P	...	Cy,E	D,S	...	....	2,188	......	....	..
-12ab2	Gilbert Kaul.........	....	Dr	124	3	P	...	Cy,E	D,S	...	....	2,188	......	9-25-48	..
-12ba	John Pust............	....	Dr	102	4	P	...	Cy,E	D,S	Tca	1.4	2,203	39.39	9-25-48	..
-13bb	John Kaul............	....	Dr	228	3	P	...	Cy,E	D,S	Ls	....	2,173	22	9-21-48	..
-13bd	Jacob E. Siegle......	....	Dr	142	4	P	...	Cy,E	D,S	Ls	....	2,160	25	9-21-48	..
-13db	L. Leivestad.........	....	Dr	703	2	P	...	F	D,S	...	....	2,156	......	....	Ca
-14ba	John Neiffer.........	....	Dr	68	4	P	...	Cy,E	D,S	Ls	....	2,190	15	9-21-48	..
-14da	Jake Meitten.........	....	Dr	265	3	P	...	Cy,E	D,S	Ls	....	2,171	9	9-21-48	..
-14dd	....	....	Du	9.9	24	W	...	Cy,H	D,O	Bp	.47	2,164	6.63	9-21-48	..
-23bc	Edwid Schmidt........	....	Dr	373	3	P	...	F	D,S	...	....	2,170	......	....	..
-31ad	Inert Amundson.......	1942	Dr	87	4	P	Tfu	Cy,H	D,S	Tca	.75	2,176	22.5	9-21-48	..
-31cd	Frank Lapp...........	....	Dr	442	2	P	...	F	D,S	...	....	2,198	......	....	..
-32cd	C. C. Kimble.........	....	Du	13.0	48	P	...	Cy,H	D,S	Bp	1.65	2,176	5.88	9-21-48	..
-32dc	John Heimbuch........	....	Dr	415	2	P	...	F	D,S	...	....	2,134	......	....	..
-33ab1	....	1948	Dr	13	2	P	...	....	O	Tca	1.21	2,113.95	2.01	5- 5-48	..
-33ab2	....	1948	Dr	14	2	P	...	....	O	Tca	2.40	2,124.16	4.4	5- 5-48	..
-33ac1	....	1948	Dr	15	2	P	...	....	O	Tca	2.02	2,120.26	7.67	5- 5-48	..
-33ac2	....	1948	Dr	15	2	P	...	....	O	Tca	2.46	2,121.42	7.46	5- 5-48	..
-33ac	G. Diegle............	1948	Dr	15	15	P	...	N	O	Tca	1.27	2,121.01	6.52	5- 5-48	..
-33ba1	....	1948	Dr	13	2	P	...	N	O	Tca	2.68	2,125.93	4.43	5- 5-48	..
-33ba2	....	1948	Dr	15	2	P	...	N	O	Tca	1.33	2,131.17	7.98	5- 5-48	..
-33ba3	R. Diegle............	1948	Dr	15.0	2	P	...	N	O	Tca	1.18	2,132.59	3.18	5- 5-48	..
-33ba4	.....do..............	1948	Dr	25.0	2	P	...	N	O	Tca	1.96	2,137.30	7.71	5- 5-48	..
-33ba5	....	1948	Dr	12.0	2	P	...	N	O	Tca	2.01	2,124.96	4.01	5- 5-48	..
-33bb1	R. Diegle............	1948	Dr	7.5	2	P	...	N	O	Tca	2.28	2,130.78	3.78	5- 5-48	..
-33bb2	.....do..............	1948	Dr	12.0	2	P	...	N	O	Tca	2.04	2,138.24	5.24	5- 5-48	..
-33bc1	.....do..............	1948	Dr	15.0	2	P	...	N	O	Tca	2.10	2,129.46	9.10	5- 5-48	..
-33bc2	.....do..............	1948	Dr	15.0	2	P	...	N	O	Tca	2.00	2,125.19	6.10	5- 5-48	..
-33bc3	.....do..............	1948	Dr	15.0	2	P	...	N	O	Tca	1.70	2,123.51	5.75	5- 5-48	..
-33bd1	.....do..............	1948	Dr	8.0	2	P	...	N	O	Tca	1.76	2,130.99	6.36	5- 5-48	..
-33bd2	.....do..............	1948	Dr	10.0	2	P	...	N	O	Tca	2.00	2,123.26	3.90	5- 5-48	..
-33bd3	.....do..............	1948	Dr	15.0	2	P	...	N	O	Tca	1.91	2,123	4.56	5- 5-48	..
-33ca	Gus Diegle...........	1948	Dr	15.0	2	P	...	N	O	Tca	2.24	2,123.03	7.24	5- 5-48	..
-33cb	.....do..............	1948	Dr	15.0	2	P	...	N	O	Tca	2.04	2,124.67	8.54	5- 5-48	..

Table 7.--Records of wells in lower Yellowstone River valley between Miles City and Glendive, Mont.--Continued

Well number	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Geologic source	Method of lift and type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (-) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks
					Dawson County--Continued										
14-54-33cc	Gus Diegle..........	....	Dr	412	2	P	...	F	S	...	....	2,122	......	....	Ca
14-55-6ab	Nels Tranymo.........	1910	Du	30.0	24	C	...	Cy,E	D,S	Bp	1.2	2,166	10.59	9-25-48	..
-6cb	W. A. Reinart........	1943	Dr	55.0	4	P	...	Cy,H	D,S	Bp	....	2,170	20.0	9-25-48	..
-6dd	Hathaway.........	....	Dn	26.7	1.5	P	...	Cy,H	D,S,O	Bp	1.22	2,139	23.93	9-25-48	..
-7db	Irvin Surd..........	1943	Dr	61	4	P	...	Cy,E	D,S	...	....	2,139	......	....	..
-7dc	Richard Larson.......	....	DD	42.0	....	P	...	Cy,H	D,S	Tca	.65	2,140	7.16	9-25-48	Ca
-18ac	Ensil...........	1942	Dr	61	4	P	...	Cy,E	D,S	...	....	2,141	......	....	..
-18ca	Jake Muller..........	....	Dr	60	4	P	Tfu	Cy,H	D,S	...	....	2,146	......	....	..
15-54-36aa	George Devier........	....	Dr	60	4	P	Tfu	Cy,H	S	...	....	2,175	......	....	..
15-55-5dd	W. Passara..........	....	Dr	23	5	P	...	Cy,E	D,S	...	....	2,115	......	....	..
-16bb	....	....	Du	20.8	6	P	...	Cy,H	D,O	Bp	.4	2,138	6.31	9-27-48	..
-16cb	Jake Denis..........	....	Du	17.4	36	W	...	Cy,H	D,S,O	Bp	1.3	2,137	9.22	9-27-48	..
-19dc	Abandoned...........	....	Dr	20.0	4	P	...	Cy,H	O	Bp	.6	2,145	13.29	9-27-48	..
-19dd	E. Hicks............	1946	Dn	17	1¼	P	...	Cy,E	D,S	...	....	2,138	......	....	..
-20ba	Geo. Finkbinder......	....	Dr	183	4	P	...	Cy,E	D,S	Bp	1.4	2,153	20.0	9-27-48	..
-29ba	H. Middlested........	1942	Dr	61	4	P	...	Cy,E	D,S	...	....	2,154	20.0	9-27-48	..
-30ad	Adam Hass...........	....	Dr	61	4	P	...	Cy,E	D,S	Bp	1.2	2,154	15.0	9-27-48	..
-30dd	Chas. Diefel.........	1942	Dr	192	4	P	...	Cy,E	D,S	Bp	1.7	2,138	11.25	9-27-48	..
-31ad	....	....	Dr	50	4	P	...	Cy,E	D,S	Tca	.9	2,167	18.75	9-27-48	..
-31ca	E. Keene............	1942	Dr	60	4	P	...	Cy,E	D,S	Tco	1.9	2,171	23.20	9-27-48	..
-33ac	H. G. Katzlee........	....	Dr	68	6	P	...	Cy,E	D,S	...	....	2,104	......	9-27-48	..
16-55-33ad	Grant Badley.........	....	Dr	84	5	P	...	Cy,H	D	...	....	2,107	......	9-27-48	..
					Prairie County										
11-49-36da	....	....	Du	18	24	C	...	Cy,H	D	...	....	....	......	....	Ca

11-50-3bd	S. S. Poabroy........	....	B	60	6	P	Tfu	Cy,H	D	Tca	.5	2,223.20	30.0	7-26-48	..
-17ac	Art Martin...........	....	Du	21	36	W	...	Cy,H	D,S,O	Tca	1.08	2,249	11.13	8-26-48	..
-30aa	Ray Gaffield.........	....	Du	13.5	36	W	...	Cy,H	S,O	Tca	2.1	2,246	11.23	8- 2-48	..
-30dd	G. G. Kalfell........	1902	..	321	3	P	...	N	D,S	...	....	2,310.1	32	7-26-48	..
-31bb	Northern Pacific R.R.	1947	Dr	151	6	P	Tfu	N	D	...	2.0	2,253	150	7-26-48	..
12-50-24bd	Fred Stickel.........	1947	Dr	1180	2	P	...	N	.....	Tca	.5	....	1.35	7-27-48	..
12-51-3dc	Unknown..............	....	Dr	67.6	4	P	Tfu	N	O	Tca	1.84	2,264.17	9.41	9- 1-48	..
-10bc	Robert Brag..........	....	Dr	......	2	P	...	N	D,S	...	....	2,200	......	....	..
-14ca	Albert Raihl.........	....	Dr	55	6	P	Tfu	Cy,H	D	...	....	2,215	55	8-27-48	..
-16ac	Lee Hubing...........	1948	Dr	26.03	6	P	...	Cy,E	D,S,O	Tca	-6.6	2,243.87	13.89	8-26-48	Ca
-16cb1	G. O. Malvern........	1948	Dr	30	4	P	...	Cy,E	D	...	....	2,250.74	30	7-28-48	..
-16cb2	J. Young.............	....	Du	11.9	2	P	...	N	O	Tca	.63	2,250.83	11.56	8-26-48	..
-16cb3	A. Braun.............	1947	Dn	21.8	2	P	...	P	D	Tca	2.4	2,052.44	17.46	7-28-48	..
-16cb4	David Covert.........	1948	Dn	21	2	P	...	Cy,E	D	...	....	2,245	15.5	7-28-48	..
-16cb5	O. W. Boyde..........	1948	Dn	23	2	P	...	Cy,E	D	...	....	2,245	......	....	..
-16cc1	A. Speidal...........	1937	Dn	22	2	P	...	Cy,H	D	...	....	2,253.20	......	....	..
-16cc2	Canop............	1941	Dn	22	2	P	...	Cy,E	D	...	....	2,256	......	....	..
-16cc3	H. McColley..........	1942	Dn	18	2	P	...	Cy,H	D	...	....	2,253	......	....	..
-16cc4	M. Flege.............	1940	Dn	25	2	P	...	Cy,H	D	...	....	2,255	......	....	..
-16cc5	S. Elhard............	1943	Dn	23	2	P	...	Cy,H	D	...	....	2,256	......	....	..
-16cd1	City of Terry........	1932	Dr	708	2	P	...	F	In	...	....	2,255	......	....	Ca
-16cd2	George Dickson.......	1948	Dr	47.2	6	P	Tfu	Cy,E	D,O	Tca	.4	2,255.73	20.97	8-26-48	..
-16da	Donald Bennett.......	1947	Du	23	1¼	P	...	Cy,E	D	...	....	2,244	......	....	..
-16db	C. W. Conner.........	1928	Dn	24.7	1¼	P	...	Cy,H	S	...	....	2,251	......	....	..
-16dc	H. C. Stith..........	1943	Dn	27.3	2	P	...	N	O	Tca	.3	2,256.22	20.50	7-28-48	..
-17dc	Harold Meidinger.....	1948	Dn	18	1½	P	...	Cy,H	D	...	....	2,251	17.5	8-19-48	..
-21ab	Kate Warner..........	1948	Dr	42.6	6	P	Tfu	....	D,O	Ls	.0	2,256.25	22.78	8-26-48	..
-21da	City of Terry........	....	Du	23.8	96	P	...	Cy,E	I	Tco	.5	2,253.72	19.6	6-30-48	..
-24bb	A. Hess..............	1947	Dn	43	1½	P	Tfu	Cy,H	D,S	Ls	....	2,261	27	8-27-48	..
12-52-1ac	Henry Schwartz.......	1936	Du	29	39	C	...	Cy,H	D,I,O	Tco	.65	2,212	26.5	8-31-48	..
-1ad	A. Schwartz..........	....	Du	33.4	31	C	...	Cy,H	D,S,I,O	Tco	.93	2,221	32.05	8-31-48	..
-2aa	J. C. Wheeler........	1900	Du	22	48	C	...	Cy,W	D,S,O	Tcu	.1	2,227.3	19.24	8- 2-48	..
-9ab	A. Shott.............	1933	Dr	63	6	P	Tfu	Cy,W	S	Tca	....	....	......	....	..
-9ac	.....do..............	1944	Dr	350	6	P	...	F	S	Ls	....	....	......	....	..
12-53-16ac	Fred Siegle..........	....	Dr	54	4	P	Tfu	Cy,E	D	...	....	2,196	......	....	..
13-52-24dd	H. Lapp..............	1942	Dr	55	4	P	Tfu	Cy,E	D,S	...	....	2,201	......	9-20-48	..
-25ad	McClellan........	1942	Dr	60	6	P	Tfu	Cy,E	D,S	Tca	1.27	2,202	42.60	9-20-48	..
-34ac1	Henry Neumiller......	1947	Du	20	4	P	...	Cy,H	D,S	Tca	1.0	2,202	18	8-28-48	..
-34ac2	....	....	Du	24.2	24	C	...	Cy,H	D,O	Bp	.43	2,204.5	19.36	8- 2-48	..
-34ac3	Rev. H. G. Schuler...	1946	Du	15.4	6	C	...	Cy,E	D,I,O	Tca	....	2,206.5	13.58	8-31-48	..

Table 7.--Records of wells in lower Yellowstone River valley between Miles City and Glendive, Mont.--Continued

Well number	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Geologic source	Method of lift and type of power	Use of water	Measuring point			Depth to water level below measuring point (feet)	Date of measurement	Remarks
										Description	Distance above or below (-) land surface (feet)	Height above mean sea level (feet)			
				Prairie County--Continued											
13-52-34ac4	David Caphart........	1945	Du	19	36	C	...	Cy,E	D,S,I,O	Tca	0.82	2,205	17.36	8-27-48	..
-34ad1	Congregational Church	1948	Du	17.4	24	C	...	Cy,E	D,O	Tca	.26	2,206	16.18	8-31-48	..
-34ad2	John Kessler.........	....	Du	20.3	24	C	...	.....	D,S,O	Tca	1.16	2,206	16.97	8-28-48	..
-34bd	August Fisher........	....	Du	23.2	24	W	...	Cy,E	I,O	Bp	.2	2,227.3	18.44	8-27-48	..
-34ea1	John Middlestaedt....	....	Du	21.8	36	C	...	Cy,H	D,I,O	Tca	.45	2,238.6	18.74	8-27-48	..
-34ca2	Hoffer...........	....	Du	17	24	C	...	Cy,W	O	Tca	1.13	2,227.3	16.26	8-27-48	Ca
-34cb	H. C. Gifford........	....	Du	19.9	30	C	...	Cy,H	D,O	Ls	....	2,225.3	17.74	8-27-48	..
-34da	Fred Kaul, Sr........	....	Du	19.7	30	C	...	Cy,H	D,S,O	Tca	.5	2,205.5	17.50	8-28-48	..
-34db1	Ebeling..........	....	Du	22.5	33	C	...	Cy,E	D,I,O	Tca	.23	2,204.7	19.48	8-31-48	..
-34db2	Christopp........	1944	Du	22.8	36	C	...	Cy,H	D,I,O	Tco	.82	2,205	20.55	8-31-48	..
13-53-7db1	Kirkpatrick......	....	Dr	47.7	6	P	Tfu	Cy,W	D,I,S	Tca	.53	2,310.75	33.76	9- 3-48	..
-7db2	.....do..............	....	Dr	39.6	3	P	Tfu	....	O	Tca	.45	2,312.45	31.10	9- 3-48	..
-17ba	Ralph Frost..........	....	Dr	60	4	P	Tfu	Cy,E	D,S	Tca	.44	2,215	30.0	9- 3-48	..
-20ab	....	1942	Dr	81	4	P	Tfu	....	....	...	....	2,207	......	9-20-48	..
-20cb	Hess.............	....	Dr	62	4	P	Tfu	Cy,H	D,S	Tca	.31	2,215	34.5	9-20-48	..
-30ab	Ralph Frost..........	....	Dr	48.8	4	P	Tfu	Cy,H	D,O	Tca	.44	2,203	22.90	9-20-48	..
-30bb	Wayne Waldo..........	....	Dr	55	4	P	Tfu	Cy,E	D,S	Tca	.61	2,201	17.17	9-20-48	..