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GEOLOGY AND GROUND-WATER RESOURCES OF THE TWO MEDICINE IRRIGATION UNIT AND ADJACENT AREAS, BLACKFEET INDIAN RESERVATION, MONTANA

by

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With a section on
Chemical Quality of Water

by

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

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Abstract

The Two Medicine Irrigation Unit, on the Blackfeet Indian Reservation of northern Montana, is irrigated by water diverted from Two Medicine Creek. Waterlogging because of overapplication of water and locally inadequate subsurface drainage is a serious problem. This study was undertaken by the U.S. Geological Survey in cooperation with the U.S. Bureau of Indian Affairs to evaluate the problem and to suggest remedies.

For this study, the geology was mapped, and data concerning 129 wells and test holes were gathered. The water level in 63 wells was measured periodically. Three test holes were drilled and 4 single-well and 1 multiple-well pump tests were made. Nineteen samples of ground water were collected and analyzed chemically, and applied irrigation water was analyzed periodically.

The project area is underlain by more than 300 feet of soft shale and sandstone comprising the Two Medicine Formation of Late Cretaceous age. This formation and the underlying Virgelle Sandstone of Late Cretaceous age are the only bedrock aquifers of economic importance in the project area, and they commonly yield enough water for domestic and stock use. The Two Medicine Formation is not permeable enough to provide adequate subdrainage of irrigated land; where the formation is exposed, or is under a thin mantle of slope wash, adequate drainage for successful irrigation farming cannot be developed. Land on the northern edge of the project fits into this category.

Unconsolidated deposits of sand, gravel, clay, and glacial till mantle the bedrock throughout much of the area. Of these, only stream alluvium and terrace deposits composed of sand and gravel are aquifers, and they underlie most of the irrigated land. The Seville Bench is the largest surface underlain by terrace deposits and makes up most of the irrigated acreage. Waterlogging is less serious on the Seville Bench than on other parts of the unit but it is, nevertheless, a problem. Tests of several wells on Seville Bench indicate that the coefficient of transmissibility of the underlying gravel beds ranges from 2,800 to 3,200 gallons per day per foot. Only about 125 gallons per minute of water is now (1957) moving under the bench at a rate of about half a foot per day. Thus the amount of water removed would not have to be great to improve the drainage many fold.

Canal leakage, downward percolation of applied irrigation water, and precipitation are the principal sources of water causing the waterlogging.

The concentration of dissolved solids in ground water from the Virgelle Sandstone, Two Medicine Formation, terrace deposits, and alluvium ranges from about 200 to 1,500 parts per million. The water is very hard, is of the magnesium bicarbonate or sodium bicarbonate type, and is generally suitable for domestic use. Water from some wells had more than 0.5 part per million iron and more than 20 parts per million nitrate.

Water supplied by the Two Medicine Canal is of the calcium bicarbonate type, commonly contains less than 100 parts per million dissolved solids, and is suitable for irrigation. Water draining from irrigated land is 10 to 30 times as mineralized as the applied irrigation water and is of the sodium sulfate-bicarbonate type. Return flows from the irrigated land only slightly affect the chemical quality of water in Cut Bank Creek upstream from the mouth of Spring Creek.

Introduction

Location and extent of area

The area described in this report is the east central part of the Blackfeet Indian Reservation in Glacier County in northwestern Montana. (See fig. 1.) Cut Bank Creek bounds the area on the north and east, and arbitrary boundaries were selected on the south and west. The ground-water geology of about 150 square miles is described. The Two Medicine Irrigation Unit, constructed by the U.S. Bureau of Indian Affairs, now includes about 50 square miles, and additional irrigation has been proposed. No municipalities are in the area, but Cut Bank (population 4,539 in 1960) is just to the east across Cut Bank Creek.

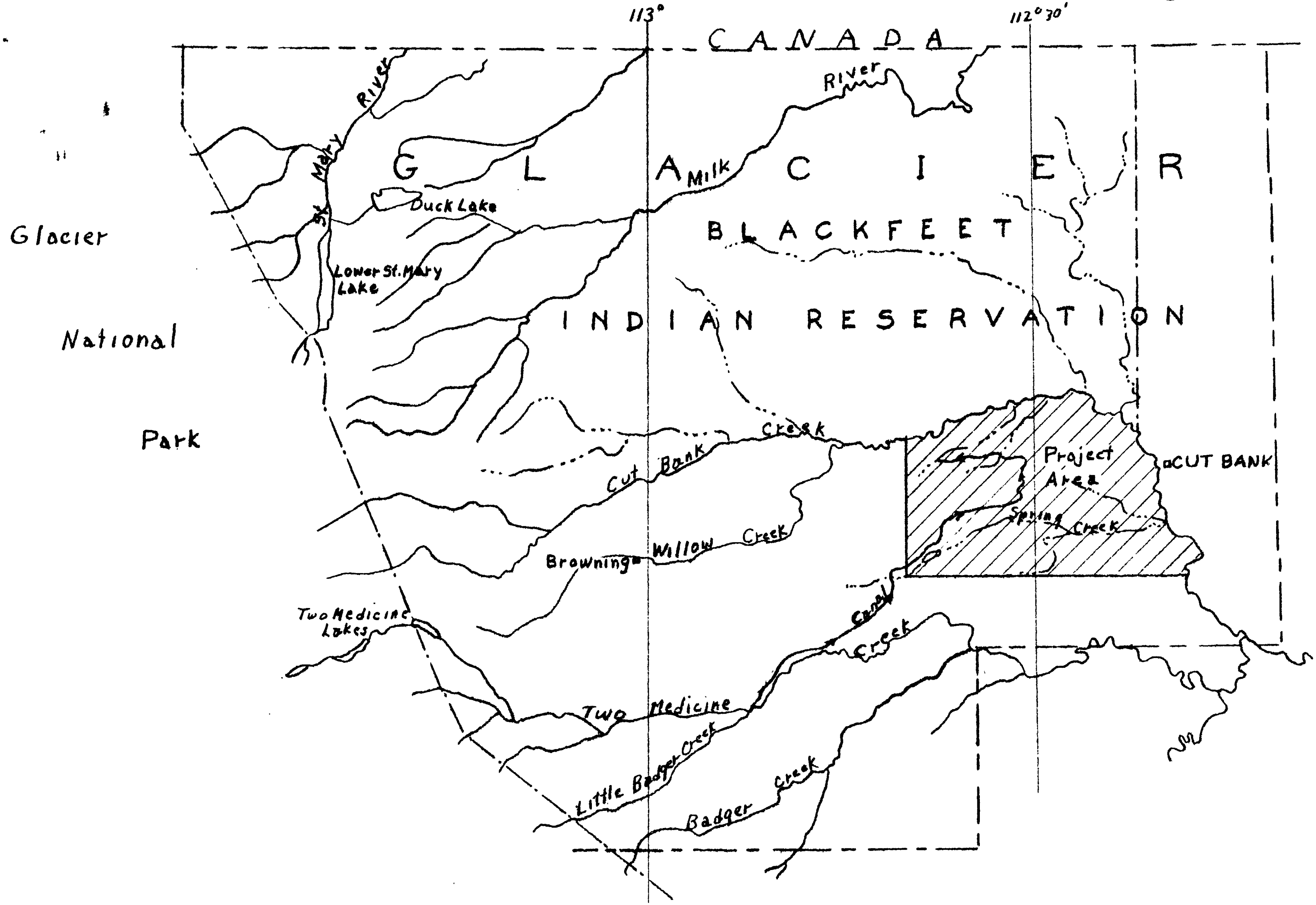

Figure 1.--Map showing location of project area.

Purpose and scope of the investigation

This report is the result of one of several ground-water studies made by the Geological Survey as part of the investigational program of the U.S. Department of the Interior for development of the land and water resources of the Missouri River Basin. The ground-water investigation, upon which this report is based, was designed to determine the geologic and hydrologic factors that influence drainage of the Two Medicine Irrigation Unit. The investigation was extended to adjacent land so that data would be available regarding the geology and ground-water hydrology of land proposed for irrigation.

During the course of the investigation, all pertinent available data were obtained on 129 wells in the area. The water level in 63 wells was measured periodically. The surficial and bedrock geology were mapped on aerial photographs and later transferred to a map. Altitudes of selected wells and geologic features were determined by spirit level or altimeter. Chemical analyses were made of 19 samples of water from 15 representative wells. A total of 24 water samples were collected at about weekly intervals from the Two Medicine Canal during the 1955 and 1956 irrigation season to determine the quality of water delivered to the unit. Twenty-three samples of water were collected for chemical analysis at 11 sites on creeks, lakes, and drains in the project area. The fieldwork upon which this report is based was done mainly during the summer and fall of 1956. Additional fieldwork was done during the spring and summer of 1957.

Previous investigations and acknowledgments

Alden (1932) described the area in his report on the physiography and glacial geology of Montana east of the Continental Divide. The stratigraphy and structure of the area have been described by Erdmann, Beer, and Nordquist (1946) and Cobban (1955). These reports were of great help in the preparation of this report.

The Soil Conservation Service of the U.S. Department of Agriculture studied drainage conditions in 3,400 acres of the Two Medicine Unit during the period 1953-54 (Long and others, 1954). Twenty-five cased auger holes were installed and the water level in them was measured 12 to 15 times between May 1953 and February 1954. These and other data were made available for study in preparation of this report.

The cooperation extended by the residents of the area greatly facilitated the investigation. The writers are grateful for the assistance and cooperation given them by personnel of the Bureau of Indian Affairs at Browning and Billings and by the Two Medicine Water User's Association at Cut Bank.

Site-numbering system

The wells and other sites listed in this report are numbered according to their location within the U.S. Bureau of Land Management's survey of the area. (See fig. 2.) The first numeral of the well or site number denotes the township; the second, the range; and the third, the section in which the well or other site is located. Lowercase letters following the section number show the location of the well or site within the section. The first letter indicates the quarter section, the second, the quarter-quarter section, and the third, the quarter-quarter-quarter section. These subdivisions of the section are lettered a, b, c, and d in a counterclockwise direction, beginning with the northeast quarter section. If two or more wells or sites are located within the same quarter-quarter-quarter section (10-acre tract) they are distinguished by numerals following the lowercase letters.

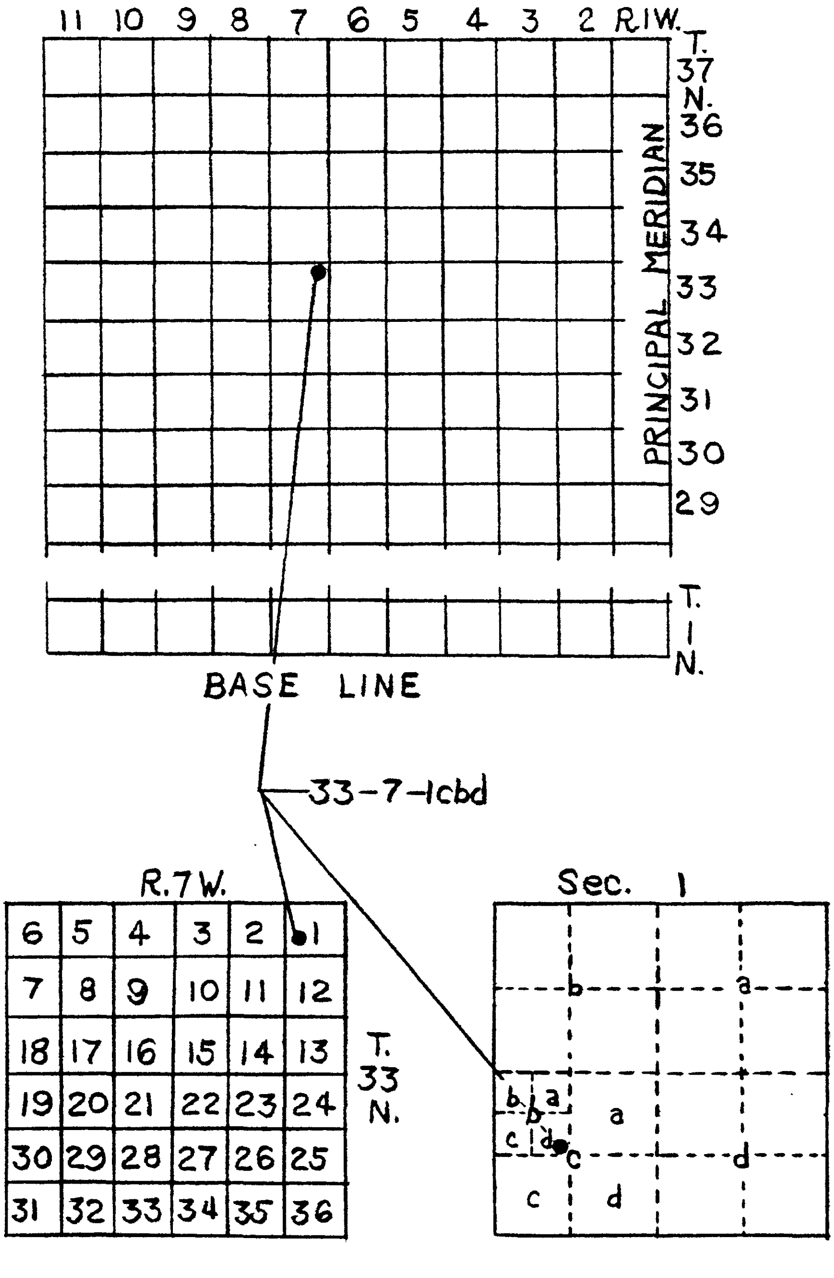

Figure 2-- Site-numbering system.

Geography

Climate

The area described in this report has a semiarid continental type climate. Abundant sunshine, low relative humidity, light precipitation, moderate to high wind movement, and wide diurnal and great seasonal variations in temperature characterize the climate. The prevailing wind is from the west. The high mountains to the west trap much of the moisture moving in from the Pacific Ocean, which accounts for the low precipitation.

The U.S. Weather Bureau has compiled weather records at Cut Bank since 1908, and a continuous record is available except for the years 1908 and 1917. The average annual precipitation from 1909 to 1955 inclusive is 11.50 inches. The maximum annual precipitation recorded was 20.99 inches in 1927, and the minimum was 5.36 inches in 1935.

Normally, about half the annual precipitation falls during May, June, and July. These months are the main growing season and the concentration of rainfall during these months is very favorable for agriculture. The normal monthly distribution of precipitation at Cut Bank is shown in figure 3. Although the average precipitation during the growing season is nearly 6 inches, radical departures from the average are common. Precipitation during these three months in 1956 totaled 10.77 inches, more than 90 percent of the average annual precipitation. However, in 1919 it was only 1.02 inches, and during the drought 1917-22 it averaged 3.4 inches.

Temperature extremes are great. Temperatures of more than 100°F have been recorded in the summers, and -30°, or colder is common in the winter. The average frost-free season is 116 days. The average dates for first and last killing frosts at Cut Bank are September 17 and May 23.

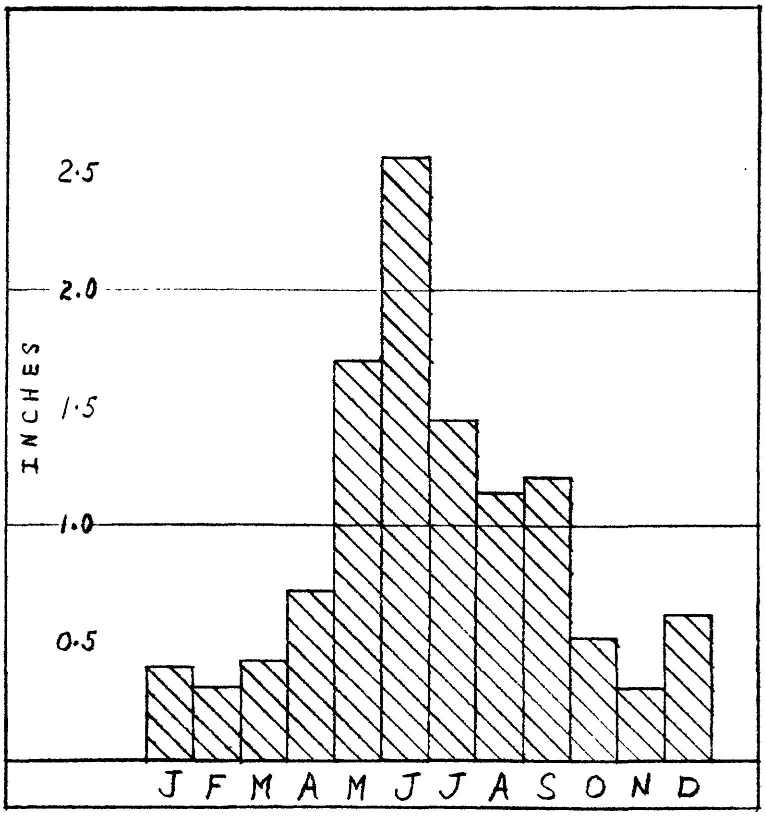

Figure 3.--Normal monthly distribution of precipitation at Cut Bank.

Agriculture and industry

Most people in the project area are engaged in farming and ranching. Small grains and hay are the principal crops raised. Large acreages are used for pasture, some of which are irrigated.

In a few places in the Two Medicine Unit the productivity of the cultivated lands has been adversely affected by an excessively high water table. Some of these areas have alkali salts at the surface and much of the land with a high water table is used only for pasture.

Much of the flat to gently rolling land west of the Two Medicine Irrigation Unit is used for raising dryland grain, and summer fallow and strip cropping are practiced extensively.

Many cattle and sheep are raised on land unsuited for cultivation. Much of the hay and some of the small grains raised on the irrigated land is fed to stock locally. The largest sheep ranches are north and west of the study area, but they depend to a large extent upon feed raised on the irrigation project for winter needs.

The Cut Bank oil and gas field is mainly east of the project area, but part of the field extends into the southeast corner. This field was Montana's largest producer between 1935 and 1956. Most of the oil and gas comes from sandstone reservoirs in the Lower Cretaceous Kootenai Formation, but some comes from the upper part of the Upper and Lower Mississippian Madison Group. Since 1950, more than two million barrels of oil has been produced annually. From 1929 to 1962, 93,322,000 barrels of oil was produced. (Mont. Oil and Gas Commission, 1961, p. 43.)

Irrigation

Most of the Two Medicine Irrigation Unit facilities were built between 1907 and 1909 to provide the Blackfeet Indian Tribe with irrigated land on which to "***raise forage and grain crops to supplement their grazing lands" (Savage, 1910, p. 3).

The Two Medicine Irrigation Unit includes 22,500 acres of irrigable land, mostly on Seville Bench. The Two Medicine canal is 32 miles long, of which 17 miles are in the irrigation unit. About 170 miles of laterals distribute the water.

The water supply for the irrigation project is obtained by diverting part of the flow of Two Medicine Creek 14 miles southwest of Spring Lake. Two Medicine Creek originates at the lower end of a chain of lakes, Lower, Middle, and Upper Two Medicine Lakes, in the southeastern part of Glacier National Park. A dam across the outlet of Lower Two Medicine Lake maintains an adequate supply of water in the lake to be used during drought.

The main canal was designed for a capacity of 142 cfs (cubic feet per second), but generally the flow is considerably less (Savage, 1910, p. 10). Figure 4 shows the quantities of water delivered through the main canal, and the quantities diverted for irrigation during the 1956 irrigation season. At least twice as much water was usually diverted as was being used.

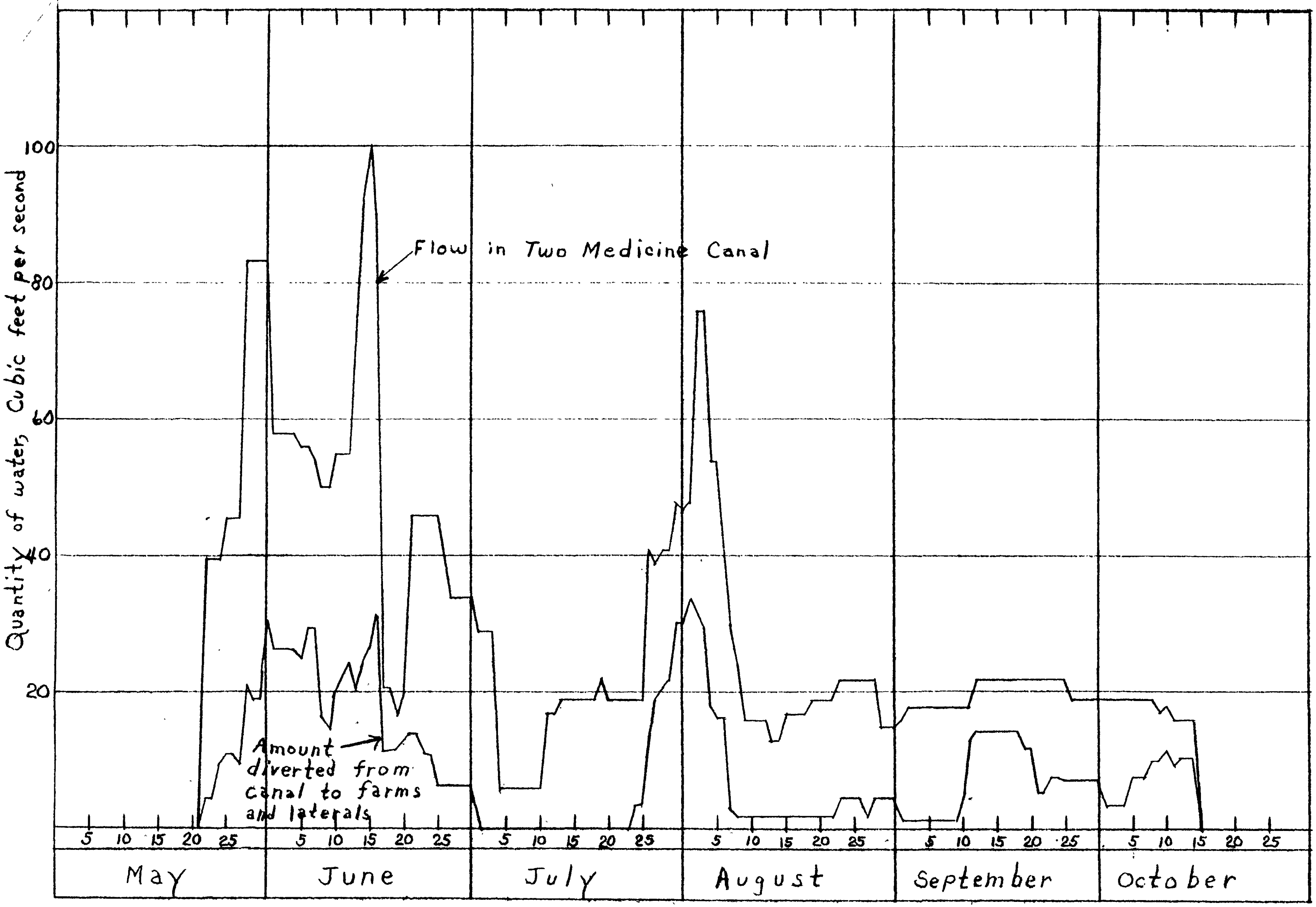

Figure 4.--Graph showing quantities of water carried in Two Medicine canal, and quantities diverted for irrigation. (Data from irrigation records, 1956, Bureau of Indian Affairs, Browning, Montana.)

The irrigation season generally extends from mid-May to mid-October. The largest amounts of water are applied early in the growing season, usually in June. Large amounts also are applied later in the season for second cuttings of forage crops, and for general pasture improvement. Irrigation water is applied mainly by controlled flooding methods from field ditches. In places, particularly where forage crops are grown, uncontrolled flooding is used. The field ditches generally are spaced 100 to 300 feet apart, and, where topographic relief is appreciable, the ditches follow the contours of the land.

Physiography

The Two Medicine Irrigation Unit is in the glaciated Missouri Plateau Section of the Great Plains Physiographic Province (Fenneman, 1931).

The most prominent physiographic features are a series of stream terraces elongated in an east-west direction. They lie 10 to 600 feet above the streams, are relatively flat, and slope toward the east at 15 to 20 feet per mile. The six mappable terraces are numbered from 1 to 6 in order of increasing height above the streams. (See fig. 5.) The four highest terraces form divides between the eastward-flowing streams.

The highest terrace remnants are near Squaw Buttes at the south edge of the area. Much of the Squaw Buttes upland is mantled by glacial drift, but remnants of terraces, numbers 6 and 5, extend from the bottom of the drift along the north edge of the upland. The altitude of the westernmost mapped remnant of the higher and older terrace (number 6) is 4,200 feet, 100 to 150 feet higher than the next lower terrace (number 5). Both terraces are older than the glacial drift, which mantles them to the west and south.

From Squaw Buttes northward, the topography is characteristically steplike. The terraces form relatively flat-topped treads, whereas the intervening areas of bedrock are in valleys or risers between the terraces. The most extensive terraces are numbers 4 and 5 which are known locally as the Seville Bench. Much of the irrigated land lies on these terraces.

The Seville Bench slopes east-northeastward at an average gradient of 20 feet per mile from an altitude of 4,100 feet near its western edge to 3,800 feet near its eastern edge. On the north and south, the Seville Bench is bounded by an escarpment.

Cut Bank Creek was shifted from its channel in several places in the eastern part of the area. The most conspicuous former courses are in secs. 11 and 14 and secs. 25 and 26, T. 33 N., R. 6 W. Rejuvenation of drainage indicates that there have been other major drainage changes beyond the project area.

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Table 2.--Generalized section of the stratigraphic units and their water-bearing characteristics

System	Series	Stratigraphic unit	Thickness (feet)	Physical characteristics	Water supply
Quaternary	Recent	Alluvium	0-25	Mainly clay, silt, and sand. Lenses of sand and gravel 5-10 feet thick in valley of Cut Bank Creek.	In valley of Cut Bank Creek, may yield moderate quantities of water to wells.
	Pleistocene	Terrace deposit number one and two	5-15	Mainly sand and gravel, lenticular.	Yields small quantities for domestic and farm uses in Spring Creek valley.
		End moraine	1-30	Till, containing many quartzite and argillite rock fragments.	Not known to yield water to wells.
		Glacial drift undifferentiated	10-150	Clayey fill with granitic and limestone fragments, stratified silt and sand, laminated clay, and very coarse gravel.	Not known to yield water to wells.
		Terrace deposit number three	5-10	Gravel derived from Belt rocks.	Not known to yield water to wells.
		Terrace deposit number four and five	10-40	Where exposed consists of two units; upper clay-silt unit and lower gravel unit.	Yields water to large number of wells on Seville Bench. Well yields range from 5 to 25 gpm.
		Terrace deposit number six	5-20	Mostly gravel derived from Belt rocks.	Probably not water-bearing.
Cretaceous	Upper Cretaceous	Two Medicine Formation	300-1,300	Mostly sandy shale and mudstone with thin beds of sandstone; lower 250 feet is mostly massive fine-grained sandstone.	Yields water nearly everywhere, largest yields obtainable from sandstone in lower 250 feet of formation.
		Virgelle Sandstone	160±	Fine to medium-grained sandstone, light-colored.	Probably yields water to deepest wells in eastern part of area.

Geology

The only bedrock exposed in the study area is the Two Medicine Formation of Late Cretaceous age. (See fig. 5 in pocket.) The bedrock dips about 100 feet per mile toward the west. At least 7,800 feet of sedimentary rocks underlie the Two Medicine Formation (Erdmann and others, 1946), but only the Two Medicine Formation and the underlying Upper Cretaceous Virgelle Sandstone are fresh-water aquifers.

Unconsolidated deposits of sand, gravel, clay, and till mantle the bedrock throughout much of the area. They were differentiated, on the basis of their lithology and mode of deposition, into the following units: stream alluvium and terrace deposits, end moraine deposited by piedmont glaciers, and undifferentiated drift deposited by the continental ice sheet. The unconsolidated deposits range in age from Pleistocene to Recent. (See table 2.)

Logs of 42 wells, test holes, and seismograph shot holes given in table 3 at the end of this report show the character of the materials penetrated.

Cretaceous System (Upper Cretaceous Series)

Virgelle Sandstone

The Virgelle Sandstone underlies the entire study area, at depths ranging from about 300 feet in the eastern part to 1,300 feet in the western part, but it is not exposed. It is well exposed in a prominent eastward-facing escarpment a few miles east of Cut Bank and in the gorge of Cut Bank Creek 2 miles downstream from the project area. The Virgelle Sandstone is about 160 feet thick, and Cobban (1955, p. 115) described it as being "*** light-gray to whitish, fine- to medium-grained, arkosic, and somewhat calcareous." It is an economically important aquifer in other parts of Montana and should yield substantial quantities of water to wells in the study area.

Two Medicine Formation

The Two Medicine Formation, which immediately underlies the unconsolidated deposits, ranges in thickness from about 300 feet in the eastern part to 1,300 feet in the western part of the area. It consists of gray to greenish-gray soft shale and sandstone and occasional thin beds of darker colored carbonaceous shale and mudstone. The lower 250 feet of the formation contains much more sandstone than the remainder of the formation and may be in part equivalent with the upper part of the Upper Cretaceous Eagle Sandstone of nearby areas. Sandstone beds also are present in the upper parts of the formation but are thinner and more lenticular than those in the lower part. In most places the sandstone is fine grained and calcareous. The Two Medicine Formation is almost entirely nonmarine and "*** contains dinosaur and other bones, scales of ganoid fishes, ostracods, and fresh-water mollusks" (Cobban, 1955, p. 116).

Quaternary System (Pleistocene and Recent Series)

Stream-built terraces are conspicuous physiographic features throughout the area. Six terraces designated numbers 1 through 6, from youngest to oldest, have been mapped. The sand and gravel deposits underlying the terraces form aquifers of different economic importance, depending on their areal extent, thickness, permeability, and availability of recharge.

Terrace deposit number six

The sixth terrace, highest and oldest in the area, is restricted to the Squaw Buttes in the extreme southern part of the area. The remnants of this terrace are about 600 feet above the level of Cut Bank Creek to the east and about 100 feet higher than the next lower terrace.

The deposit that underlies the sixth terrace is composed largely of pebble- to cobble-size gravel and minor amounts of sand and has a maximum thickness of 20 feet. The cobbles are subrounded and consist mainly of red and green quartzite and argillite and minor amounts of limestone. The surface of the limestone fragments have marked etching and solution patterns, and the relative amount of limestone in the deposits probably has been reduced by leaching since deposition. The quartzite, argillite, and limestone fragments in the terrace deposit were derived largely from rocks of the Belt Series, which crop out extensively in the mountains to the west.

Terrace deposit number five

The fifth terrace, the Seville Bench, is the most extensive terrace in the project area. The main remnant of this terrace is 15 miles long and as much as 4 miles wide. Much of the land served by the Two Medicine irrigation system is on the eastern part of the fifth terrace. The western part is used for raising small grain by dry-farming methods. The terrace is underlain by as much as 40 feet of unconsolidated materials.

The terrace deposit consists of a lower layer, composed of coarse gravel mixed with finer grained materials, and an upper layer, composed of clay, silt, and scattered pebbles and cobbles. In places the upper 2 to 5 feet of the terrace deposit has been deformed, probably by frost action.

Terrace deposit number four

The fourth terrace, which is rather extensive along the southern edge of the Seville Bench, seems to have been carved from part of the fifth terrace. Remnants of this terrace were observed nowhere else in the area studied. This terrace is only about 15 feet lower than the fifth terrace and it may have been eroded by melt-water streams which existed only for a relatively short time. Stream gravel deposits, which range from a few to possibly 40 feet in thickness underlie the fourth terrace.

Terrace deposit number three

Remnants of the third terrace are mainly located along the south side of the valley of Spring Creek, but some remnants are present along Cut Bank Creek. This terrace is about 50 feet lower than the fourth terrace. Deposits beneath it consist of 5 to 10 feet of moderately well-sorted pebbles of argillite and quartzite.

End moraine

About 12 square miles of end moraine was mapped in the southwestern part of the study area. According to Alden (1932, p. 106) a piedmont glacier named the Two Medicine Glacier formed these deposits in early Wisconsin time. The end moraine consists in most places of about 30 feet of glacial till, a heterogeneous mixture of rock fragments ranging in size from clay to boulders, and mantles terraces 5 and 6 and bedrock. The glacier diverted Two Medicine Creek to the south, and the end moraine blocked its former valley, which is now occupied by Spring Lake and Spring Creek. The relation of the end moraine to remnants of the third terrace indicates that the glacial deposits were formed after development of the third terrace and before the lower terraces were formed.

Glacial drift undifferentiated

About 10 square miles of undifferentiated glacial drift was mapped in the southeast corner of the area. A continental ice sheet, which came from the north and east, deposited the glacial drift. Granitic rocks in the dark-brown clayey till distinguishes it from till deposited by the piedmont glaciers from the west. Lacustrine and glaciofluvial sediments and some ice-rafted boulders are associated with the glacial drift. Lacustrine sediments underlie the till in places and fill, or partly fill, stream channels cut into bedrock. They consist of light-buff silt and dark-brown clay and are in part varved, indicating seasonal variations in deposition.

Alden (1932, p. 105-106) discussed the relation and age of the continental and piedmont glaciers. He assigned an early Wisconsin age to the deposits of both ice sheets. The lacustrine deposits were formed when the advancing continental ice sheet blocked drainage from the area. Glacial Lake Cut Bank, as it was called by Alden, became extensive and, at its highest level, reached an altitude of almost 4,000 feet. At this altitude it covered much of the study area. Granitic pebbles and boulders observed on the third, fourth, and fifth terraces probably were dropped from icebergs floating on this lake. The fact that granitic cobbles have not been found on the lower two terraces and that remnants of these terraces are preserved on the surface of the undifferentiated glacial drift, proves that the advance of the ice sheets antedates the second terrace.

Terrace deposit number two

Remnants of the second terrace are rather extensive in the valleys of Cut Bank and Spring Creeks. This terrace is about 90 feet lower than the third terrace. The deposit underlying the second terrace consists of 5 to 15 feet of gravel mixed with finer materials and overlain by 5 to 8 feet of fairly well-sorted sand. This deposit is probably, in part, outwash material derived from glaciers to the west.

Terrace deposit number one

The lowest stream terrace is not as extensive as the higher terraces, but small parts of it remain in the valleys of both Spring and Cut Bank Creeks. The first terrace is 20 to 40 feet below the second terrace. Its height above Cut Bank Creek ranges from 10 to 15 feet in the northwestern part of the area to about 110 feet in the southeastern part. This marked change in gradient between the stream that formed the terrace and the present drainage probably is related to Pleistocene drainage changes which caused rejuvenation of Cut Bank Creek. The deposit underlying the first terrace consists of 5 to 15 feet of sand and gravel.

Alluvium

Recent alluvium, ranging in thickness from 0 to 25 feet, underlies the flood plain of Cut Bank Creek and its principal tributaries. The deposits are most extensive in the valley of Cut Bank Creek above sec. 20, T. 34 N., R. 6 W., where the creek turns abruptly to the south. In this reach the alluvium is coarse, and several gravel pits are in operation. Elsewhere, the alluvial deposits are more heterogeneous and consist largely of clay- to cobble-sized fragments.

Surface water

Cut Bank Creek drains about 971 square miles upstream from the gaging station near Cut Bank. At its confluence with Two Medicine Creek, 12 miles south of Cut Bank, the combined streams form the Marias River.

Records of flow in Cut Bank Creek are short-term and intermittent, but the data available indicate that the flow of the stream is subject to large fluctuations. Minimum flows of 5 cfs were recorded in late November 1905 and December 1954. The maximum flow of 8,810 cfs was recorded on June 5, 1908 (U.S. Geological Survey Water Supply Paper 1389). The largest discharges usually are in June, when the most snow melts in the mountains, and when rainfall is greatest. The minimum flows usually are in the winter, when the flow is sustained almost entirely by ground-water discharge.

Spring Creek and Caddis Creek (name adopted for use in this report) are the main tributaries to Cut Bank Creek within the project area. Spring Creek flows from springs in the swampy valley east of Spring Lake. At times, water is diverted from the Two Medicine Canal into the west end of the lake, and as much as 15 cfs flows into Spring Creek.

Caddis Creek and the numerous smaller creeks in the area usually flow only during the irrigation season and for short periods after intense rainfall or rapid snowmelt. Generally, the flow in each of these creeks is less than 0.5 cfs.

Ground water

General concepts of occurrence

Almost all ground water is originally derived from precipitation. Water may enter the ground by downward percolation of rain, melted snow, and applied irrigation water, or by downward or lateral percolation from streams or ditches in which the water is above the ground-water level.

Virtually all ground water is moving from places of intake or recharge to places of discharge. The rate of movement may differ considerably from one area to another, but velocities of a few tens to a few hundreds of feet per year probably are most common under natural conditions.

Ground water may be discharged from an area by underflow into other areas, by direct evaporation from the ground surface, by plant transpiration, by pumping or flowing from wells and springs, and by seepage to streams, lakes, and ponds.

Any rock formation or stratum that will yield water in sufficient quantity to be of importance as a source of supply is called an aquifer (Meinzer, 1923, p. 52). The water moving through an aquifer from recharge areas to discharge areas may be thought of as being in transient storage in the ground. The amount of water that can be thus stored in an aquifer depends on the porosity of the material (ratio of volume of rock openings to the total volume of the rock, expressed as a percentage), and the volume of the aquifer. Unconsolidated deposits such as clay, sand, and gravel are generally more porous than consolidated deposits such as shale, sandstone, and limestone. The capacity of a rock formation to yield water may be much less than its porosity would indicate because part of the water is held in the pore spaces by molecular attraction between the water and the rock; the smaller the pore, the greater percentage of water thus held. If the pore spaces are large and interconnected, as they are in clean sand and gravel, the water is transmitted readily, and the formation is said to be permeable. On the other hand, if the pore spaces are very small, as in clay, the water is transmitted very slowly or not at all, and the rock is said to be impermeable.

Hydraulic properties of an aquifer are expressed as coefficients of transmissibility, permeability, and storage. The coefficient of transmissibility, as commonly used by the U.S. Geological Survey, is the number of gallons of water per day that may be transmitted through a cross section 1 mile wide extending the full height of the aquifer under a gradient of 1 foot per mile. The coefficient of permeability is obtainable by dividing the coefficient of transmissibility by the thickness of the aquifer, in feet. The coefficient of storage is the amount of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

Where the water in an aquifer is not confined, its upper surface is called the water table, and the water is said to be under water-table conditions. Gravity drainage causes water to be yielded from storage in a water-table aquifer when the water table is lowered, as in the vicinity of pumped wells or drains. Where the water is confined in the aquifer by an overlying relatively impermeable stratum so that the water in a well penetrating the aquifer rises above the base of the confining bed, the water is said to be under artesian conditions. An artesian aquifer remains saturated unless the water level is lowered below the top of the confining bed as by pumping; water is yielded mainly because of the compression of the aquifer by the weight of overlying beds, and to some extent by expansion of the water itself owing to lowered pressure.

Depth to water in wells and fluctuations of the water table

Ground water under the irrigated land on the Seville Bench is under artesian pressure during a part of the year. The silt and clay beds underlying the land surface act as a semiconfining layer that impedes the upward movement of water. However, capillary movement in the fine-grained material in conjunction with artesian pressure probably cause a significant movement of water toward the land surface, thus contributing to waterlogging and salt deposition at and near the land surface.

Periodic measurements of the water level were made in 63 selected wells to determine water-table fluctuations in the unconsolidated deposits. Water-level fluctuations are greatest in aquifers underlying the Two Medicine Irrigation Unit but differ considerably from place to place because of local recharge or discharge. Water levels generally are highest during June or July, the months of greatest precipitation and application of irrigation water. The water-level measurements are tabulated in table 4 at the end of this report.

Figures 6 and 7 (in pocket) show the depths to water during two periods of observation during 1956 and 1957. Figure 6 shows that during July 12-23, 1956, the depth to water was less than 6 feet in more than half of that part of the Two Medicine Irrigation Unit that lies on Seville Bench. By March 1957 the depth to water had declined to more than 6 feet in about 90 percent of the same area. (See fig. 7 in pocket.)

Determinations of aquifer properties

An aquifer test is a field method whereby the main hydraulic properties of an aquifer can be determined. Knowledge of these properties, the coefficients of storage and transmissibility, is necessary for the proper estimation of the optimum yields of wells and effectiveness of drains. The approximate coefficient of transmissibility of an aquifer can be computed from data obtained from a test using a single pumped well (single-well test); the approximate coefficients of both storage and transmissibility can be computed from data from a test using one or more observation wells and a pumped well (multiple-well test) if the test is sufficiently long.

During this study 4 single-well tests and 1 multiple-well test were made. These tests were made at the sites of 3 Geological Survey test wells (33-7-1cbd, 33-7-2abb, and 33-7-3dbb) and 2 farm wells (33-7-3cbd and 33-7-9cdd). The test wells completely penetrated the aquifer and were cased with 4-inch steel casing, which was perforated opposite the water-bearing strata. The farm wells, large-diameter dug wells cased with concrete and brick, only partly penetrated the aquifer. The test wells are in the irrigated part of the Seville Bench; the farm wells are in the nonirrigated part of the bench, but one of them (33-7-3cbd) is only 400 feet west of the Two Medicine Canal.

Transmissibility coefficients were computed from the tests by using the nonequilibrium formula as developed by Theis (1935), and are summarized in table 5. The aquifer-test data are given in table 6 at the end of this report. The results of the test at well 33-7-2abb probably are the most reliable, as an observation well was used. Using the early data of this test, a coefficient of transmissibility of 3,000 gpd per foot was computed. The test was not long enough for reliable determination of the coefficient of storage. The data indicate a recharging source about 130 feet from the pumped well. An irrigation ditch that was carrying water at the time of the test was probably the source of recharge. The ditch is 144 feet from the pumped well.

Table 5.--Summary of well test data

Well number	Aquifer thickness (feet)	Rate of pumping (gpm)	Specific capacity (gpm per foot drawdown)	Coefficient of trans-missibility (gpd per foot)	Coefficient of permeability (gpd per square foot)
33-7-1cbd (USGS 3)	13	11	4	3,200	250
33-7-2abb (USGS 1)	10	5	0.6	3,000	300
33-7-3dbb (USGS 2)	8	5	.6	2,800	350
33-7-3cbd (Farm well)	8	15	5.5	4,000	500
33-7-9cdd (Farm well)	20	25	11	9,000	450

Ground water in the bedrock formations

Where water-bearing unconsolidated deposits are absent, or are too thin to yield adequate quantities of ground water, wells have been drilled to aquifers in the underlying bedrock. Most of these aquifers are in the Two Medicine Formation and consist of fine-grained sandstone or sandy shale beds having low permeabilities. Three wells, 32-5-6bad, 32-6-1ada, and 33-6-11cba, which are 310, 285, and 343 feet deep respectively, may tap the upper part of the Virgelle Sandstone. Yields from the relatively thin sandstone beds that are common in the upper part of the Two Medicine Formation would be less than yields from the thick beds of sandstone in the lower part of the formation and in the underlying Virgelle Sandstone. The beds of sandstone in the lower 250 feet of the Two Medicine Formation and the underlying Virgelle Sandstone may yield as much as 50 to 100 gpm to wells.

The movement of ground water in the bedrock aquifers is controlled by the topography and structure. In shallow bedrock aquifers that are partially exposed in stream valleys, ground water moves from areas of recharge in the central parts of the benches toward the valley bottoms. The little data available concerning the deeper bedrock aquifers indicate that the movement of ground water is westward down the dip of the bedrock formations.

The permeability of the Two Medicine Formation is not adequate to allow the amount of water normally applied for irrigation to percolate downward. Thus, the parts of the project area where irrigation water is applied on soils immediately underlain by the formation have become waterlogged--that is the water table is at or near the ground surface. Because of the low permeability of the rocks there is little possibility that this condition can be corrected. The waterlogging is most pronounced along the northern edge of the project area. (See fig. 6.)

Ground water in the unconsolidated deposits

The deposits of unconsolidated materials underlying terraces 4 and 5 are the most economically important aquifer in regard to both ground-water supply and drainage. About half the wells in the area tap these deposits. The wells are bored or dug to depths ranging from 10 to 25 feet and yield from 1 to 10 gpm. Few, if any, of the wells fully penetrate the aquifer and those near the edges of Seville Bench, where the terrace deposits are thin, reportedly fail during the late winter or early spring. These well failures are caused by lowering the water table below the bottoms of the wells by natural drainage of the aquifer; in some places, failures probably could be prevented by deepening the wells.

Other unconsolidated deposits can yield little water because they lack recharge, are thin, are of small areal extent, or are impermeable. Locally, small supplies of water for domestic and stock needs probably can be developed.

Recharge, movement, and discharge of the ground water in the unconsolidated deposits

Precipitation directly on the area, excess irrigation water, and underflow from the west, recharge the unconsolidated deposits. The data available do not permit a quantitative evaluation of the amounts of recharge contributed by each source; however, the effects of recharge caused by precipitation and percolation of irrigation water are shown for comparative purposes in the hydrographs of wells 33-7-4cdb, 33-7-9cdd, and 33-7-10dac. (See fig. 8.)

Well 33-7-4cdb is about 250 feet downslope from the Two Medicine Canal. The hydrograph of this well shows the effects of recharge caused primarily by canal leakage. The water level rose steadily throughout the 1956 irrigation season from 14.48 feet below the land surface to a peak of 10.61 feet in October, when irrigation ceased.

Well 33-7-9cdd is in the nonirrigated part of Seville Bench. The hydrograph of this well shows that the natural fluctuations of the water table in the well's vicinity were only minor. These probably were caused by recharge from underflow and precipitation.

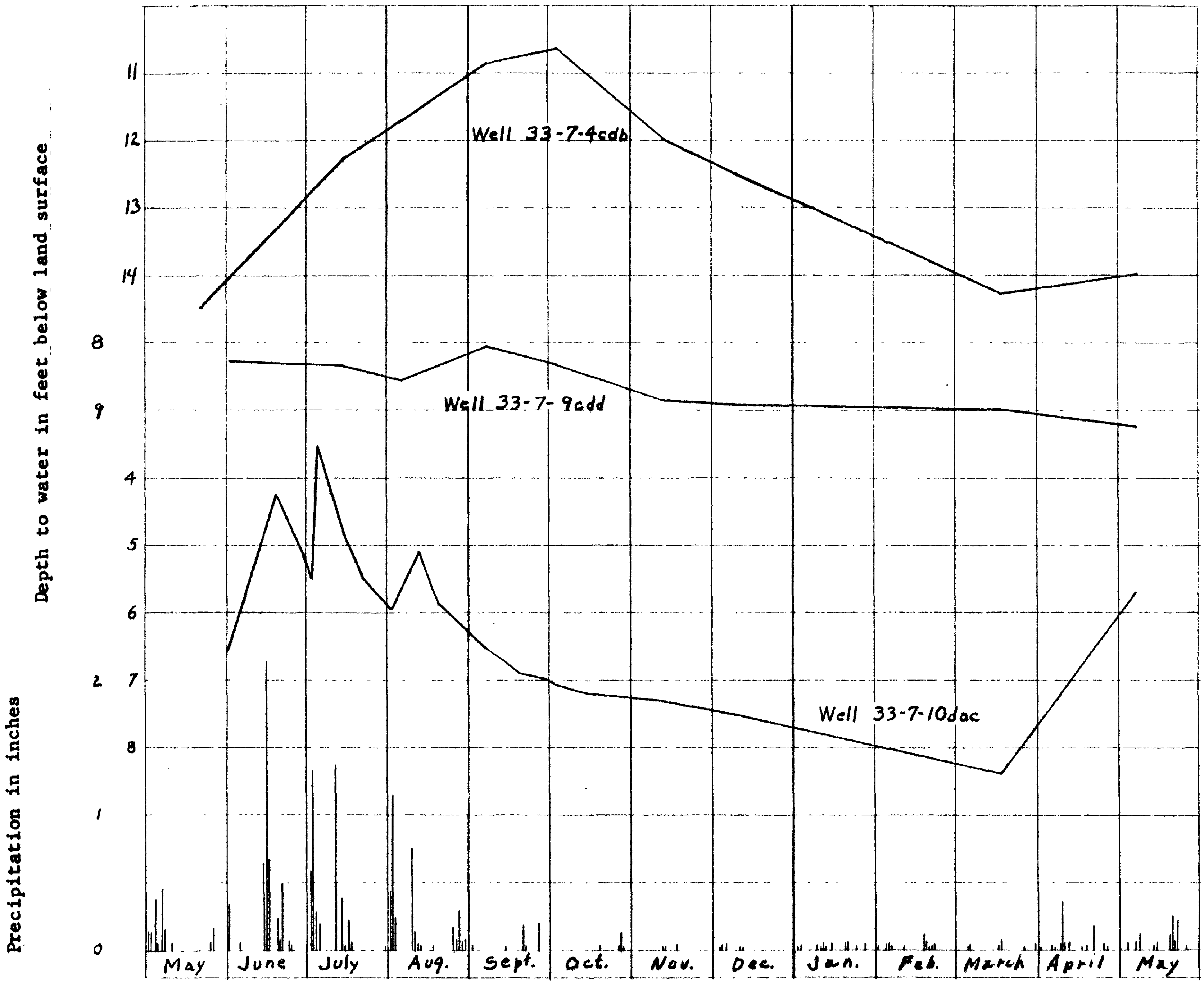

Figure 8.--Hydrograph of selected observation wells and graph showing daily precipitation at Cut Bank, May 1956 to May 1957.

The hydrograph of well 33-7-10dac, on Seville Bench, shows that the water level peaked on June 22, July 5, and August 13, 1956, and then declined steadily through March 20, 1957. Between March 20 and May 8, 1957 water again entered the irrigation ditch, and the water level in the well rose sharply. The peaks during the summer of 1956 can be correlated somewhat with periods of precipitation and with heavy applications of irrigation water. The apparent lack of recharge from precipitation, July 11-17, 1956, may have resulted partly because of a high soil-moisture demand due to lack of irrigation during early July. (See fig. 4.)

Figure 9 (in pocket) shows contours of equal altitude on the piezometric surface of part of the aquifer underlying Seville Bench. The contours are based on water-level measurements made in 41 wells. The ground water moves generally eastward from areas of recharge to areas of discharge under an average hydraulic gradient of about 20 feet per mile. Locally, near effluent streams, movement is toward the streams; along the southern edge of the Seville Bench, the movement is south or southeastward.

Ground water is discharged mainly along the northern and eastern edges of Seville Bench at the heads of Caddis Creek and many smaller intermittent creeks. Many small springs and extensive growths of cattails and other water-loving plants characterize the areas of discharge.

Estimate of the quantity of water moving through the terrace deposits underlying Seville Bench

An estimate of the quantity of water that flows through the aquifer can be made by use of a modification of Darcy's equation. In Darcy's equation,

$$Q = PIA \qquad (1)$$

where

Q = gallons per day

P = permeability in gallons per day per square foot

I = slope as a ratio, and

A = area of section, in square feet

let

$$A = mL \qquad (2)$$

where

m = thickness of aquifer, in feet, and

L = length of section, in feet

and let

$$P = \frac{T}{m} \qquad (3)$$

where

T = transmissibility.

Substituting (2) and (3) in (1),

$$Q = \frac{T}{m} \cdot I \cdot mL = TIL \qquad (4)$$

which is the modified equation.

From a cross section along the 3,940-foot contour line on the piezometric surface (fig. 9 in pocket), the following data were obtained. The length of the section through the Seville Bench is about 15,000 feet and the slope of the piezometric surface at the section is 0.004. The coefficient of transmissibility as determined from aquifer test data is about 3,000 gpd/ft. Substituting these numerical values in equation (4):

$$Q = 3{,}000 \times 0.004 \times 15{,}000$$

$$= 180{,}000 \text{ gpd}$$

$$= 125 \text{ gpm}$$

The velocity of flow of the ground water can be determined by use of the equation:

$$v = \frac{Q}{P\ A}$$

where

Q = cubic feet per day

P = porosity, in percent

A = cross-sectional area, in square feet

v = velocity, in feet per day

The area of the cross section is about 110,000 square feet, assuming 7 feet of saturation; the flow (Q) in cubic feet per day is 180,000/7.48; and the porosity is estimated to be 40 percent. Substituting these values in the above equation, the velocity is

$$v = \frac{24{,}000}{0.40 \times 110{,}000} = 0.55 \text{ foot per day}$$

The fact that the amount of water moving through the aquifer is rather small and that the rate of movement is low suggests that removal of a relatively small quantity of water would lower the piezometric surface considerably.

Drainage of waterlogged terrain

To effectively lower the piezometric surface in waterlogged land, several basic conditions must be met. The main requisites are: (1) a good hydraulic connection between the drain and the aquifer, (2) an intercept drain should extend as nearly as possible at right angles to the slope of the water table, (3) other conditions being equal, the drain should be located where the piezometric surface is the highest, and (4) the drain should be located as far upgradient as practicable. From the main requisites it is apparent that the important hydrologic data to be considered are the depth to gravel, the direction of movement of the ground water, and depth to water.

The depth to water map (fig. 6) shows an area of high water levels. Interceptor drains that parallel the piezometric surface contours and that conform to the surface topography may be located any place within the high-water-level area. Logs of wells (table 3) indicate that depth to gravel may be about 10 feet in some places. To be effective drains should penetrate the gravel aquifers through their entire length. Consideration should be given to the installation of relief wells at intervals along the bottom of the open or tile drains through areas where the drains would have to be excessively deep to intercept the aquifer. The use of relief wells would also allow more flexibility in the location of the drains. As a drain is usually more effective when it drains down gradient from the point of interception, a drain should be located towards the upper end of the high-water-level area. A drain constructed to flow in a northerly direction could start in the NE¼ of sec. 10 T. 33 N., R. 7 W. and extend across the area obtaining the desired slope by following the surface topography. Another drain would probably be needed 3,000-4,000 feet east of the first one depending on the amount of lowering of the water level that was desired between the drains.

Another possibility is to construct an outlet ditch, which will also act as a drain, from the head of the coulee in the SE¼ of sec. 1, T. 33 N., R. 7 W. to about the center of sec. 3. Drains that would approximately parallel the 3,955-foot piezometric contour (fig. 9 in pocket) and obtain the desired slope by following the surface topography could be installed from the south and the north to discharge into the outlet ditch. If the outlet ditch did not effectively drain the eastern part of the high-water-level area, lateral drains could be added in that part of the area.

Chemical quality of the water

By Russell H. Langford

Natural water is rarely pure but is commonly a solution of principally bicarbonate, sulfate, and chloride. Silica, iron, manganese, sodium, potassium, fluoride, nitrate, boron, hydrogen sulfide, oxygen, and carbon dioxide are present also, but usually in small amounts.

The amount and kind of chemical constituents in water depend on the past environment of the water. Rainwater contains only small amounts of dissolved solids and gases; however, as water infiltrates the earth's crust, it dissolves gases--principally carbon dioxide--and soluble minerals. Water charged with carbon dioxide is a particularly good solvent of carbonate rocks, such as limestone and dolomite. Fine-grained rocks, such as shale, expose considerable surface area to the solvent action of the water, and these fine-grained rocks usually yield highly mineralized water. Sand and gravel are more resistant to the solvent action of water, and aquifers composed of these constituents usually yield water of low mineralization under natural conditions.

The suitability of a water for various uses depends to a large extent on its chemical quality. As part of the investigation of the ground-water resources of the Two Medicine Unit, studies were made to determine the chemical quality of the water and to evaluate the suitability of the water for agricultural and domestic use.

Samples of water were collected in August 1956 from representative wells that tap the Virgelle Sandstone, Two Medicine Formation, terrace deposits, and alluvium in the project area. Samples of water were collected from pumped wells and from a nearby distribution canal during aquifer tests in July 1957. Samples of drainage water from irrigated lands were collected in October 1956 when the overland runoff affected the chemical quality of drainage water less than it did in August. Locations of sampling sites are shown on figure 9 (in pocket).

Some chemical-quality data were available for the project area as a result of previous studies by the Geological Survey. In 1950 and 1951, the chemical quality of water in Cut Bank Creek downstream from oil-field drainage near Cut Bank was studied. From August 1955 to October 1956, studies were made to determine the chemical quality of irrigation water supplied by Two Medicine Canal, of water in Spring Lake, and of water in Cut Bank Creek and other creeks in the area. (See fig. 9 in pocket.)

In the chamical analyses given in this report the mineralization of the water is expressed both in parts per million (ppm) and in tons per acre-foot of dissolved solids. A part per million is a unit weight of a constituent in a million unit weights of water. Tons per acre-foot are computed by multiplying parts per million by 0.00136 and, for this report, are computed from the residue on evaporation at 180°C. For water containing more than 1,000 ppm of dissolved solids, the calculated concentration of dissolved solids is shown as well as the residue on evaporation. The calculated concentration is determined by adding the concentrations of the individual constituents; before summation, bicarbonate is converted to equivalent carbonate by dividing its concentration in parts per million by 2.03.

The specific conductance of the water, which is expressed in micromhos at 25°C, is a measure of the ability of the water to conduct an electric current and is related to the amount and the chemical types of dissolved material. Becuase it is related to the amount of dissolved material, it can be used for approximating the mineralization of the water.

The pH indicates the degree of acidity or alkalinity of water. A pH of 7 indicates that the water is neither acid nor alkaline; progressively higher than 7 denotes increasing alkalinity, and progressively lower than 7 denotes increasing acidity.

Percent sodium and sodium-adsorption-ratio are useful in evaluating the suitability of water for irrigation. They are calculated, with concentrations in equivalents per million, as follows:

$$\text{Percent sodium} = \frac{100\ Na}{Ca + Mg + Na + K}$$

$$\text{Sodium-adsorption-ratio} = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

An equivalent per million is a unit for expressing the concentration of a chemical constituent in terms of the equivalent weight of the ion. One equivalent per million of a positively charged ion (cation) will react with one equivalent per million of a negatively charged ion (anion). Because the positive and negative charges are balanced in a solution, the total of the equivalents per million of the principal cations (calcium, magnesium, sodium, and potassium) is approximately equal to the total of the equivalents per million of the principal anions (bicarbonate, carbonate, sulfate, chloride, fluoride, and nitrate). Parts per million are converted to equivalents per million if multiplied by a factor that is the reciprocal of the equivalent weight of the ion:

Constituent	Factor	Constituent	Factor
Calcium (Ca^{++})......	0.04990	Bicarbonate (HCO_3^-)...	0.01639
Magnesium (Mg^{++})....	.08224	Carbonate ($CO_3^=$)......	.03333
Sodium (Na^+)........	.04350	Sulfate ($SO_4^=$)........	.02082
Potassium (K^+)......	.02558	Chloride (Cl^-)........	.02820
		Fluoride (F^-).........	.05263
		Nitrate (NO_3^-)........	.01613

Chemical characteristics of the water

Ground water

Analyses of water from 15 selected wells on the Two Medicine Unit are given in table 7 and the chemical characteristics of water from the Virgelle Sandstone, Two Medicine Formation, terrace deposits, and alluvium in the project area are illustrated by bar diagrams in figure 10. On figure 10 concentrations are scaled in equivalents per million. The height of the bar diagram is proportional to the total mineralization of the water, and the relative heights of the component parts of the bar diagram indicate the chemical type of the water. For example, water from well 34-7-36dda2 is of the sodium sulfate-bicarbonate type and is highly mineralized (1,500 ppm of dissolved solids), whereas water from well 33-6-8bcd is of the magnesium bicarbonate type and is of low mineralization (234 ppm of dissolved solids).

Table 7.--Chemical analyses of ground water, Two Medicine unit, Mont.

[Samples collected Aug. 2, 1956, and results in parts per million except as indicated]

Well number	Depth of well (ft)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Residue on evaporation at 180°C	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25°C)	pH
Virgelle (?) sandstone																						
32-5-6bac	110	12	0.50	46	18	192	1.7	410	0	111	123	0.1	0.1	0.19	717	0.98	190	0	68	6.1	1,220	7.8
Two Medicine formation																						
33-7-2bdc	47	8.3	0.03	21	39	236	1.4	487	5	245	43	2.4	7.8	0.20	859	1.17	212	0	71	7.1	1,350	8.2
11dbd	105	7.4	.19	18	26	228	1.8	482	10	195	31	1.5	7.1	.25	800	1.09	150	0	76	8.1	1,280	8.4
33-8-13cac	60	12	.40	30	44	122	1.7	403	8	74	41	2.0	40	.10	584	.79	256	0	51	3.3	967	8.3
25bda	50	8.5	.11	31	30	33	1.8	274	0	31	6.5	.8	15	.09	291	.40	199	0	26	1.0	513	8.1
Terrace deposits																						
33-6-8bcd	11.3	9.0	0.05	23	36	13	1.6	242	2	26	0.5	1.0	5.0	0.07	234	0.32	204	2	12	0.4	433	8.3
9cbd	19.5	10	.54	17	76	146	.8	543	8	139	26	2.0	27	.25	737	1.00	356	0	47	3.4	1,170	8.3
33-7-2abb3 a/	22	......	....	21	44	118	......	308	0	188	30		1.0	....	....	....	232	0	53	3.4	876	7.7
2abb3 b/	22	......	....	21	45	112	......	304	0	170	32		2.9	....	....	....	236	0	51	3.2	899	8.0
3cbd c/	10.5	......	....	29	115	65	......	572	0	90	63		36	....	....	....	546	77	21	1.2	1,150	8.1
3cbd d/	10.5	......	....	35	121	68	......	600	0	85	72		49	....	....	....	584	92	20	1.2	1,270	7.9
3cdc1	13.4	10	.02	26	76	45	.3	453	5	50	17	1.2	10	.10	479	.65	376	0	21	1.0	839	8.2
3dbb e/	22	8.5	.08	15	28	17	1.2	188	0	27	3.0	.8	3.5	.04	183	.25	154	0	19	.6	340	8.1
3dbb f/	22	7.6	.04	16	28	16	1.2	185	0	27	3.0	.8	4.1	.03	186	.25	154	2	18	.6	343	8.2
9cdd	12.7	10	.02	17	46	64	8.5	375	9	46	10	1.5	41	.11	469	.64	232	0	43	2.4	775	8.4
9cdd g/	12.5	......	....	20	57	99	......	452	0	56	15		47	....	....	....	284	0	43	2.6	874	7.7
13dbc	12.8	11	.00	30	68	36	.6	442	17	49	9.0	1.4	19	.14	448	.61	354	0	18	.8	777	8.4
34-7-36dda2	9.5	9.2	.04	24	86	376	.8	568	24	534	99	3.2	6.7	.50	h 1,500	2.04	414	0	66	8.0	2,220	8.4
Alluvium																						
33-8-10cbb	13.6	11	0.03	47	39	61	1.5	369	6	58	14	0.7	21	0.16	440	0.60	278	0	32	1.6	751	8.3

a Sample obtained July 17, 1957 after 1 hour of pumping.
b Sample obtained July 17, 1957 after 5 hours of pumping.
c Sample obtained July 19, 1957 after 35 minutes of pumping.
d Sample obtained July 19, 1957 after 200 minutes of pumping.
e Sample obtained July 16, 1957 at start of aquifer test.
f Sample obtained July 16, 1957 after 4½ hours of pumping.
g Sample obtained July 20, 1957 after 2 hours of pumping.
h Calculated, 1,450 ppm.

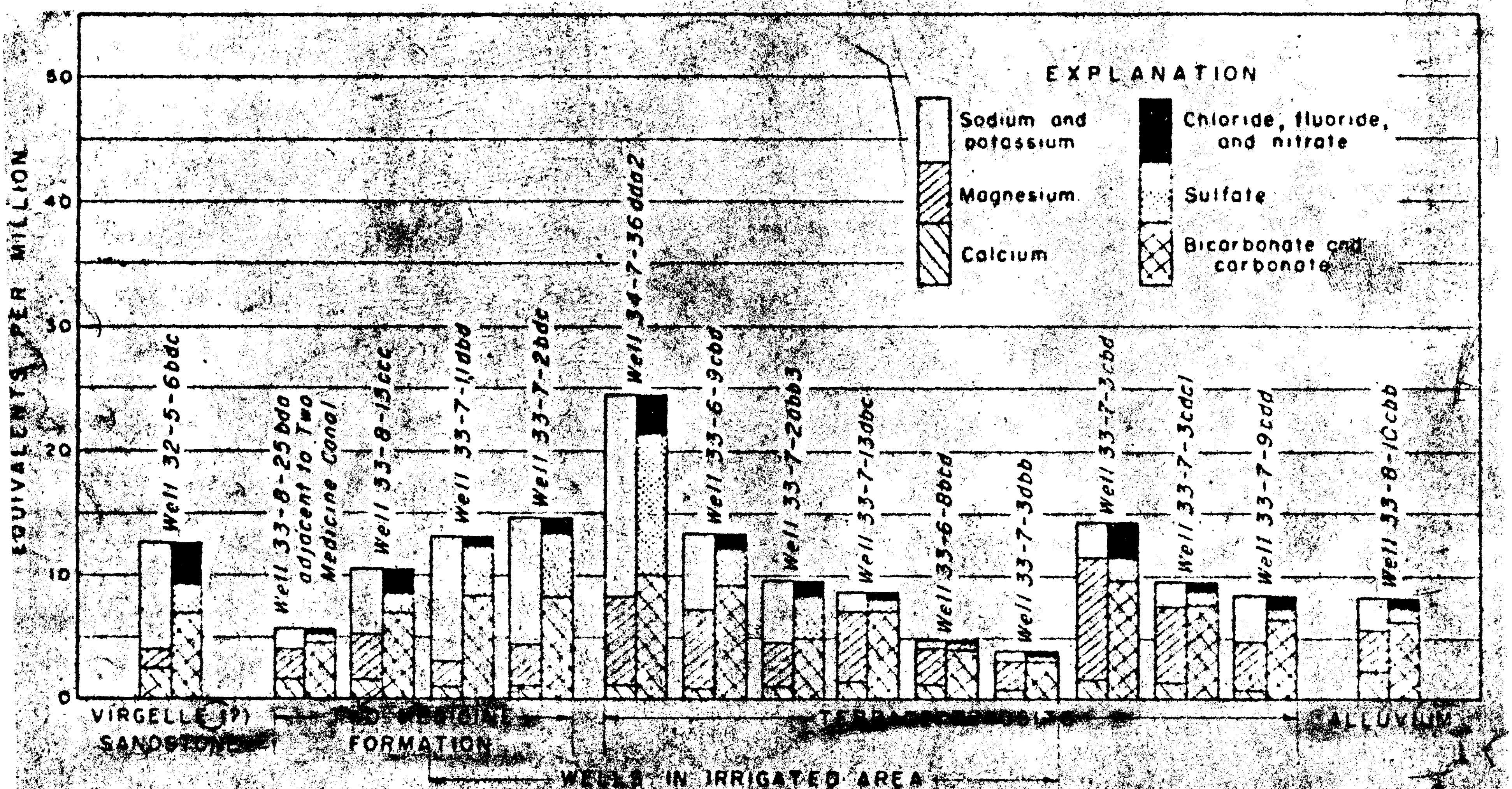

Figure 10. — characteristics of ground water

General conclusions can be made as to the chemical quality of the ground water and the effect of hydrology and geology on water quality. The ground water is derived from canal leakage, applied irrigation water, precipitation, and underflow. The relative contribution of each source differs from place to place; therefore, the chemical quality of the water also differs from place to place. Also, because the water table is only a few feet below the land surface in parts of the project area, evapotranspiration affects the quality of ground water.

The mineralization of ground water ranged from 183 to 1,500 ppm of dissolved solids. The relatively highly mineralized water contains principally sodium, magnesium, sulfate, and bicarbonate. The relation of concentration of chloride, fluoride, and boron to mineralization is nearly linear; the water of relatively high mineralization contains higher concentrations of these substances than the water of low mineralization. The concentration of calcium in ground water, however, remains fairly constant regardless of the degree of mineralization. (See table 7.)

Generally, water contains more calcium than magnesium. However, water from terrace deposits, alluvium, and the Two Medicine Formation contained more magnesium than calcium. The relatively high concentration of magnesium could indicate that magnesium minerals are more prevalent or more soluble than calcium minerals in the surficial deposits, that magnesium is present in higher concentrations than calcium in the irrigation water being applied, and (or) that some calcium salts are precipitating out of the percolating ground water and the infiltrating irrigation water. Probably, the prevalence of soluble magnesium minerals and the precipitation of calcium salts account for the relatively high concentrations of magnesium in the water because calcium, not magnesium, is the predominant cation in the applied irrigation water and because the major part of the cementing material in terrace deposits in parts of the project area is calcium carbonate.

Most of the water from terrace deposits and alluvium is of the magnesium bicarbonate type, but in some of the water sodium and (or) sulfate are present in significant amounts. The Virgelle Sandstone and the Two Medicine Formation yield water of the sodium bicarbonate type. (See fig. 10.)

All of the ground water is hard to very hard, and water from some wells contains nitrate in rather high concentrations. Concentrations of nitrate greater than about 20 ppm in ground water may indicate contamination by organic matter. Well 33-7-3cbd is a shallow large diameter dug well in a barnyard and is easily susceptible to contamination by surface drainage. After 35 minutes of pumping, the water contained 36 ppm of nitrate and after 200 minutes, 49 ppm. Apparently the ground-water reservoir in the vicinity of the pumped well was being recharged by water that contained high concentrations of nitrate.

Although most of the sampled ground water was clear, colorless, and odorless, water from well 32-5-6bdc, which taps the Virgelle Sandstone, was cloudy and had an odor of hydrogen sulfide. In addition to the data shown in table 7, water from this well contained 0.05 ppm of manganese, which, along with the 0.50 ppm of iron, cound have contributed to the cloudiness of the water after the sample was exposed to the air.

The temperature of the water represented by analyses in table 7 ranges from 45° to 51°F. However, only water dipped from dug wells or pumped through a plumbing system had a temperature over 45°. The temperature of water from the Virgelle Sandstone was not determined.

Applied irrigation water

Water supplied by the Two Medicine Canal originates as precipitation in the high mountains to the west and is diverted from Two Medicine Creek in T. 31 N., R. 10 W. Because the water has been in contact principally with relatively insoluble rocks of Precambrian age, it is of low mineralization, even though part of the drainage basin of the creek downstream from the Two Medicine Lakes to the diversion is underlain by rocks of Cretaceous age. The water contains less than 100 ppm of dissolved solids most of the time and is of the calcium bicarbonate type. Analyses of 24 samples of water from the main canal are given in table 8, the average chemical characteristics are depicted on figure 11. The maximum, minimum, and average concentrations are given in the table that follows.

Summary of analyses of irrigation water

	Concentration		
	Maximum	Minimum	Average
Calcium (Ca)...............ppm..	31	15	20
Magnesium (Mg).............ppm..	9.6	3.9	5.8
Sodium (Na)................ppm..	7.0	1.3	2.6
Bicarbonate and carbonate, as HCO_3..................ppm..	94	63	79
Sulfate (SO_4)..............ppm..	61	7.5	15
Dissolved solids...........ppm..	164	64	89
Hardness as $CaCO_3$..........ppm..	117	54	73
Percent sodium..................	11	5	7
Sodium-adsorption-ratio.........	.3	.1	.1
Specific conductance ....micromhos at 25°C...	270	114	157

Table 8.--Chemical analyses of applied irrigation water, Two Medicine unit, Mont.

[Results in parts per million, except as indicated]

Date of collection	Estimated water discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Residue on evaporation at 180°C	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25°C)	pH
Two Medicine Canal in NE¼NE¼ sec. 15, T. 33 N., R. 7 W.																						
1955																						
Aug. 3	15	3.0	0.00	20	6.1	2.5	1.2	72	3	13	0.5	0.1	3.0	0.04	96	0.12	75	5	7	0.1	151	8.6
Aug. 17	....	2.9	.06	21	5.9	3.5	.7	87	0	16	.5	.1	1.2	.01	100	.14	[illegible]	10	9	.2	177	7.5
Aug. 24	....	2.6	.05	18	7.1	3.9	1.2	51	0	13	.0	.1	.7	.00	[illegible]	.13	74	8	10	.2	162	7.5
Aug. 31	....	2.3	.05	24	5.8	3.2	.4	91	0	16	.7	.0	.5	.02	95	.13	84	9	8	.2	178	7.9
Sept. 7	....	1.5	.06	23	6.4	3.1	1.3	85	2	16	.5	.2	.2	.01	97	.13	84	11	7	.1	175	8.4
Sept. 14	....	2.0	.06	24	6.8	3.2	.6	94	0	17	.0	.1	.7	.01	106	.14	88	11	7	.1	187	7.8
1956																						
May 31	90	3.6	.05	18	4.3	1.9	.8	72	0	13	.0	.1	.6	.03	77	.10	63	6	6	.1	131	7.3
June 8	75	3.3	.08	15	4.8	1.3	.5	66	0	10	.0	.1	.3	.02	72	.10	57	3	5	.1	119	7.7
June 16	90	2.6	.03	17	4.2	1.4	.4	57	0	11	.0	.1	1.0	.02	73	.10	[illegible]	5	5	.1	128	6.9
June 22	45	2.8	.03	15	3.9	1.4	.4	53	0	7.5	.0	.1	.4	.02	64	.09	54	2	5	.1	114	7.7
June 29	25	2.8	.02	16	4.7	1.6	.6	58	0	10	.0	.1	.3	.01	58	.09	59	3	5	.1	125	7.9
July 6	7	3.9	.03	31	9.6	7.0	.7	84	0	61	.0	.1	.8	.04	164	.22	117	48	11	.3	270	7.2
July 13	28	4.2	.02	17	5.3	2.1	.2	65	3	12	.0	.1	1.0	.06	79	.11	64	6	7	.1	139	8.5
July 20	20	4.0	.02	17	5.5	2.1	.4	66	4	12	.0	.1	.1	.05	79	.11	65	4	6	.1	140	8.7
July 27	60	3.2	.01	18	5.9	2.1	.5	75	0	14	.0	.1	.4	.04	81	.11	[illegible]	7	6	.1	147	7.7
Aug. 3	120	3.7	.01	18	5.6	2.1	.5	76	0	11	.0	.0	.3	.02	80	.11	68	6	6	.1	144	7.6
Aug. 10	25	3.0	.01	19	5.5	2.1	.5	77	0	11	.0	.0	.4	.02	84	.11	70	7	6	.1	150	7.7
Aug. 17	40	2.7	.00	19	5.5	2.3	.4	77	0	11	.0	.0	.3	.02	83	.11	70	7	7	.1	149	7.7
Aug. 24	50	2.9	.01	18	5.1	2.3	.4	78	0	11	.0	.0	.2	.01	83	.11	[illegible]	6	7	.1	150	8.1
Aug. 31	60	2.6	.01	21	6.7	2.7	.4	84	0	15	.0	.0	.2	.00	94	.13	80	11	7	.1	170	7.6
Sept. 7	45	3.3	.01	21	6.0	2.7	.4	86	0	10	.0	.1	.2	.01	92	.13	77	6	7	.1	161	8.0
Sept. 14	30	2.7	.01	21	5.7	2.7	.4	84	0	11	.0	.0	.3	.01	91	.12	76	7	7	.1	152	7.4
Sept. 21	30	3.0	.00	22	5.9	2.7	.5	88	0	14	.0	.1	.3	.01	91	.12	79	7	7	.1	170	7.5
Sept. 28	50	2.9	.01	22	5.6	2.5	.4	85	0	13	.0	.0	.4	.01	91	.12	78	7	6	.1	165	7.7
Distribution canal in NW¼NW¼SE¼ sec. 3, T. 33 N., R. 7 W.																						
1957																						
July 16	....	4.2	0.04	22	5.6	3.1	0.5	85	0	19	0.4	0.1	0.2	0.02	90	0.12	78	8	8	0.2	162	8.0

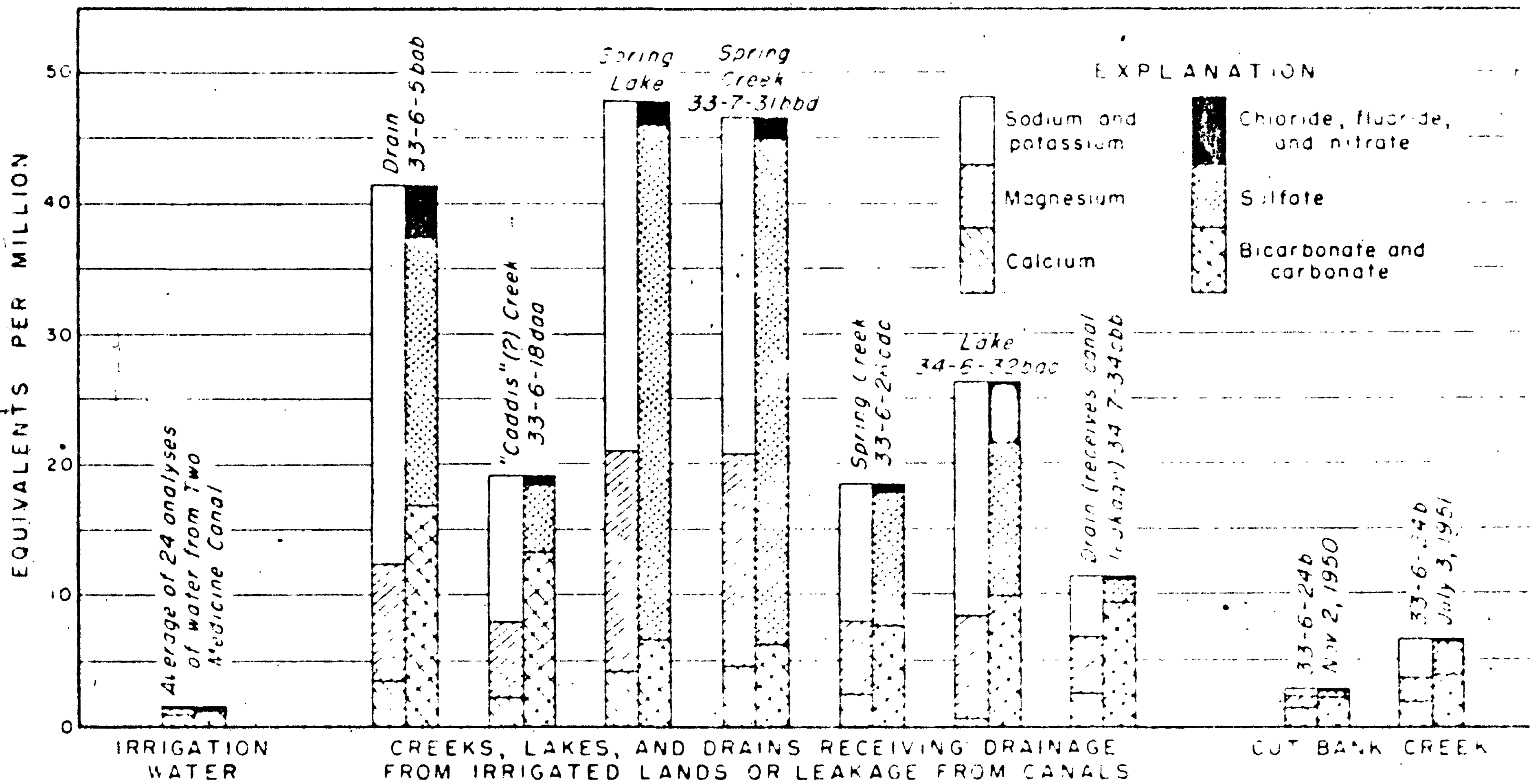

Figure 11. --Chemical characteristics of surface water

The sample obtained on July 6, 1956, may not be representative of water usually supplied by the canal. Omission of concentrations for this sample from the summary would reduce the maximum considerably, but would reduce the average only slightly. The increased mineralization probably was due to increased mineralization of water in Two Medicine Creek. Water from the creek near the canal diversion was more highly mineralized on July 3 than on preceding and following days and, in fact, was more highly mineralized than on any other day of sampling during the 1956 water year (October 1, 1955 to September 30, 1956). The water of relatively high mineralization on July 3 was associated with high flows on that day, was diverted into the canal, and appeared at the canal station near Cut Bank 3 days later.

In addition to analyses of water from the main canal, an analysis of water from a distribution canal also is given in table 8. Because the distribution canal may be a source of recharge to well 33-7-3dbb, samples from both the canal and the well were obtained during an aquifer test.

Water from creeks, lakes, and drains

Water draining from irrigated lands in the Two Medicine Unit is 10 to 30 times as mineralized as the applied irrigation water. Chemical analyses of water from Cut Bank Creek, two drains, Caddis and Spring Creeks, Spring Lake, and an unnamed lake are given in table 9; sampling sites are shown on figure 9; and chemical characteristics are shown graphically on figure 11.

Sodium, sulfate, and bicarbonate are the principal dissolved constituents in the drainage water, and the concentration of magnesium is significantly greater than that of calcium. In most of the irrigated lands in the western part of the United States, drainage contains higher concentrations of sodium salts than calcium or magnesium salts. The predominance of sodium in drainage from irrigated lands is the result of evapotranspiration and selective plant uptake. Evapotranspiration commonly causes precipitation of calcium and magnesium salts because they are generally less soluble than sodium salts; plants tend to take up more calcium and magnesium than sodium.

Table 9.—Chemical analyses of water from creeks, lakes, and drains, Two Medicine unit, Mont.

[Results in parts per million, except as indicated]

Location a/	Date of collection	Water discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Calculated	Dissolved solids: Residue on evaporation at 180°C	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25°C)	pH
Drain																								
33-6-9bcb..	Oct. 12, 1956	b 0.1	18	0.03	70	110	550	3.0	991	25	1,010	135	2.2	1.6	0.48	2,500	2,620	3.56	628	0	69	11	3,530	8.3
Caddia Creek																								
33-6-14caa.	....do........	b 0.4	12	0.12	48	70	254	1.9	784	15	265	21	2.2	1.3	0.31	1,070	1,100	1.50	400	0	58	5.5	1,650	8.3
Spring Lake																								
32-8-3.....	Aug. 4, 1955	....	4.1	0.09	78	221	725	16	508	0	1,950	61	0.5	0.4	0.91	3,210	3,290	4.47	1,100	683	55	8.1	4,070	7.5
	May 15, 1956	c 3,953.26	5.4	.02	85	206	592	11	391	8	1,940	57	.6	.7	.65	3,100	3,250	4.45	1,000	720	55	7.9	3,970	8.2
Spring Creek																								
33-7-31bbd.	Oct. 12, 1956	b 2	2.5	0.03	93	197	575	13	358	0	1,890	51	.6	6.6	0.68	3,010	3,160	4.30	1,040	722	54	7.7	3,800	7.7
33-6-26cca.	....do........	....	1.6	.01	52	67	239	3.8	456	9	560	21	.9	.6	.28	1,120	1,150	1.56	406	17	56	5.2	1,670	8.3
Lake																								
34-6-32bca.	....do........	....	3.7	0.02	13	96	405	5.8	263	169	575	170	0.5	1.0	0.23	1,570	1,650	2.24	425	0	67	8.5	2,340	9.8
Drain d/																								
34-7-34cbb.	....do........	b 0.2	14	0.02	51	53	106	1.7	576	0	90	8.5	1.8	0.8	0.16	.....	611	0.83	344	0	40	2.5	994	8.1
Cut Bank Creek																								
34-6-25a...	Aug. 3, 1955	....	4.2	....	....	....	9.2	1.0	140	4	19	0.5	0.0	0.2	0.02	.....	147	0.20	121	0	14	0.4	271	8.4
33-6-2ca...	....do........	....	3.0	....	....	....	14	.8	152	0	29	.6	.1	.0	.02	.....	152	.21	124	0	20	.5	292	8.2
	Nov. 2, 1950	....	4.5	0.02	28	12	12		137	0	25	2.0	.3	.3	.....	.....	168	.23	118	6	18	.5	263	7.7
	Dec. 8, 1950	....	6.1	.04	42	18	85		208	0	54	3.0	.2	1.0	.....	.....	257	.35	179	8	23	.8	434	8.0
	Jan. 4, 1951	....	8.2	.04	49	17	26		217	0	61	3.0	.2	3.7	.....	.....	288	.39	198	14	23	.8	461	7.5
	Feb. 2, 1951	....	5.0	.04	40	16	24		217	0	54	3.5	.0	2.1	.....	.....	262	.36	188	10	22	.8	447	7.5
	Mar. 7, 1951	....	7.4	.06	57	20	34		340	0	13	3.5	.4	.4	.....	.....	320	.44	224	0	25	1.0	543	7.3
33-6-8bb...	Apr. 3, 1951	....	7.2	.03	35	12	28		154	0	45	1.5	.2	2.8	.....	.....	228	.31	117	0	34	1.1	339	7.5
	May 3, 1951	....	8.3	.03	36	25	62		208	0	142	4.5	.2	1.2	.....	.....	394	.54	192	21	41	1.9	603	7.9
	June 6, 1951	e 549	4.8	.04	34	14	24		163	0	53	2.0	.1	1.1	.....	.....	218	.30	141	7	27	.9	358	8.0
	July 3, 1951	e 1,160	7.4	.02	39	22	68		238	0	129	2.5	.2	1.1	.....	.....	404	.55	186	0	44	2.2	611	7.8
	Aug. 1, 1951	e 717	4.0	.02	32	13	16		157	0	34	1.0	.2	.5	.....	.....	178	.24	132	3	21	.6	309	7.5
	Sept. 6, 1951	e 324	5.0	.01	39	20	44		205	0	98	3.0	.2	.9	.....	.....	320	.44	180	12	35	1.4	510	7.9
	Aug. 3, 1955	e 216	1.5	....	....	....	18	1.0	150	0	37	1.0	.1	.0	.03	.....	168	.23	128	5	23	.7	315	8.2
32-5-34da..	....do........	....	.6	....	....	....	59	1.7	160	4	153	4.4	.2	.1	.09	.....	364	.50	184	46	41	1.9	596	8.5

a See well-numbering system.
b Estimated.
c Lake elevation - feet above mean sea level datum.
d Drain may receive canal leakage.
e At gaging station at Cut Bank, 1 3/4 miles upstream.

Cut Bank Creek

Return irrigation flows only slightly affect the chemical quality of water in Cut Bank Creek upstream from the mouth of Spring Creek. On August 3, 1955, samples were collected from Cut Bank Creek upstream from irrigated lands, upstream from Cut Bank, and downstream from Cut Bank. (See fig. 9 in pocket.) Concentrations of dissolved solids were 147, 152, and 168 ppm, respectively, and the increase was due principally to the increase in concentrations of sodium and sulfate. (See table 9.) The mean discharge of the creek at the gaging station at Cut Bank was 216 cfs on August 3 and was only slightly higher on the preceding few days. The analyses show the minor changes in quality that probably occur when the flow of the creek is about 200 cfs. Late in August and in September during periods of relatively low discharge, return irrigation flows probably affect the chemical quality of the water to a greater degree than they do during periods of relatively high discharge.

Samples from Cut Bank Creek downstream from Cut Bank (33-6-24b) were obtained once a month from November 1950 to September 1951 to determine the degree of pollution from oilfield wastes. Chemical analyses in table 9 show that during this period the concentrations of dissolved solids in the water ranged from 168 ppm in the fall to 404 ppm during high flow in summer. The chemical characteristics of the water are shown graphically in figure 11.

Spring Lake and Spring Creek

Spring Lake receives leakage from Two Medicine Canal, and only a relatively small amount of water overflows from the lake into upper Spring Creek. Thus, over the years, evaporation has concentrated the dissolved solids in the lake water. Analysis of a single sample obtained near the north shore of the lake in August 1955 indicated that the concentration of dissolved solids was in excess of 3,000 ppm and that sodium sulfate was the principal dissolved salt. In May 1956 a more comprehensive study of the chemical quality of the lake water was made. Forty-four samples were obtained from many parts of the lake at different depths. Because the specific conductance of the individual samples varied by only 50 micromhos, the samples were composited for analysis. Thus, the analysis in table 9 for the composite sample (May 15, 1956) is more representative of the chemical quality of the lake than the analysis of the single sample obtained August 4, 1955.

In October 1956, samples of water were obtained from Spring Creek near the lake outlet and near the mouth. (See fig. 9 in pocket.) The chemical characteristics and mineralization of the water from upper Spring Creek were almost identical to those of the lake water. (See table 9.) However, near the mouth of the creek, the water was only about one-third as mineralized as the lake water, although sodium sulfate was still the principal dissolved salt. Drainage from irrigated lands, inflow from tributaries, and leakage from canals probably account for the dilution of the highly mineralized water.

Other lakes, creeks, and drains

Several other creeks, lakes, and drains were studied to determine the chemical quality of drainage from the irrigated lands. Probably the analyses of water from Caddis Creek (33-6-18daa) and from the drain on the eastern part of Seville Bench (33-6-5bab) are more representative of drainage from irrigated lands than the analyses of water from the unnamed lake (34-6-32bac) and from the drain on the northern part of Seville Bench (34-7-34cbb). The extremely high pH and concentration of carbonate and the low concentration of calcium in water from the unnamed lake, as compared with that from other sources, indicate that evaporation has caused precipitation of calcium carbonate. (See table 9 and fig. 11.) Some of the water in the drain on the northern part of Seville Bench may be direct canal leakage; the concentration of dissolved solids in water from this drain was lower than that of water from any other sampled drain or creek that receives drainage from irrigated lands in the project area.

Suitability of the water for use

Most ground water in the area is used for domestic and agricultural purposes. Because the area is not developed industrially, the suitability of the water for industrial uses is not evaluated in this report. However, the chemical-quality data for the project area can be compared with water-quality tolerances for various industrial applications given in publications such as Water Quality Criteria (Calif. State Water Pollution Control Board, 1952).

Domestic use

The U.S. Public Health Service (1962) has established standards for sanitary, bacteriological, and chemical requirements of water used for drinking and culinary purposes on interstate common carriers. The standards have been adopted by the American Water Works Association as recommended limits for all public water supplies. Although the standards are not compulsory for water that is used locally, they are measures of the suitability of water for domestic use. The standards for some of the chemical constituents are given in the following table:

Maximum recommended concentration, in parts per million

Constituent	Maximum
Iron and manganese (Fe + Mn)................	0.3
Magnesium (Mg).............................	125
Sulfate (SO_4).............................	250
Chloride (Cl)..............................	250
Fluoride (F)...............................	1.7*
Dissolved solids...........................	500[a]

[a]1,000 ppm permitted if water of better quality is not available.

* Where 5-year average of maximum daily air temperature is 50.0° to 53.7°F. Lower limit for warmer climate. (U.S. Public Health Service, 1962, p. 8)

most ground water sampled in the project area contained less than the maximum recommended concentrations.

Water from only a few wells contained iron in concentrations slightly higher than the recommended limit. (See table 7.) Iron in water tends to stain porcelain fixtures and laundry and can be tasted when the concentration is greater than about 0.5 ppm.

Although specific limits are not established for hardness, water having a hardness of less than 60 ppm is considered to be soft; 60 to 120 ppm, moderately hard; 120 to 200 ppm, hard; and more than 200 ppm, very hard. Soft water is suitable for most uses without further softening and very hard water usually requires softening for most uses in the home. In the project area ground water is hard to very hard, but most of the hardness is of the carbonate or temporary type. Temporary hardness, in contrast to permanent (or noncarbonate) hardness, can be partly removed by boiling the water.

Although requirements for nitrate are not established by the U.S. Public Health Service, high concentrations of nitrate in the drinking water of infants have caused cyanosis. Some investigators recommend that nitrate in infant's drinking water should not exceed about 45 ppm. Several wells yield water containing more than 20 ppm, but only 2 yielded water containing more than 45 ppm of nitrate. (See table 7.) These two wells are shallow dug wells in or near barnyards and are susceptible to contamination. The lowest concentrations of nitrate in ground water from the project area were in water from a deep drilled well (32-5-6bac) and from two newly drilled (1957) test wells (33-7-2abb3 and -3dbb).

Agricultural use

Stock watering is an important agricultural use of water in the project area. Although not much is known regarding the relation of quality of water to health of stock, water having a total mineralization of less than 2,500 ppm is considered to be good for stock watering (Calif. State Water-Pollution Control Board, 1952, p. 155). On the basis of this criterion, ground water in the project area is rated good for stock watering.

Although ground water is used in the project area only for supplementary irrigation of small gardens, the suitability of the water for irrigation can be evaluated by methods of the U.S. Salinity Laboratory Staff (1954). The ground water has a low to medium sodium hazard and a medium to high salinity hazard; sodium-adsorption-ratio is the measure of sodium hazard, and specific conductance is the measure of salinity hazard. The water should be used on permeable soils having adequate drainage and should be applied in excess of crop needs to flush the soils. Boron concentrations are sufficiently low in the ground water so that even boron-sensitive crops would not be injured.

Surface water now being used for irrigation in the area is suitable for irrigation; salinity and sodium hazards both are low, and concentrations of boron are very low. (See fig. 12.)

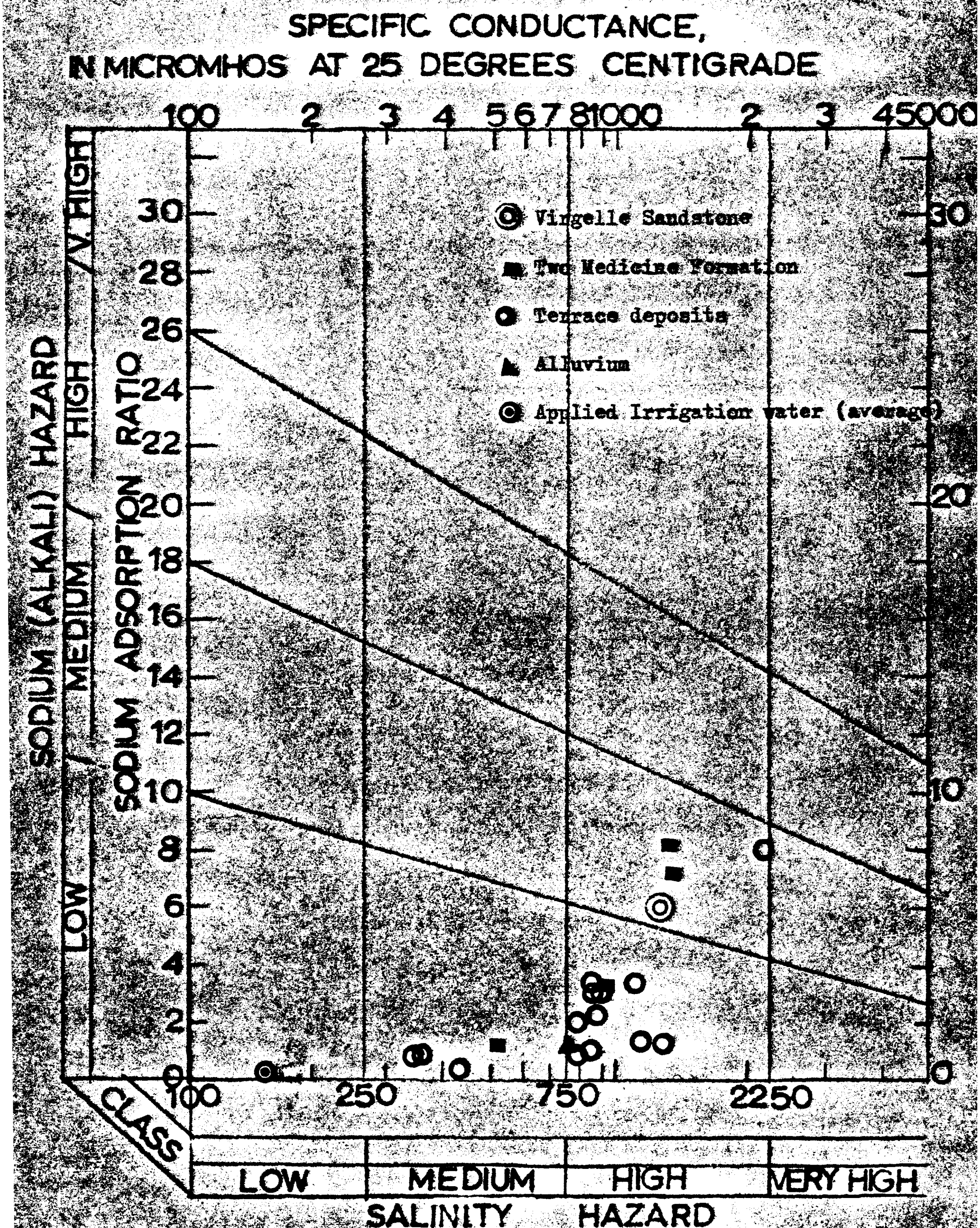

Figure 14.--Comparison of water from various sources in terms of suitability for irrigation. Adapted from U. S. Salinity Lab. Staff, 1954

Summary

Interbedded shale and sandstone of the Two Medicine Formation of Late Cretaceous age underlie the Two Medicine Irrigation Unit. These rocks are sufficiently permeable to yield small to moderate amounts of water to wells but cannot convey water fast enough to provide adequate drainage of irrigated land.

In much of the project area, rocks of the Two Medicine Formation are mantled by gravelly terrace deposits laid down by ancient streams flowing eastward from the Rocky Mountains. Land underlain by these deposits comprises most of the irrigated acreage. Glacial drift also mantles a part of the project area.

Waterlogging, due to inadequate drainage, is severe where irrigated land is directly underlain by the Two Medicine Formation. Less severe, but nevertheless serious, waterlogging is present on irrigated parts of Seville Bench, which is the largest of the surfaces underlain by terrace deposits.

The basic problem is that the transmissibility of the terrace deposits is inadequate to permit water to drain away through the deposits as fast as recharge is applied. As a result the water table rises to very near the ground surface during the irrigation season.

Two approaches to the problem can be considered. The first is that the amount of recharge be reduced to the amount that can be transmitted by the deposits; and the second is that means be found to remove the excess ground water.

The first of these approaches does not produce any remedies that seem economically feasible. The means and timing of water application are largely based on the experience and judgment of the individual farmers and it is unlikely that the amount applied could be appreciably reduced without extensive modification of the distribution system or impaired crop yields. Recharge as leakage from the Two Medicine Canal seems to be a major factor in causing waterlogging but the small amount (125 gpm) of water estimated to be moving through the deposits is less than the minimum leakage that can be realistically expected through the bottom of even a well-sealed ditch.

As means to appreciably reduce recharge are lacking, it seems that the second approach must be followed. Open drain ditches are the most economical and commonly used method of removing excess ground water. Two systems of drains appear to be feasible. The first would require two north-flowing drains 3,000-4,000 feet apart. One drain would be about 2,000 feet east of and generally parallel to the Two Medicine Canal; the other would be about 3,000-4,000 feet east of the first. The second system would require an east-west drain from the head of the coulee in the SE¼ of sec. 1, T. 33 N., R. 7 W. to about the center of sec. 3. Wing drains that could approximately parallel the 3,955-foot piezometric contour (fig. 13) and obtain the desired slope by following the surface topography could be installed from the south and the north to discharge into the outlet ditch.

Because of the small amount of water causing the problem, the discharge from the drains need not be large but a good hydrologic connection between the bottom of the drains and the most permeable part of the deposits would be needed. A layer of clay and silt as much as 10 feet thick covers the more permeable gravel in many places. Relief wells, installed in the bottom of the drain ditches, might be necessary where the clay and silt are too thick to be penetrated by a ditch of reasonable (6 to 9 feet) depth.

The very low permeability of the rocks of the Two Medicine Formation precludes establishment of an adequate and economical system of subdrainage where land directly underlain by them is irrigated.

Ground water in the project area ranges in mineralization from about 200 to 1,500 ppm of dissolved solids. Magnesium and bicarbonate are the major dissolved constituents in most water from terrace deposits and alluvium, although sodium and sulfate also are present in significant amounts in water from some wells. Sodium and bicarbonate are the major dissolved constituents in water from the Two Medicine Formation and Virgelle Sandstone.

A few shallow wells produce water that contains relatively high concentrations of nitrate, which indicates possible contamination of the water. Most ground water is very hard (more than 200 ppm) and has a temperature of about 45° to 48°F.

Irrigation water supplied by the Two Medicine Canal is of the calcium bicarbonate type and contains less than 100 ppm of dissolved solids. Conversely, water draining from irrigated lands is 10 to 30 times as mineralized as the applied water and is of the sodium sulfate-bicarbonate type. Spring Lake contains water that is highly mineralized (more than 3,000 ppm of dissolved solids) and that is of the sodium sulfate type. Return flows from irrigated lands affect only slightly the chemical quality of water in Cut Bank Creek upstream from Spring Creek.

Although the ground water is very hard, it is generally otherwise suitable for domestic use. The ground water has a medium salinity and sodium hazard with respect to its use for irrigation and is rated as good for stock watering.

The applied irrigation water is suitable for irrigation because of low sodium and salinity hazards and low concentrations of boron.

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Table 1.--Record of wells and springs.

Well number: See explanation of well-numbering system in text.
Topographic location: H, hillside; L, level or nearly so; S, gentle slope; SD, shallow depression.
Type of well: B, bored well; DD, dug and drilled well; Dr, drilled well; Du, dug well; Sp, spring.
Depth of well: Reported depths below the land surface are given in feet; measured depths are given in feet and tenths below measuring points.
Type of casing: C, concrete (brick tile or pipe); P, iron or steel pipe; T, clay tile; W, wood.

Character of material: G, gravel; S, sand; Ss, sandstone.
Method of lift: C, horizontal centrifugal; CY, cylinder; F, natural flow; N, none; P, pitcher pump; S, submersible turbine; T, turbine; VC, vertical centrifugal; J, jet.
Type of power: B, butane; E, electric; G, gas engine; H, hand operated; T, tractor; W, windmill.
Use of water: D, domestic; I, irrigation; In, industrial; N, not being used; O, observation; P, public supply; S, stock.
Depth to water: Measured depths to water level are given in feet, tenths and hundredths; reported depths to water level are given in feet.

Well number	Owner or tenant	Year drilled	Topographic location	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift	Use of water	Measuring point: Distance above land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Remarks
32-5- 6bdc	Hanna Porter Co.	----	S	Dr	310	7	P	Ss	Virgelle (?) Sandstone	S	D		3,712			Strong sulfide gas odor. Chemical analysis
32-6- 1ada	J. H. Wiley	1952	S	Dr	285	4	P	Ss	---------do---------	T	D		3,682			Strong sulfide gas odor
33-6- 3ccb	Alfred E. Allison	1952	S	Dr	70	6	P	Ss	---------do---------	J	D,S		3,752	37.8	6-11-56	
6aba	Blackfeet Tribe	----	L	Dr	89	6	P	Ss	---------do---------	CY	N	0.4	3,904.25	10.15	5-15-56	
6bbc	Ted Pendergrass	1935	L	Dr	88.7	5	P	Ss	---------do---------	J	D,S	0.5	3,918.03	7.82	5-15-56	
6ddb	SCS #48	1953	L	B	9	3	P	G	Terrace deposits	N	O	---	3,913.30	dry	5-15-56	
6cbc	Everett LaGrand	----	L	Du	11.0	36	W	G	---------do---------	CY	D	1.1	3,918.80	9.4	6- 1-56	
6cdd	SCS #91	1953	L	B	8.2	3	P	G	---------do---------	N	O	0	3,906.22	3.65	5-15-56	
7bcb	Tony Niesskens	----	L	Dr	19.2	6	W	--	-------------------	CY	D	0.2	3,920.22	6.86	6- 1-56	
7ccc	M. L. Romsa	----	L	Dr	15.7	6	P	--	-------------------	CY	S	1.2	3,925.50	7.86	6- 4-56	
8acd	Sam Bird (Abandoned)	----	L	Dr	25	5	P	--	-------------------	CY	S	---	--------	6	-------	Reported data
8bca	Sam Bird	----	L	Du	9.3	36	W	G	Terrace deposits	N	S	0.6	3,899.23	8.83	6- 6-56	Recorder installed
8bcd	-----do-----	----	L	Du	11.3	36	--	G	---------do---------	CY	D	0	3,899.48	6.4	6- 6-56	
8ccd	Red Tibbits	----	L	Dr	18.8	5	P	--	-------------------	CY	D	0.6	3,903.08	8.3	6- 7-56	
8dcd	Julia Crow Eyes	----	L	Dr	20.5	5	P	--	-------------------	CY	---	0.8	3,890.28	7.98	6- 7-56	

33-6- 9cbd	Robt. E. Young	----	L	Dr	19.5	5	P	G	-------------------	VC	D	---	3,875.51	3.20	7-20-56	M.P. 1.8 ft. below L.S.
9cdb	Blackfeet Tribe	----	L	Dr	52.5	6	P	--	-------------------	CY	N	2.1	--------	22	6- 6-56	
9dda	Christine Runningrabbit	----	L	Dr	159	6	P	--	-------------------	N	---	1.8	--------	59.2	7-24-56	
10aac	Ed Reagen	----	H	Dr	-----	---	--	--	-------------------	--	N	---	--------	----	-------	
10adb	Kieth Gustafson	----	H	Dr	200	6	P	Ss	Virgelle (?) Sandstone	CY	D,S	---	--------	----	-------	
10dac	W. B. Brenner	1956	H	Dr	24.0	6	P	--	-------------------	N	---	2.2	3,728	14.47	7-20-56	
11cba	Glacier Enterprises	1956	H	Dr	343	6	P	Ss	-------------------	S	D	---	--------	13.4	-------	
16aab	Oil Field Lumber Co.	----	L	Du	18	24	--	--	-------------------	C	D,S	0	3,855	13.36	3-20-57	
17bca	Pat LaTray	----	L	Du	12.0	40x48	W	G	Terrace deposits	N	D	1.4	3,904.07	10.79	5-21-56	
17ccc	------------	----	SD	Dr	17.7	6	P	--	-------------------	CY	S	1.65	3,885.03	4.39	5-21-56	
18ada	Mary Manytailfeathers	----	L	Dr	37.0	6	P	--	-------------------	CY	N	0.5	3,916.44	29.76	5-21-56	
28bcb	John and Alva Atkins	----	L	Dr	46.7	6	P	--	-------------------	N	N	0	3,738	7.61	8-28-56	
30bcb	J. D. Maguire	1938	S	Dr	86	4	P	S	-------------------	CY	D,S	---	--------	10	-------	
33-7- 1ada	Walter Wetzel	1938	L	Dr	90	---	--	--	-------------------	CY	S	0	--------	11.0	5-29-56	Sulphur taste
1adc	-----do-----	1956	L	Dr	72	5	P	S	-------------------	VC	D	---	--------	----	-------	
1dda	Federal Reserve	----	L	Du	14.5	5	P	--	-------------------	CY	N	0.6	3,921.15	8.59	6- 1-56	
1aaa	SCS #34	1953	L	B	9.6	3	P	G	-------------------	N	O	1.4	3,919.70	9.3	5-11-56	
1add	SCS #60	1953	L	B	5.2	3	P	--	-------------------	N	O	0.6	--------	dry	5-11-56	
1bbd	SCS #46	1953	L	B	7.3	3	P	--	-------------------	N	O	0.7	--------	6.91	5-16-56	
1bca	SCS #44	1953	L	B	8.1	3	P	--	-------------------	N	O	0.9	3,932.66	6.42	5-16-56	
1cca	SCS #73	1953	L	B	9.7	3	P	--	-------------------	N	O	0.8	3,932.09	3.89	5-17-56	
1dac	SCS #75	1953	L	B	8.5	3	P	--	-------------------	N	O	1.45	3,921.50	4.32	5-17-56	
1ddd	SCS #89	1953	L	B	8.6	3	P	--	-------------------	N	O	0.75	3,921.10	6.64	5-11-56	
2abb1	F-107	----	L	Du	7.7	30	W	--	-------------------	N	O	0	3,939.59	2.57	7-31-56	
2abb2	SCS #28	1953	L	B	8.8	3	P	--	-------------------	N	O	.55	3,940.51	4.45	5-17-56	
2add	SCS #56	1953	L	B	9.2	3	P	--	-------------------	N	O	1.2	3,935.91	4.72	5-17-56	
2bbb	SCS #26	1953	L	B	7.8	3	P	--	-------------------	N	O	0.8	3,950.01	6.8	5-11-56	
2bdc	John Meyer	----	L	Dr	47.0	6	P	--	-------------------	CY	D	0.3	--------	7.59	6- 4-56	
2cbb	SCS #52	1953	L	B	8.5	3	P	--	-------------------	N	O	1.4	--------	6.6	5-11-56	
2cdb	SCS #69	1953	L	B	12.1	3	P	--	-------------------	N	O	0.8	3,953.58	7.88	5-17-56	
2cdd	SCS #83	1953	L	B	8.0	3	P	G	Terrace deposits	N	O	0	3,948.10	2.35	7- 6-56	
2dcc	Albert Eiland	----	L	Du	10.6	24	W	--	-------------------	P	N	0.8	3,945.93	4.97	6- 4-56	
2ddc	L. M. Smith - SCS #84	1953	L	B	12.0	6	P	--	-------------------	N	O	---	3,946.43	5.25	7-19-56	
3cac	Cliff Guith	----	L	Du	9.2	36	C	--	-------------------	N	N	0	3,967.42	3.67	6- 4-56	
3cba	-----do-----	----	L	Du	10	36	W	--	-------------------	N	N	0.5	3,967.55	4.99	6- 4-56	
3cbd	-----do-----	----	L	Du	10.5	36	W	--	-------------------	CY	S	0.5	3,968.12	6.04	5-28-56	
3cdc1	Federal Reserve	----	L	Du	13.4	24	--	--	-------------------	J	D	0.2	3,968.77	5.69	5-28-56	
3cdc2	-----do-----	----	L	Du	13.4	36	--	--	-------------------	N	N	1.1	3,969.04	5.85	5-28-56	
3cdc3	-----do-----	----	L	B	11.5	15	P	--	-------------------	CY	D	0.1	--------	4.97	5-28-56	
3ddd	Chet Guith	----	L	Du	8.20	36	C	--	-------------------	J	S	0	3,956.55	4.68	6- 4-56	
4cdb	Rosa Foundagun	----	H	Du	17.9	30	W	--	-------------------	CY	S	0.55	3,954.06	15.03	5-25-56	

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33-7- 9bab	--------------	----	L	DD	-----	---	--	--	-------------------	--	--	---	3,981.07	dry at 12 ft.	-------	
9bca	--------------	----	L	Du	9.8	24	W	G	-------------------	N	N	0	3,988.41	7.94	9-17-56	
9cdd	Don LaGrand	----	L	Du	12.7	72	C	--	-------------------	--	--	0	3,992.79	8.26	5- 1-56	
10abd	SCS #93	1953	L	B	8.3	3	P	--	-------------------	N	O	0.9	3,963.92	6.83	5-14-56	
10dac	Kyle Momberg	----	L	Du	10.9	36	W	--	-------------------	CY	N	0.4	3,966.20	6.97	6- 1-56	
11aaa	SCS #85	1953	L	B	8.6	3	P	--	-------------------	N	O	0.5	3,938.24	6.73	5-11-56	
11abb	L. M. Smith	----	L	Du	11	60	C	--	-------------------	CY	D,S	---	--------	----	-------	
11aac	SCS #97	1953	L	B	9.0	3	P	G	Terrace deposits	N	O	0.8	3,945.70	4.8	5-11-56	
11adc	Dan Haggerty	1941	L	Dr	210	5	P	--	Two Medicine Formation	J	D	---	--------	----	-------	
11bab	Ed Gobert	1938	L	Dr	35	5	P	S	-------------------	VC	D	---	3,953.25	6.7	6- 4-56	
11cdd	Kyle Momberg	----	L	Dr	60	---	--	--	-------------------	CY	D,S	---	--------	----	-------	
11dba1	Harry T. Novak	----	L	Du	10.5	24	C	--	-------------------	CY	N	0	3,948.35	6.98	6- 1-56	
11dba2	-----do-----	----	L	Du	10	---	C	--	-------------------	--	D	---	--------	7.74	6- 4-56	
11dbd	Don Weaver	1952	L	Dr	105	4	P	Ss	-------------------	J	D	---	--------	10.58	6- 1-56	
12baa	SCS #87	1953	L	B	9	3	P	G	Terrace deposits	N	O	1.35	--------	8.48	5-11-56	
12dad	F. R. Baker	----	L	Dr	15	6	P	--	-------------------	CY	N	0.6	3,925.08	7.17	6- 1-56	
13aaa	Norbert Hietpas	----	L	Dr	40	---	--	--	-------------------	CY	D,S	---	--------	----	-------	
13caa1	Martha Garrow	1945	L	Du	11	30	P	--	-------------------	--	D	---	--------	----	-------	
13caa2	-----do-----	----	L	Du	12.5	48	W	G	Terrace deposits	CY	S	0	3,920.42	6.97	5-21-56	
13daa	Chas. Keller	----	L	Dr	20.5	5	P	--	-------------------	--	D	---	3,912.70	9.3	5-18-56	
13dbc	Winston Hyssop	----	L	Du	12.8	24	W	G	Terrace deposits	J	S	0	3,920.72	10.23	5-21-56	
13cbd	Lester Gardner	1945	L	Du	11.5	40	W	G	---------do---------	CY	D,S	0	3,928.76	11.27	5-22-56	
13cdd	Robert Barlow	----	L	Dr	65.2	6	P	Ss(?)	-------------------	CY	D,S	0.6	--------	12.25	5-21-56	
14bba	Kyle Momberg	----	S	Dr	60	---	--	--	-------------------	CY	S	---	--------	-----	-------	Unable to measure
14dca	John Sather	----	L	Du	14.0	48	C	G	Terrace deposits	J	D	0.31	--------	11.47	5-22-56	
14ddb	John Broadhead	----	L	Du	12	---	--	--	-------------------	--	D	---	--------	-----	-------	Sealed
19cdd	Wiley Welch	----	S	Dr	60	5	P	--	-------------------	CY	D	---	--------	-----	-------	Sealed
20bdb	--------------	----	L	Dr	61.8	5	P	--	-------------------	N	N	---	4,009.00	16.68	5-22-56	
25aab	Blackfoot Hereford Ranch	----	S	Dr	82.0	6	P	--	-------------------	CY	N	---	3,839.00	18.50	5-18-56	
27bac	Don Peterson	----	S	Du	6.2	---	--	--	-------------------	N	N	1.7	3,839.00	4.9	7-12-56	
27bac	-----do-----	----	S	Du	7.9	40	C	G	-------------------	N	S	1.0	--------	6.4	7-12-56	
33-8- 1adb	Walter Sinnett	1933	S	Du	24.0	18	P	Ss	-------------------	CY	D,S	1.13	3,928.39	16.0	5-25-56	
1dcb	Anton Royland	1936	S	Dr	60	8	P	S	-------------------	J	D,S	---	--------	8.15	5-23-56	
3cab	Blackfeet Tribe	----	S	Dr	87.5	6	P	--	-------------------	CY	N	---	--------	26.72	5-23-56	
3dad	Harold Murphy Brown	1955	S	Du	8.0	30	W	G	-------------------	J	D	---	3,953.89	6.23	5-23-56	
10cbb	George T. Kawaniski	----	S	Du	13.6	36	T	G	-------------------	CY	D	0	3,985.38	6.04	5-23-56	
11cbd	Maggie Runningcrane	----	S	Dr	16.7	5	P	--	-------------------	N	S	0.6	4,017.43	9.38	8-10-56	
13bbb	Seismograph shot hole	----	L	Dr	12.0	8	N	G	-------------------	N	N	0	4,048.2	4.52	8- 6-56	
13ccc	Francis Manley	----	L	Dr	60.0	5	P	--	-------------------	D	S	---	--------	10.0	5-24-56	
21ddd	------------	----	L	Dr	88.0	6	P	--	-------------------	CY	N	---	4,116.38	10.42	5-15-56	
25bda	Wiley Welch	1930	S	Dr	50.0	---	--	--	-------------------	CY	S	---	--------	18.0	7-10-56	
26bcc	-----do-----	----	H	Dr	50+	4	P	--	Two Medicine Formation	N	N	0	4,098.0	35.6	10- 2-56	

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34-6-31dcc	SCS #36	1953	L	B	9.6	3	P	G	Terrace deposits	N	O	1.2	--------	7.78	5-15-56	
32cdd	Phil Pendergrass	1938	H	Dr	36.5	6	P	--	--------------------	CY	D	0.8	3,839	4.82	6- 4-56	
34-7-21dbb	Theodore Brown	----	L	B	22.0	6	P	--	--------------------	CY	N	1.07	3,790	5.12	5-25-56	
23abb1	Dick Barnard	----	L	Du	5.0	42x30	W	G	Alluvium	N	N	-3.20	3,746	1.81	5-29-56	
23abb2	-----do-----	----	L	Du	9.40	60x30	W	G	---------do---------	CY	S	1.7	--------	6.42	5-29-56	
23dad	-----do-----	----	S	Dr	43.6	6	P	--	--------------------	VC	D	-6.88	3,876.14	10.90	5-29-56	
25bac	Frank Conway	1956	L	Dr	100+	5	P	--	--------------------	--	--	0	--------	39.2	5-29-56	
25bca	-----do-----	----	L	Dr	33.8	6	P	--	--------------------	N	N	---	3,914.89	23.99	5-29-56	
25bdb	-----do-----	----	S	Dr	47.5	6	P	--	--------------------	CY	S	0.55	--------	8.36	5-29-56	
26adb	Gene Joedobell	----	L	Dr	72.5	6	P	--	--------------------	N	N	0.6	3,923.73	23.49	5-29-56	
29add	Blackfeet Tribe	----	L	Dr	100.0	5	P	--	--------------------	CY	--	0.6	3,876.0	21.75	5-25-56	
30baa	Brian Connelly	1938	H	Dr	82.8	5	P	Ss(?)	--------------------	CY	N	---	3,848.0	29.92	5-25-56	Corrosive to pipe
31adb	Marvin Johnson	----	L	Du	12.0	---	--	G	Terrace deposits	--	--	---	--------	-----	5-25-56	
31dda	Wm. Gilham	----	L	Dr	32(?)	---	--	--	--------------------	CY	S	2.1	--------	11.18	5-25-56	
32dad	----------	----	L	Dr	59.0	5	P	--	--------------------	CY	N	0.5	3,919.06	31.3	5-25-56	
34add	Blackfeet Tribe	1938	L	Dr	90-100	5	P	Ss	--------------------	J	D	-5.5	--------	3.53	5-29-56	
34bab	George Horn #2	1946	L	Dr	100+	6	P	--	--------------------	CY	N	1.4	--------	58.0	5-28-56	
35aab	Alfreda Bird Connally	----	L	Dr	40.0	5	P	--	--------------------	VC	D,S	0.2	3,928.71	9.13	5-29-56	Corrosive 3929.16
35cbb	SCS #1	1953	L	B	7.7	3	P	G	Terrace deposits	N	O	---	3,944.90	dry	5-11-56	
35dbb	SCS #3	1953	L	B	8.6	3	P	G	---------do---------	N	O	1.0	3,938.99	dry	5-11-56	
36bbb	Beverly Loring	----	L	Dr	50	---	--	S	--------------------	J	D,S	---	--------	-----	-------	
36bdd	Helen Conway	----	L	Dr	52.2	6	P	--	--------------------	CY	S	---	--------	6.16	-------	Unfit for drinking
36caa	SCS #7	1953	L	B	8.75	3	P	G	Terrace deposits	N	O	0	3,923.55	5.93	5-11-56	
36cba	Alice Juneau	----	L	Dr	54	---	--	--	--------------------	CY	D	0.3	3,928.07	5.59	7-19-56	
36cbb	SCS #5	1953	L	B	8.5	3	P	G	Terrace deposits	N	O	0.4	3,929.69	6.80	5-11-56	
36cca	SCS #18	1953	L	B	9.2	3	P	G	---------do---------	N	O	0.5	3,928.90	6.22	5-16-56	
36dda1	Jim McNutt	----	L	Du	14.2	24	P	G	---------do---------	CY	N	0.65	3,920.72	8.14	5-29-56	
36dda2	-----do-----	----	L	Du	9.5	24	P	G	---------do---------	N	D	0.3	--------	7.90	5-29-56	
34-8-36acc	Art Hall	1940	S	Dr	63	6	P	--	--------------------	CY	D,S	---	--------	-----	-------	
36ddd1	Nellie Dustybull Fuile	----	S	Sp	----	24	--	--	--------------------	VC	D,S	0	--------	0	-------	Spring
36ddd2	-----do-----	----	S	Dr	52	5	P	--	--------------------	N	N	0.78	3,909.51	12.67	5-25-53	

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Table 3.--Logs of wells, test holes, and seismograph shot holes

Material	Thickness (feet)	Depth (feet)
32-6-1dd		
Clay, brown	60	60
Shale	90	150
32-6-16dd (Shot hole 1958)		
Clay	20	20
Shale, brown	20	40
Shale, blue	45	85
32-8-9ad (Shot hole 1976)		
Boulders	10	10
Clay	25	35
Shale	65	100
33-6-5ad (Shot hole 1900)		
Boulders	15	15
Clay	35	50
Shale	35	85
33-6-6aa (Shot hole 1901)		
Gravel	15	15
Clay and shale, brown	55	70
Shale, blue	25	95
33-6-6bad (S.C.S. test 49)		
Clay	7	7
Gravel	8	15
Sandstone	6	21

Table 3.--Logs of wells, test holes, and seismograph shot holes (cont'd)

Material	Thickness (feet)	Depth (feet)
33-6-7ab (Shot hole 1898)		
Fill	10	10
Clay, brown	60	70
Shale, blue	20	90
32-6-7aa (Shot hole 1965)		
Clay and gravel	40	40
Shale, blue	55	95
33-6-8ad (Shot hole 1902)		
Gravel and boulders	25	25
Clay	15	40
Shale	35	75
33-6-11cc (Shot hole 1921)		
Clay	20	20
Sandstone	15	35
Shale, blue	60	95
33-6-16cc (Shot hole 1903)		
Clay and broken rock	60	60
Shale	25	85
33-6-23ca (Shot hole 1922)		
Sandstone	45	45
Sandstone and shale	55	100
33-7-1aa (Shot hole 1895)		
Gravel and boulders	20	20
Clay	40	60
Shale	35	95

Table 3.--Logs of wells, test holes, and seismograph shot holes (cont'd)

Material	Thickness (feet)	Depth (feet)
33-7-1bad (S.C.S. test 45)		
Clay	8	8
Gravel	8	16
Shale	8	24
33-7-1cbd (U.S.G.G. test 3)		
Clay topsoil	1	1
Sand, medium to coarse, well-sorted and clean.	13	14
Gravel, pebble- to cobble-size, appears clean.	4	18
Shale, sandy, gray	4	22
33-7-1dd (Shot hole 1899)		
Gravel and boulders	20	20
Clay	30	50
Shale, blue	45	95
33-7-2abb (U.S.G.S. test 1)		
Clay and silt, yellowish-gray	8	8
Gravel, mostly pebble-size, takes water	2	10
Gravel, pebble- to cobble-size	8	18
Shale, sandy	4	22
33-7-2cca (S.C.S. test 69)		
Silt	6	6
Clay, silt, and sand	7	13
Gravel	2	15
Shale	1	16
33-7-2cdd (S.C.S. test 83)		
Clay	6	6
Gravel	6	12
Shale	3	15

Table 3.--Logs of wells, test holes, and seismograph shot holes (cont'd)

Material	Thickness (feet)	Depth (feet)
33-7-2ddc (S.C.S. test 84)		
Clay	9	9
Gravel	8	17
Shale	8	25
33-7-3acc (S.C.S. test 50)		
Clay	4	4
Gravel	11	15
Sandstone	4	19
33-7-3cdd (S.C.S. test 79)		
Clay	6	6
Gravel	11	17
Clay	1	18
Gravel	2	20
Shale	3	23
33-7-3dbb (U.S.G.S. test 2)		
Clay, yellowish-gray, sandy	10	10
Sand, fine to medium	4	14
Gravel	4	18
Shale, greenish-gray	4	22
33-7-9dd (Shot hole 1936)		
Gravel and boulders	30	30
Clay	10	40
Shale, blue, hard	55	95
33-7-13cc (Shot hole 1904)		
Clay and shale	50	50
Clay	10	60
Shale	45	105

Table 3.--Logs of wells, test holes, and seismograph shot holes (cont'd)

Material	Thickness (feet)	Depth (feet)
33-7-18dd (Shot hole 1912)		
Gravel and boulders	40	40
Clay, brown	10	50
Shale, blue	45	95
33-7-27dd (Shot hole 1935)		
Boulders	20	20
Clay	20	40
Shale	50	90
33-8-1bb (Shot hole 1893)		
Gravel and boulders	35	35
Sandstone	20	55
33-8-2bb (Shot hole 1870)		
Clay	30	30
Shale, blue	45	75
33-8-14dc (Shot hole 1943)		
Gravel and boulders	30	30
Clay	15	45
Shale, blue, hard	55	100
33-8-15cc (Shot hole 1940)		
Gravel and boulders	25	25
Clay and shale, brown	40	65
Shale, blue, hard	35	100

Table 3.--Logs of wells, test holes, and seismograph shot holes (cont'd)

Material	Thickness (feet)	Depth (feet)
33-8-25dd (Shot hole 1937)		
Gravel and boulders	25	25
Clay	10	35
Shale, blue, hard	60	95
33-8-28dd (Shot hole 1939)		
Gravel and boulders with clay streaks	60	60
Gravel and boulders	10	70
Shale, blue	40	110
33-8-33cc (Shot hole 910)		
Gravel and boulders	30	30
Clay and shale	55	85
33-8-34dd (Shot hole 911)		
Clay	20	20
Gravel and boulders	45	65
Shale, hard	20	85
34-6-28dc (Shot hole 1897)		
Clay and sandstone "ledges"	40	40
Shale	45	85
34-6-31cb (Shot hole 1944)		
Gravel and clay	15	15
Shale, brown	55	70
Shale, blue	25	95

Table 3.--Logs of wells, test holes, and seismograph shot holes (cont'd)

Material	Thickness (feet)	Depth (feet)
34-6-32bb (Shot hole 1896)		
Clay and gravel	20	20
Shale, brown	50	70
Shale, blue	20	90
34-7-30ad (Shot hole 1883)		
Boulders	20	20
Sandstone	15	35
Sandstone and shale	65	100
34-7-31cc (Shot hole 1892)		
Gravel and boulders	35	35
Sandstone and shale	40	75
34-7-35ccd (S.C.S. test 14)		
Clay	5	5
Gravel	10	15
Shale	2	17
34-7-35ddb (S.C.S. test 16)		
Silt	3	3
Clay	3	6
Clay, sand, and gravel	3	9
Gravel	5	14
Shale	2	16

Table 4.--Water levels in observation wells

(In feet below land surface)

33-6-6aba

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
May 16	9.74	Oct. 9	8.88	May 9	9.46
July 20	6.19	1957		May 28	8.40
Sept. 10	8.35	March 20	9.58		

33-6-6bdb (S.C.S. 48)

Date	Water level	Date	Water level	Date	Water level
1956		1956		1956	
May 15 dry at	8.00	Aug. 6	5.94	Sept. 7	6.93
July 9	5.54	Aug. 13	5.83	Sept. 21	7.43
July 23	5.70	Aug. 20	6.01	Oct. 2	7.75
July 31	6.05	Aug. 27	6.41	Nov. 14 dry at	8.00

33-6-6cbc

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
June 1	8.30	Oct. 4	9.18	March 20	8.60
July 19	7.78	Nov. 16	9.38	May 9	8.40
Sept. 10	8.87				

33-6-6cdd (S.C.S. 91)

Date	Water level	Date	Water level	Date	Water level
1956		1956		1956	
May 15	3.65	Aug. 20	4.07	Dec. 10	4.60
July 9	2.95	Aug. 27	4.17	1957	
July 23	4.01	Sept. 7	4.39	May 9	4.28
July 31	4.51	Sept. 21	4.60	May 31	4.30
Aug. 6	3.80	Oct. 2	4.55	July 13	5.45
Aug. 13	3.58	Nov. 14	4.35	Nov. 14	4.48

33-6-7bcb

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
June 1	6.66	Oct. 4	6.07	May 8	6.45
July 19	3.80	Nov. 16	6.17		
Sept. 10	5.78				

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

33-6-7ccc

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
June 4	6.66	Nov. 16	5.94	May 30	6.29
July 19	4.47	1957		July 14	4.70
Aug. 8	4.46	May 9	5.75		
Oct. 4	5.13				

33-6-8bca

Date	Water level	Date	Water level	Date	Water level
1956		1956		1956	
June 6	8.23	Aug. 16	6.69	Oct. 7	7.17
June 18	8.17	Aug. 24	6.86	Oct. 16	7.20
June 27	7.78	Aug. 31	6.97	1957	
July 5	7.63	Sept. 7	7.08	May 9	7.84
July 13	7.07	Sept. 15	7.15	May 30	7.81
July 20	7.05	Sept. 22	7.17	July 14	7.30
July 30	7.12	Sept. 29	7.11	Nov. 14	8.05
Aug. 7	6.82				

33-6-8bcd

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
June 6	6.40	Nov. 16	6.18	May 9	6.68
July 20	5.55	Dec. 11	6.04	May 30	6.78
Aug. 8	6.86	1957		Nov. 14	6.95
Oct. 4	5.50	Mar. 21	7.20		

33-6-8dcd

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
June 7	7.18	Nov. 16	7.32	May 9	6.09
July 20	6.25	Dec. 11	7.34	May 30	7.03
Sept. 10	6.90	1957		July 15	7.00
Oct. 4	7.27	Mar. 21	7.55	Nov. 14	8.04

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

Date	Water level	Date	Water level	Date	Water level
		33-6-16aab			
1957		1957		1957	
Mar. 20	13.36	May 30	13.89	Nov. 14	12.97
May 9	13.77	July 15	12.47		
		33-6-17bca			
1956		1956		1957	
May 21	9.39	Nov. 16	7.04	May 9	9.00
July 13	7.43	Dec. 11	dry at 9.50	May 30	8.23
Sept. 10	6.78	1957		July 15	6.50
Oct. 4	6.76	Mar. 21	dry at 9.50	Nov. 14	7.20
		33-6-17ccc			
1956		1956		1957	
May 21	2.74	Oct. 4	3.63	Mar. 20	3.85
July 13	0.78	Nov. 16	3.59	May 9	3.40
Aug. 8	3.88	Dec. 11	3.53	Nov. 14	3.55
Sept. 10	3.13				
		33-6-28bcb			
1956		1957		1957	
Aug. 28	7.61	May 9	9.50	Nov. 14	9.55
Oct. 2	7.80	May 30	9.60		
Nov. 14	8.24				
		33-7-1aaa (S.C.S. 34)			
1956		1956		1956	
May 11	7.90	Aug. 20	5.08	Dec. 10	7.60
July 9	2.85	Aug. 27	5.42	1957	
July 23	4.27	Sept. 7	6.04	May 9	7.95
July 31	5.24	Sept. 21	6.44	May 28	7.20
Aug. 6	5.00	Oct. 2	6.62	July 13	4.19
Aug. 13	4.80	Nov. 14	7.42	Nov. 14	6.50

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

Date	Water level	Date	Water level	Date	Water level
		33-7-1bca (S.C.S. 44)			
1956		1956		1957	
May 16	5.52	Aug. 27	5.87	Mar. 21	6.60
July 10	3.42	Sept. 7	6.06	May 9	5.41
July 23	4.61	Sept. 21	6.23	May 29	5.28
July 31	5.28	Oct. 2	6.24	July 13	5.71
Aug. 6	5.47	Nov. 14	6.13	Nov. 14	6.90
Aug. 13	5.53	Dec. 10	6.05		
Aug. 20	5.67				
		33-7-1cca (S.C.S. 73)			
1956		1956		1957	
May 17	3.09	Aug. 27	2.44	Mar. 21	4.93
July 10	1.88	Sept. 7	2.80	May 9	3.13
July 23	2.17	Sept. 21	3.05	May 29	3.58
July 31	2.75	Oct. 2	3.25	July 13	2.81
Aug. 6	2.20	Nov. 14	3.45	Nov. 14	4.46
Aug. 13	1.79	Dec. 10	3.38		
Aug. 20	2.35				
		33-7-1dac (S.C.S. 75)			
1956		1956		1957	
May 17	2.87	Aug. 27	3.80	Mar. 21	3.93
July 10	2.25	Sept. 7	4.21	May 9	2.88
July 23	3.25	Sept. 21	4.47	May 29	3.53
July 31	3.92	Oct. 2	4.35	July 13	5.28
Aug. 6	3.21	Nov. 14	3.20	Nov. 14	4.69
Aug. 13	2.91	Dec. 10	3.55		
Aug. 20	3.58				
		33-7-1dda			
1956		1956		1957	
June 1	7.99	Oct. 4	9.26	May 9	8.61
July 6	6.90	Nov. 16	9.45	May 30	8.23
July 19	7.46	1957		July 13	8.96
Aug. 8	8.24	Mar. 20	8.96	Nov. 14	8.68
Sept. 10	8.96				

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

33-7-1ddd (S.C.S. 89)

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
May 11	5.89	Aug. 20	5.84	Mar. 20	6.61
July 9	3.56	Aug. 27	6.07	May 8	6.64
July 23	4.93	Sept. 6	6.38	May 30	6.63
July 30	5.52	Sept. 21	6.61	July 13	6.95
July 31	5.56	Oct. 2	6.70	Nov. 14	6.91
Aug. 6	5.55	Nov. 14	6.70		
Aug. 13	5.50	Dec. 10	7.00		

33-7-2abb1

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
July 31	2.57	Sept. 7	2.67	Mar. 20	6.13
Aug. 6	1.90	Sept. 21	2.65	May 8	3.19
Aug. 13	1.51	Oct. 2	2.59	May 28	3.45
Aug. 20	2.17	Nov. 14	3.34	July 13	5.05
Aug. 26	2.46				

33-7-2abb2 (S.C.S. 28)

Date	Water level	Date	Water level	Date	Water level
1956		1956		1956	
May 17	3.90	Aug. 20	2.35	Dec. 10	4.18
July 9	2.21	Aug. 27	2.46	1957	
July 23	2.75	Sept. 7	2.70	Mar. 20	6.25
July 31	3.35	Sept. 21	2.45	May 8	3.62
Aug. 6	2.28	Oct. 2	2.37	May 28	2.95
Aug. 13	2.00	Nov. 14	3.75	Nov. 13	2.87

33-7-2add (S.C.S. 56)

Date	Water level	Date	Water level	Date	Water level
1956		1956		1956	
May 17	3.52	Aug. 20	4.12	Dec. 10	5.00
July 10	2.11	Aug. 27	4.39	1957	
July 23	2.90	Sept. 7	4.70	May 9	4.01
July 31	3.79	Sept. 21	5.05	May 29	4.35
Aug. 6	3.84	Oct. 2	5.16	July 13	5.45
Aug. 13	3.84	Nov. 14	5.03		

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

33-7-2bbb (S.C.S. 26)

Date	Water level	Date	Water level	Date	Water level
1956		1956		1956	
May 11	6.00	Aug. 20	3.54	Dec. 10	6.06
July 6	0.91	Aug. 27	3.63	1957	
July 9	1.54	Sept. 7	3.89	Mar. 20	6.10
July 23	1.72	Sept. 21	3.69	May 8	5.19
July 31	3.75	Oct. 2	3.61	May 28	4.37
Aug. 6	3.34	Nov. 14	5.56	July 13	3.72
Aug. 13	3.24			Nov. 13	3.32

33-7-2cdb (S.C.S. 69)

Date	Water level	Date	Water level	Date	Water level
1956		1956		1956	
May 17	7.88	Aug. 20	6.65	Dec. 10	7.34
July 10	6.88	Aug. 27	6.65	1957	
July 23	6.22	Sept. 7	6.80	May 8	6.70
July 31	6.55	Sept. 21	6.95	May 28	6.80
Aug. 6	6.84	Oct. 2	6.98	July 12	Dry
Aug. 13	6.71	Nov. 14	7.38	Nov. 13	Dry

33-7-2cdd (S.C.S. 83)

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
July 6	2.35	Aug. 27	4.65	Mar. 20	6.20
July 23	3.45	Sept. 6	4.97	May 8	5.49
July 31	4.15	Sept. 21	5.27	May 30	5.49
Aug. 6	3.99	Oct. 2	5.53	July 13	5.32
Aug. 13	3.99	Nov. 14	5.96	Nov. 13	4.96
Aug. 20	4.33	Dec. 10	6.06		

33-7-2ddc (S.C.S. 84)

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
July 19	2.55	Aug. 20	4.77	Mar. 20	7.30
July 23	3.27	Aug. 27	5.41	May 8	6.30
July 30	4.68	Sept. 6	5.86	May 30	6.47
July 31	4.26	Sept. 21	6.31	July 13	3.63
Aug. 1	0.87	Oct. 2	6.53	Nov. 13	5.25
Aug. 6	3.10	Nov. 14	6.34		
Aug. 13	3.70				

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

33-7-3cac

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
June 4	3.67	Aug. 7	1.86	May 8	3.89
June 20	2.15	Sept. 8	2.44	May 28	3.33
July 17	1.70	Oct. 3	2.33	July 13	3.41
July 31	2.31	1957		Nov. 13	4.60
Aug. 3	1.59	Mar. 21	6.70		

33-7-3cba

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
June 4	4.49	Sept. 8	1.94	May 8	3.70
June 20	2.90	Oct. 3	2.21	May 28	3.57
July 17	1.10	Dec. 11	4.69	July 13	4.10
July 31	2.75	1957		Nov. 13	4.10
Aug. 3	2.13	Mar. 21	6.58		
Aug. 7	2.14				

33-7-3cbd

Date	Water level	Date	Water level	Date	Water level
1956		1957		1957	
May 28	5.54	Mar. 21	6.57	July 13	5.49
July 17	3.13	May 8	4.44	Nov. 13	4.76
Sept. 8	3.63	May 28	4.57		
Oct. 3	3.86				

33-7-3cdc2

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
May 28	4.75	Nov. 14	3.18	May 8	3.87
July 17	2.28	Dec. 11	4.48	May 28	3.78
Aug. 7	2.66	1957		July 13	3.83
Sept. 8	3.06	Mar. 21	5.08	Nov. 13	3.98
Oct. 3	3.08				

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

Date	Water level	Date	Water level	Date	Water level
		33-7-3ddd			
1956		1956		1956	
June 4	4.68	Sept. 8	4.83	Nov. 14	5.26
July 17	2.61	Oct. 3	5.53		
		33-7-4cdb			
1956		1956		1957	
May 25	14.48	Nov. 14	11.97	May 8	13.97
July 16	12.25	Dec. 11	12.48	May 29	13.22
Aug. 6	11.68	1957		July 12	12.13
Sept. 8	10.84	Mar. 20	14.24	Nov. 13	12.12
Oct. 3	10.61				
		33-7-9bca			
1956		1957		1957	
Sept. 17	7.94	Mar. 20	8.52	July 12	8.47
Oct. 3	8.08	May 8	8.04	Nov. 13	8.78
Nov. 14	8.36	May 29	8.08		
Dec. 11	8.55				
		33-7-9cdd			
1956		1956		1957	
June 1	8.26	Nov. 14	8.83	May 8	9.24
July 16	8.35	Dec. 11	8.91	May 29	9.42
Aug. 6	8.58	1957		July 12	9.60
Sept. 8	8.03	Mar. 20	9.00	Nov. 13	10.02
Oct. 3	8.33				
		33-7-10abd (S.C.S. 93)			
1956		1956		1957	
May 14	5.93	Aug. 20	3.45	Mar. 20	6.68
July 11	2.62	Aug. 27	3.69	May 8	5.00
July 23	3.22	Sept. 7	3.89	May 30	3.66
July 31	3.57	Sept. 21	4.23	Nov. 13	3.50
Aug. 6	2.87	Nov. 14	4.82		
Aug. 13	2.93				

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

33-7-10dac

Date	Water level	Date	Water level	Date	Water level
1956		1956		1956	
June 1	6.57	Aug. 13	5.10	Nov. 14	7.34
June 22	4.22	Aug. 22	5.88	Dec. 11	7.54
June 25	4.64	Aug. 31	6.26	1957	
June 29	5.16	Sept. 7	6.51	Mar 20	8.40
July 2	5.46	Sept. 15	6.70	May 8	5.67
July 5	3.56	Sept. 22	6.87	May 30	4.66
July 11	4.14	Sept. 29	6.98	July 13	6.09
July 17	4.82	Oct. 2	7.02	Nov. 13	3.81
July 25	5.48	Oct. 7	7.11		
Aug. 2	5.97	Oct. 16	7.20		

33-7-11aaa (S.C.S. 85)

Date	Water level	Date	Water level	Date	Water level
1956		1956		1956	
May 11	6.23	Aug. 20	4.61	Dec. 10	5.99
July 9	2.54	Aug. 27	4.98	1957	
July 23	3.75	Sept. 6	5.14	Mar. 20	7.28
July 30	4.53	Sept. 21	5.40	May 8	5.48
July 31	4.58	Oct. 2	5.55	May 30	5.58
Aug. 6	4.10	Nov. 14	5.46		
Aug. 13	4.06				

33-7-11aac (S.C.S. 97)

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
May 11	4.00	Aug. 20	4.86	Mar. 21	5.25
July 10	3.40	Aug. 27	5.43	May 9	6.03
July 23	4.46	Sept. 7	5.88	May 29	4.04
July 30	5.24	Sept. 21	6.18	July 13	5.99
July 31	5.30	Oct. 2	6.33	Nov. 14	4.70
Aug. 6	2.08	Nov. 14	6.30		
Aug. 13	4.00	Dec. 10	6.50		

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

33-7-11dbal

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
June 1	6.98	Oct. 14	8.00	May 9	7.80
July 16	5.32	1957		July 13	7.79
Aug. 7	6.24	Mar. 21	8.02	Nov. 14	6.86
Sept. 10	7.27				

33-7-12baa (S.C.S. 87)

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
May 11	7.13	Aug. 20	5.16	Mar. 20	7.10
July 9	3.22	Aug. 27	5.58	May 8	6.10
July 23	4.40	Sept. 6	5.83	May 30	5.65
July 30	5.21	Sept. 21	6.05	July 13	6.05
July 31	5.28	Oct. 2	6.08	Nov. 14	6.40
Aug. 6	4.81	Nov. 14	5.70		
Aug. 13	4.66	Dec. 10	6.41		

33-7-12dad

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
June 1	5.57	Oct. 4	4.60	May 8	5.86
July 19	3.20	Nov. 16	4.94	May 30	6.14
Aug. 8	3.43	1957		July 14	4.66
Sept. 10	4.29	Mar. 21	6.98	Nov. 14	4.58

33-7-13caa2

Date	Water level	Date	Water level	Date	Water level
1956		1956		1956	
May 21	6.97	Aug. 8	5.77	Dec. 11	6.76
July 12	4.98	Nov. 16	6.67		

33-7-13cbd

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
May 22	11.27	Nov. 16	9.65	May 30	10.80
July 12	8.32	1957		July 14	8.10
Sept. 10	8.68	Mar. 21	10.53	Nov. 14	10.08
Oct. 4	8.62	May 9	10.73		

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

Date	Water level	Date	Water level	Date	Water level
		33-7-13daa			
1956		1956		1957	
May 18	8.60	Nov. 16	8.29	May 9	8.43
July 12	7.28	Dec. 11	8.30	May 30	8.62
Aug. 8	7.50	1957		July 14	9.20
Sept. 10	8.10	Mar. 21	8.50	Nov. 14	8.17
Oct. 4	8.30				
		33-7-13dbc			
1956		1956		1957	
May 21	10.20	Oct. 4	8.55	May 9	10.05
July 12	6.66	Nov. 16	9.10	May 30	10.18
Aug. 8	7.39	1957		July 14	7.80
Sept. 10	8.18	Mar. 21	10.07	Nov. 14	10.00
		33-7-20bdb			
1956		1956		1957	
May 22	15.68	Nov. 16	12.90	May 29	15.10
July 10	12.77	Dec. 11	13.20	July 12	15.28
Sept. 12	11.82	1957		Nov. 13	15.64
Oct. 17	12.34	Mar. 20	14.46		
		33-8-3dad			
1956		1956		1957	
May 23	6.23	Oct. 2	5.54	Mar. 20	5.83
July 16	5.79	Nov. 14	6.25	May 8	5.62
Aug. 6	5.70	Dec. 11	6.38	May 29	5.60
Sept. 8	5.78			Nov. 13	6.45

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

Date	Water level	Date	Water level	Date	Water level
		33-8-10cbb			
1956		1956		1957	
May 23	6.04	Nov. 14	6.75	May 8	5.84
July 16	6.10	Dec. 11	6.67	May 29	6.17
Aug. 6	6.83	1957		July 12	7.13
Sept. 8	7.03	Mar. 20	5.53	Nov. 13	7.29
Oct. 2	7.18				
		33-8-11cbd			
1956		1956		1957	
Aug. 10	8.78	Nov. 14	10.80	May 8	11.22
Sept. 8	9.23	Dec. 11	11.05	May 29	11.52
Oct. 2	9.85			July 12	12.51
		33-8-21ddd			
1956		1956		1957	
May 15	10.42	Nov. 14	9.80	May 8	10.06
Aug. 6	9.75	Dec. 11	10.00	May 28	10.06
Sept. 7	9.73	1957		July 12	10.17
Oct. 2	9.77	Mar. 20	10.00	Nov. 13	10.44
		34-7-21dbb			
1956		1956		1956	
May 25	4.05	Sept. 8	4.33	Nov. 14	4.93
Aug. 7	4.13	Oct. 3	4.53		
		34-7-23abb1			
1956		1956		1957	
May 29	5.01	Oct. 4	6.96	May 9	4.97
July 19	4.61	Nov. 14	6.89	May 30	5.70
Aug. 7	6.58	Dec. 11	6.62	July 13	6.83
Sept. 10	6.94			Nov. 13	7.10

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

Date	Water level	Date	Water level	Date	Water level
		34-7-23dad			
1956		1956		1956	
May 29	17.78	Sept. 10	12.83	Nov. 14	13.67
July 19	13.35	Oct. 4	12.91		
		34-7-25bca			
1956		1956		1956	
May 29	23.74	Sept. 10	16.41	Dec. 12	18.39
July 19	16.66	Oct. 4	17.49		
Aug. 7	15.53	Nov. 14	18.35		
		34-7-32dad			
1956		1956		1957	
May 25	30.80	Oct. 3	30.30	Mar. 21	30.18
July 16	28.05	Nov. 14	30.35	Nov. 13	31.56
Aug. 6	29.14	Dec. 11	30.53		
Sept. 8	29.62				
		34-7-35aab			
1956		1956		1957	
May 29	9.13	Oct. 4	9.30	May 9	9.44
July 19	7.44	Nov. 14	9.79	May 30	9.33
Aug. 7	8.08	1957		July 13	9.92
Sept. 10	8.88	Mar. 21	9.86	Nov. 13	11.35
		34-7-35cbb (S.C.S. 1)			
1956		1956		1957	
May 11	dry at 7.00	Aug. 27	5.75	Mar. 20	dry at 7.00
July 9	4.21	Sept. 7	6.23	May 8	6.80
July 23	4.63	Sept. 21	6.31	May 28	4.98
July 31	5.30	Oct. 2	6.95	July 13	4.95
Aug. 6	4.97	Nov. 14	6.95	Nov. 13	3.74
Aug. 13	5.02	Dec. 10	dry at 7.00		
Aug. 20	5.41				

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

Date	Water level	Date	Water level	Date	Water level
		34-7-35dbb (S.C.S. 3)			
1956		1956		1957	
May 11	dry at 8.00	Aug. 27	7.15	Mar. 20	dry at 8.00
July 9	5.68	Sept. 7	7.34	May 8	7.81
July 23	6.13	Sept. 21	7.63	May 28	7.70
July 31	5.98	Oct. 2	7.68	July 13	dry at 8.00
Aug. 6	6.96	Nov. 14	dry at 8.00	Nov. 13	7.12
Aug. 13	6.82	Dec. 10	dry at 8.00		
Aug. 20	6.98				
		34-7-36cca (S.C.S. 18)			
1956		1956		1956	
May 16	5.72	Aug. 20	4.35	Dec. 10	5.28
July 9	2.04	Aug. 27	4.69	1957	
July 23	5.25	Sept. 7	5.19	May 9	5.24
July 31	3.74	Sept. 21	4.06	May 28	4.35
Aug. 6	3.91	Oct. 2	3.33	July 13	5.45
Aug. 13	4.04	Nov. 14	4.89	Nov. 13	4.08
		34-7-36caa (S.C.S. 7)			
1956		1956		1957	
May 11	5.93	Aug. 20	4.71	Mar. 20	7.65
July 6	1.69	Aug. 27	5.13	May 9	5.48
July 9	2.45	Sept. 7	5.69	May 28	5.70
July 23	3.75	Sept. 21	5.70	July 13	7.26
July 31	4.45	Oct. 2	5.25	Nov. 13	5.75
Aug. 6	4.21	Nov. 14	5.60		
Aug. 13	4.18	Dec. 10	5.95		

Table 4.--Water levels in observation wells (cont'd)

(In feet below land surface)

34-7-36cbb (S.C.S. 5)

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
May 11	6.40	Aug. 20	5.66	Mar. 20	5.87
May 29	6.41	Aug. 27	5.92	May 8	5.99
July 9	3.90	Sept. 7	6.29	May 28	6.27
July 23	4.63	Sept. 21	6.60	July 13	7.21
July 31	5.29	Oct. 2	6.72	Nov. 13	7.25
Aug. 6	5.46	Nov. 14	6.45		
Aug. 13	5.44	Dec. 10	6.60		

34-7-36dda1

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
May 29	7.49	Oct. 4	7.93	May 9	8.17
July 19	3.85	Nov. 16	8.46	May 28	8.15
Aug. 8	5.60	1957		July 13	9.29
Sept. 10	7.10	Mar. 21	9.29		

34-8-36ddd2

Date	Water level	Date	Water level	Date	Water level
1956		1956		1957	
May 25	11.87	Nov. 14	9.69	May 8	11.20
July 16	9.44	Dec. 11	9.99	May 29	11.13
Aug. 6	8.55	1957		July 12	10.43
Sept. 8	8.86	Mar. 20	11.10	Nov. 13	9.75
Oct. 3	9.20				

Table 6.--Aquifer test data

Well 33-7-1cbd (USGS 3)
July 20, 1957
Static water level 5.11 feet below measuring point
Pumping rate 11 gpm

Drawdown

Time since pumping started (minutes)	Depth to water (feet)
7	6.89
10	7.16
15	7.29
20	7.41
25	7.36
30	7.39
40	7.63
50	7.64
60	7.68
70	7.71
80	7.71
90	7.75
100	7.76
120	7.79
140	7.85
160	7.93
180	7.97

Recovery

Time since pumping stopped (minutes)	Depth to water (feet)
2	6.41
3	6.24
4	6.15
5	6.08
6	6.01
7	5.95
8	5.90
9	5.84
10	5.80
12	5.76
14	5.68
16	5.63
18	5.58
20	5.55
23	5.51
26	5.47
30	5.43
35	5.38
40	5.35
45	5.32
50	5.29
60	5.26
70	5.23

Table 6.--Aquifer test data (cont'd)

Well 33-7-2abb (USGS 1)
July 18, 1957
Static water level 3.50 feet below measuring point
Pumping rate 5 gpm

Drawdown		Recovery	
Time since pumping started (minutes)	Depth to water (feet)	Time since pumping stopped (minutes)	Depth to water (feet)
2	8.83	1	8.00
7	12.22	2	7.39
9	12.78	3	6.30
10	13.26	4	5.70
13	14.01	5	5.68
15	14.23	6	5.56
23	16.31	7	5.44
	pumping rate reduced		
25	15.49	8	5.31
28	13.87	9	5.15
30	12.92	10	4.98
32	12.18	12	4.65
35	11.35	14	4.45
40	10.19	17	4.31
45	10.12	20	4.23
50	10.54	25	4.14
55	10.45	30	4.08
60	10.50	35	4.04
70	10.45	40	4.00
80	10.37	50	3.96
93	10.39	60	3.91
100	10.38	70	3.88
120	10.42	80	3.85
140	10.57	90	3.83
160	10.72	100	3.81
180	10.74	120	3.78
200	10.73	140	3.76
220	10.76	160	3.74
240	10.83	180	3.73
260	10.84	200	3.72
280	11.04	229	3.70
300	11.12		

Table 6.--Aquifer test data (cont'd)

Observation well 33-7-2abb (SCS 28)
July 18, 1957
Well located 25.4 feet from pumped well
Static water level 3.73 feet below measuring point

Drawdown		Recovery	
Time since pumping started (minutes)	Depth to water (feet)	Time since pumping stopped (minutes)	Depth to water (feet)
1	3.75	1	4.35
2	3.79	2	4.34
3	3.82	3	4.33
4	3.85	4	4.31
5	3.88	5	4.25
6	3.91	6	4.24
7	3.94	7	4.24
8	3.97	8	4.23
9	3.98	9	4.21
10	4.00	10	4.20
11	4.02	12	4.17
12	4.04		
13	4.05	16	4.12
14	4.06	18	4.03
15	4.07	20	3.85
16	4.08	22	4.07
17	4.09	24	4.05
18	4.10	26	4.04
19	4.11	28	4.03
20	4.12	32	4.01
22	4.14	35	4.00
24	4.14	40	3.98
26	4.16	50	3.96
28	4.16	60	3.93
30	4.17	70	3.91
34	4.18	80	3.90
42	4.17	90	3.89
45	4.17	100	3.87
50	4.17	120	3.86
60	4.19	140	3.84
70	4.20	160	3.83
80	4.21	180	3.82
90	4.22	200	3.82
100	4.23	229	3.82

Table 6.--Aquifer test data (cont'd)

Observation well 33-7-2abb (SCS 28) - continued

Drawdown		Recovery	
Time since pumping started (minutes)	Depth to water (feet)	Time since pumping stopped (minutes)	Depth to water (feet)
120	4.25		
140	4.27		
160	4.29		
180	4.30		
200	4.31		
220	4.32		
240	4.33		
260	4.34		
280	4.34		
300	4.35		

Table 6.--Aquifer test data (cont'd)

Well 33-7-3dbb (USGS 2)
July 16, 1957
Static water level 4.22 below measuring point
Pumping rate 5 gpm

Drawdown		Recovery	
Time since pumping started (minutes)	Depth to water (feet)	Time since pumping stopped (minutes)	Depth to water (feet)
5	11.35	1	10.31
11	11.79	2	8.21
19	11.03	3	6.85
	adjusted pumping rate		
20	11.09	4	5.99
25	11.34	5	5.45
30	11.57	6	5.10
35	11.71	7	4.89
40	12.59	8	4.73
45	12.42	9	4.62
50	12.12	10	4.55
55	12.06	12	4.46
60	12.06	14	4.41
70	12.20	17	4.35
80	12.10	20	4.34
90	12.00	25	4.31
106	12.68	30	4.30
120	12.58	40	4.27
146	13.94	50	4.25
160	13.46	60	4.23
180	13.53	80	4.21
205	13.35	100	4.20
225	13.25	120	4.19
250	13.53	150	4.17
		200	4.15

Table 6.--Aquifer test data (cont'd)

Well 33-7-3cbd (Farm well)
July 19, 1957
Static water level 6.04 below measuring point
Pumping rate 15 gpm

Drawdown		Recovery	
Time since pumping started (minutes)	Depth to water (feet)	Time since pumping stopped (minutes)	Depth to water (feet)
1	6.09	1	8.65
2	6.13	2	8.55
3	6.20	3	8.46
4	6.25	4	8.37
5	6.30	5	8.28
6	6.38	6	8.20
7	6.43	8	8.03
8	6.50	10	7.87
9	6.57	12	7.75
10	6.65	14	7.63
12	6.77	17	7.48
14	6.83	20	7.35
16	6.91	25	7.20
18	6.97	30	7.07
20	7.00	40	6.91
23	7.06	50	6.80
26	7.10	60	6.71
30	7.14	70	6.64
35	7.18	80	6.60
40	7.23	90	6.57
45	7.27	100	6.53
50	7.31	120	6.48
55	7.35	140	6.44
60	7.37	160	6.40
70	7.56		
80	7.67		
90	7.76		
100	7.85		
110	7.93		
120	8.03		
130	8.13		
140	8.24		
160	8.37		
180	8.47		
200	8.61		
220	8.76		

Table 6.--Aquifer test data (cont'd)

Well 33-7-9cdd (Farm well)
July 20, 1957
Static water level 9.69 feet below measuring point
Pumping rate 25 gpm

Drawdown		Recovery	
Time since pumping started (minutes)	Depth to water (feet)	Time since pumping stopped (minutes)	Depth to water (feet)
1	9.86	1	11.85
2	9.96	2	11.77
3	10.06	3	11.67
4	10.14	4	11.58
5	10.22	5	11.50
6	10.30	6	11.42
7	10.38	7	11.34
8	10.45	8	11.27
9	10.50	9	11.21
10	10.56	10	11.15
12	10.67	12	11.04
14	10.77	14	10.94
16	10.86	16	10.85
18	10.94	18	10.77
20	11.02	22	10.64
23	11.11	24	10.58
26	11.18	27	10.50
30	11.28	30	10.44
35	11.37	35	10.38
40	11.45	40	10.31
45	11.51	45	10.25
50	11.58	50	10.20
55	11.63	55	10.15
60	11.69	60	10.11
70	11.75	70	10.06
80	11.80	80	10.01
90	11.84	90	9.98
100	11.87	100	9.96
120	11.93	110	9.94
140	11.99	120	9.92
		130	9.91