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GEOLOGICAL SURVEY CIRCULAR 238

GROUND-WATER CONDITIONS IN THE SOIL AND MOISTURE CONSERVATION DEMONSTRATION AREA NEAR TORRINGTON, GOSHEN COUNTY WYOMING

By F. N. Visher and H. M. Babcock

WITH A SECTION ON THE CHEMICAL QUALITY OF THE GROUND WATER

By W. H. Durum and R. A. Krieger

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Prepared as part of program of the
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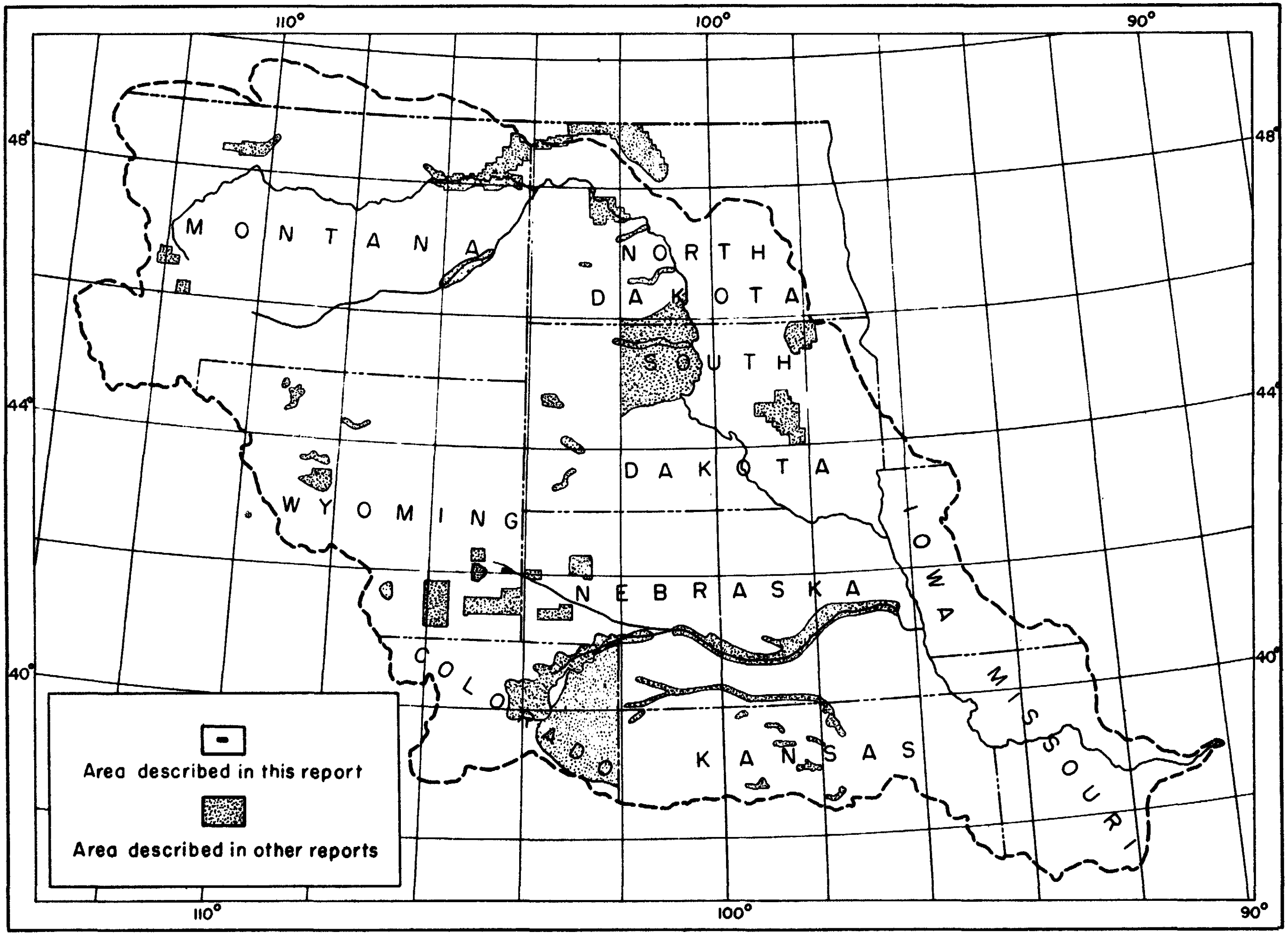

Map of the Missouri River Basin showing areas in which ground-water studies have been made under Missouri Basin Development Program

CONTENTS

ILLUSTRATIONS

TABLES

GROUND-WATER CONDITIONS IN THE SOIL AND MOISTURE CONSERVATION DEMONSTRATION AREA NEAR TORRINGTON, GOSHEN COUNTY, WYOMING

ABSTRACT

The Soil and Moisture Conservation Demonstration Area, described in this report, is about 6 miles southwest of Torrington, Goshen County, Wyo. Most of the area is underlain by fine-grained slope wash; all irrigated land in the area is underlain by this material. The Brule formation, a fractured siltstone, underlies the slope wash in the northern part of the area; the Chadron formation, predominantly a tight clay, underlies the slope wash in the central part of the area; and a coarse sand and gravel underlies the slope wash in the southern part of the area. Shallow unconfined ground water is contained in the slope wash within about 10 feet of the land surface in most of the area.

Seepage from canals and laterals, from irrigation water applied to the land, and from precipitation are the sources of ground-water recharge. In the part of the area that is adjacent to the Fort Laramie canal, where the slope wash is underlain by the Brule formation, seepage from the canal is the source of considerable ground-water recharge. Water moves away from the canal through fractures in the Brule formation and thence upward through the slope wash under hydrostatic head, which in some places is sufficient to force the water to the surface.

Transpiration by plants and evaporation from the land surface are the main means of ground-water discharge in the area. In most of the area, the capillary fringe extends to the root zone of the plants and, in part of the area, it reaches the land surface. Where water is discharged through evaporation and transpiration the dissolved materials in the water are left behind and cause an increase in the minerals in the soil and in the ground water. In places, the evaporation of ground water has left deposits of harmful salts on the land surface.

In order to reclaim land that has been damaged by the high water table, the water table must be lowered sufficiently to prevent the capillary fringe from extending to the surface and subsurface drainage must be provided to prevent an accumulation of dissolved minerals in the water. However, owing to the low permeability of the slope-wash material, drains that would remove the excess ground water probably could not be installed economically.

Seeps in the area adjacent to the Fort Laramie canal are caused by leakage from the canal through fractures in the Brule formation. In an attempt to determine the best method of preventing the movement of water away from the canal, the United States Bureau of Reclamation installed an asphalt membrane lining in a section of the canal and grouted two sections of the canal with portland cement. Attempts to prevent leakage from the canal apparently were successful only in the section that was lined with asphalt. Where the canal was grouted with portland cement, leakage continued at about the same rate as prior to the grouting. Preventing seepage from the Fort Laramie canal would alleviate waterlogging only in the part of the area

that is underlain by the Brule formation and would not appreciably affect the level of the water table in the rest of the area.

Chemical-quality data are particularly helpful in determining the source of water in waterlogged areas, the effects of leakage from the Fort Laramie canal on the kind and quantity of minerals in the slope wash and bedrock, and the drainage characteristics of shallow water-bearing materials.

Reconnaissance data show that water from the slope wash and bedrock deposits differed widely in composition and concentration and tures in the Brule formation and percolates to the slope wash closely resemble that of the irrigation water. Water that percolates more slowly through unfractured parts of the Brule formation generally contains more dissolved solids. Samples from shallow sources down slope from the canal showed some seasonal variation in chemical character, whereas water at the lower part of the area remained, for the most part, unchanged.

Limited chemical-quality data support other hydrologic evidence that drainage is more rapid in the areas where slope wash overlies deposits of sand and gravel.

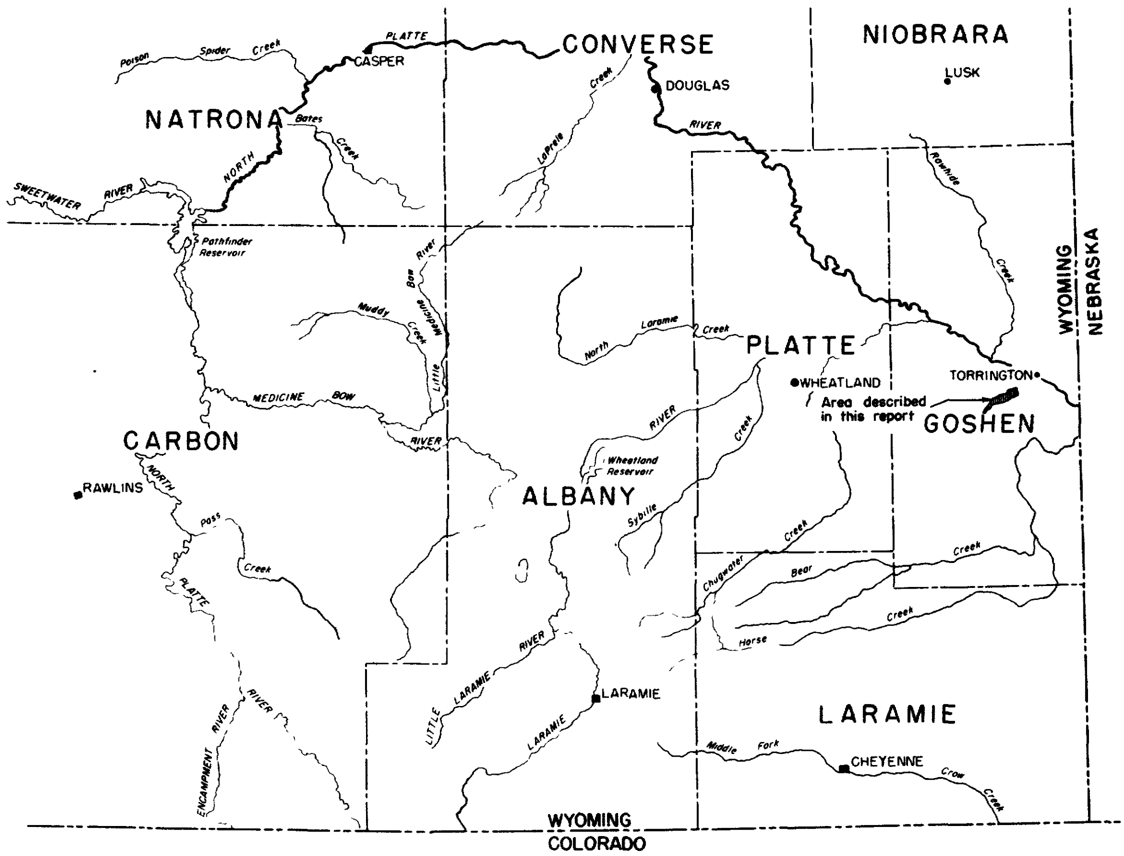

Figure 1.--Index map of southeastern Wyoming showing location of the Soil and Moisture Conservation Demonstration Area.

ranged from a calcium bicarbonate type having 464 ppm of dissolved solids to a mixed sodium sulfate-sodium bicarbonate type having 2,410 ppm of dissolved solids.

The analyses of 19 samples, including resamples from augered test holes and springs, provide the data from which the section on the chemical quality of ground water was prepared. The character and composition of water that seeps from the canal through frac-

INTRODUCTION

Location and extent of area

The Soil and Moisture Conservation Demonstration Area described in this report is in Goshen County in southeastern Wyoming. (See fig. 1.) It is about 6 miles southwest of Torrington and lies within the Goshen irrigation district. It comprises all or parts of secs. 25-28 and 32-35, T. 24 N., R. 62 W., sixth principal meridian, and covers an area of about 2,500 acres. It is bounded on the north by the Fort Laramie canal and on the south by the Cherry Creek drain; it lies between mile stations 36.1 and 39.9 of the Fort Laramie canal. (See pl. 1.)

Purpose and scope of the investigation

This investigation is one of several being made by the U. S. Geological Survey as a part of the program undertaken by the Department of the Interior for the control, conservation, development, and use of the water resources of the Missouri River basin. The investigations form an integrated segment of the North Platte Project soil- and moisture-conservation operations that are being conducted by the U. S. Bureau of Reclamation to demonstrate economically feasible methods of conserving irrigation water and restoring the productivity of waterlogged lands. The purposes of this investigation were to determine the cause of waterlogging of farm land that is irrigated by the Fort Laramie canal and to determine the effectiveness of the canal lining and grouting by the U. S. Bureau of Reclamation in sections of the Fort Laramie canal.

The principal field work upon which this report is based was done by F. N. Visher and H. M. Babcock during the period March 1949 to November 1950. The study was under the general supervision of A. N. Sayre, chief of the Ground Water Branch of the U. S. Geological Survey, and G. H. Taylor, regional engineer in charge of the ground-water investigations in the Missouri River basin, and under the immediate supervision of S. W. Lohman, district geologist for Colorado and Wyoming. The quality-of-water studies were made under the general supervision of S. K. Love, chief of the Quality of Water Branch of the U. S. Geological Survey, and under the immediate supervision of P. C. Benedict, regional engineer in charge of the quality-of-water studies in the Missouri River basin. The water analyses were made by M. B. Florin, W. M. Barr, and R. P. Orth, chemists in the laboratory of the Quality of Water Branch, U. S. Geological Survey, Lincoln, Nebr.

Acknowledgments

The writers wish to express their appreciation to all those who aided in this study. Mr. Harry Kelly, manager of the Goshen Irrigation District, permitted access to records of irrigation in the area. Personnel of the U. S. Bureau of Reclamation instrumentally determined the altitudes of the measuring points of the observation wells.

History and methods of the investigation

The Fort Laramie canal and distribution laterals were constructed and placed in service in the years 1916-23. A short time after irrigation began, seeps developed to a considerable extent in the farm land adjacent to the Fort Laramie canal and to a lesser extent in the farm land farther away from the canal. In an attempt to reclaim the land for agricultural use, open drains were constructed in some of the waterlogged areas. These drains were difficult to construct because the saturated material that was to be drained was unstable; it flowed into the drains and caused the banks to slough. In an attempt to overcome this difficulty approximately 1,300 feet of 18-inch concrete tile were placed in the bottom of a drain in the SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 27. This attempt, however, was unsatisfactory because the fine-grained slope-wash material worked its way inside the tile and filled it.

In the fall of 1949 the U. S. Bureau of Reclamation selected two sections of the Fort Laramie canal for experimental determinations of the possibility of stopping seepage from the canal. One section of the canal was lined with an asphalt membrane, and another section was treated by grouting the bedrock under the south bank of the canal with portland cement. The sections of the canal that were selected for the experiment are shown on plate 1.

The U. S. Geological Survey made periodic measurements of the water level in 87 observation wells to determine the effectiveness of the lining and grouting of the canal and to determine the cause of waterlogging of the farm land. The location of these wells is shown on plate 1 and all pertinent data on the wells are given in table 6. Water levels were measured once a month except during the irrigation season when they were measured semimonthly. The water-level measurements are given in tables 4 and 5. The altitude of the measuring point of the observation wells was determined with a spirit level. Thirteen of the observation wells are test holes that were drilled and cased, 71 are driven piezometer tubes, 2 are drilled stock wells, and 1 is a dug test well, which is equipped with a recording gage.

In several places, two or three piezometer tubes of different lengths were installed side by side in order that the vertical movement of ground water could be determined. The tubes were driven into fine-grained slope wash consisting mainly of silt. Considerable difficulty was encountered in the installation of tubes that would reflect fluctuations of the water table, because the material flowed into the bottom ends of the tubes and sealed them. After much experimentation, a method of installation was developed that allowed free movement of water into or out of the bottom of the tubes. The materials used for each installation were sand, water, a strip of metal about 1 by 3 inches cut from a tin can, a length of $\frac{1}{2}$-inch pipe, a $\frac{1}{2}$- by $\frac{1}{2}$-inch rivet, and a $\frac{1}{2}$- by $1\frac{1}{2}$-inch rivet. The rivets were the same nominal size as the pipe, but the oversize of the inside diameter of the pipe allowed easy removal of the rivets. The over-all length of one of the rivets was the same as its diameter, whereas the length of the other rivet, which was used as a driving head, was three times its diameter to keep it from bouncing out of the end of the pipe when the pipe was being driven. The method of installation is illustrated in figure 2 and is described as follows:

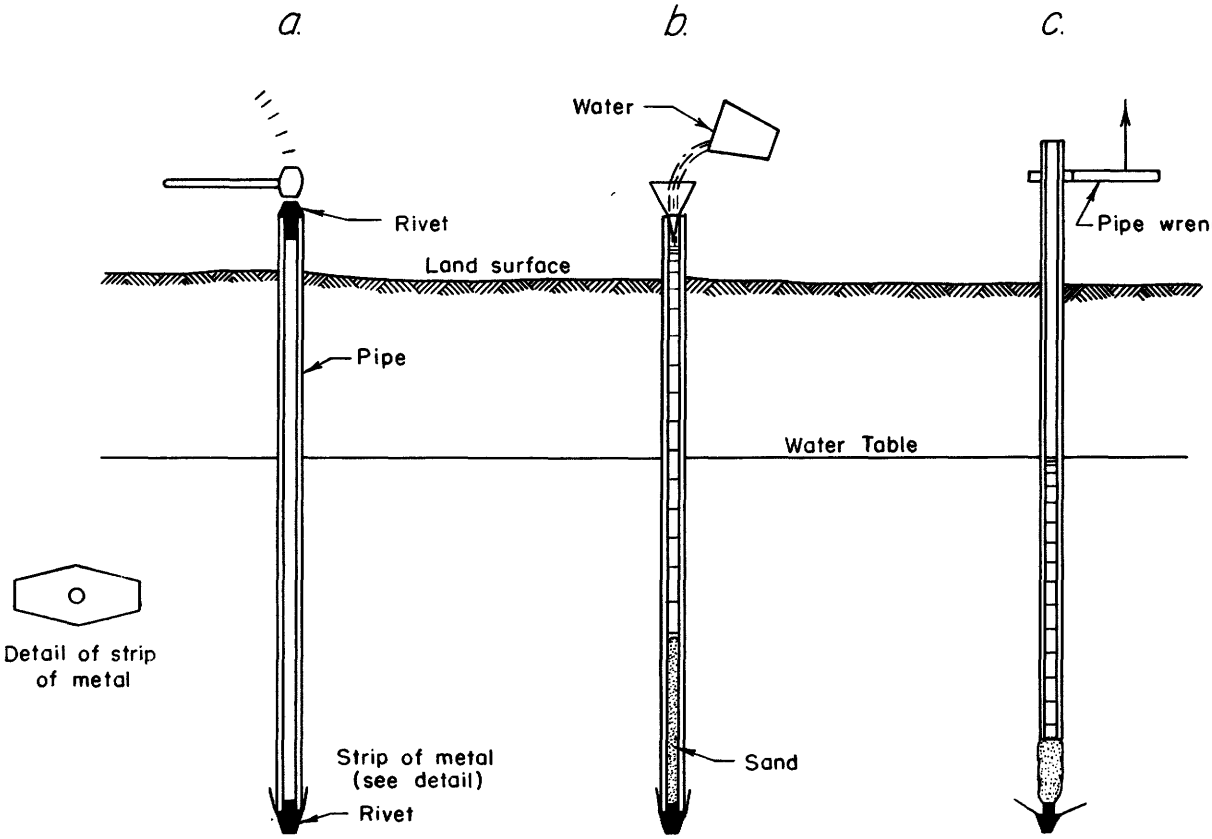

Figure 2.--Sketch showing method of installing piezometer.

(a) The strip of metal was folded through the middle and a rectangular hole large enough to accomodate the rivet was cut in the middle of the strip.

(b) The short rivet was inserted first through the hole in the strip of metal, then into the bottom of the pipe. The ends of the strip of metal were folded up along the sides of the pipe and the pipe was driven into the ground. The long rivet was used in the top of the pipe as a driving head.

(c) When the pipe had been driven to approximately 6 inches below the desired depth, the bottom 18 inches of the pipe was filled with sand, and the remainder of the pipe was filled with water.

(d) The pipe was then pulled up about 6 inches. As the pipe was lifted, the ends of the strip of metal spread out and held the rivet at the bottom of the hole. The weight of the water on top of the sand forced part of the sand out of the end of the pipe into the space formerly occupied by the pipe. The sand in and just below the pipe serves as a well screen; it keeps out the fine material but allows the water to enter the pipe.

A half-inch pipe was the smallest that could be driven without difficulty. Pipes as long as 21 feet were installed in this manner. In some places the pipe could be pushed the entire depth by hand; in other places a slip hammer, consisting of a larger pipe with a plug of steel welded in the end, or an 8-pound maul was used.

Fourteen core holes were drilled with a hydraulic rotary drilling machine and 45 test holes were driven or jetted with a 1-inch diameter soil tube in order to determine the character and thickness of the materials that underlie the area. From data obtained by these tests, a map showing bedrock geology and the contour of the bedrock surface (pl. 2) and diagrammatic geologic sections (pl. 3) of the area were prepared. Pertinent data on the test holes are given in tables 7 and 8.

The soil tube used in this investigation consists of short sections of 1-inch tubing, the lowermost of which contains sections of a brass liner to receive the sample. The bottom end is equipped with a retractable driving point and a cutting shoe. The tube was driven by hand or by a gasoline hammer, which was brought into position by means of a tripod

Figure 3.--Driving soil tubes with gasoline hammer. A hand hammer may be seen on the far left side of the end of the truck. Photograph by G. H. Taylor.

that was mounted on the back of a truck. (See fig. 3.) Normally, the soil tube is driven to the depth at which sampling is to begin, the point is retracted, and the tube is then driven several more feet to force the sample into the brass cylinders. However, if the point was retracted more than a few inches when sampling below the water table, the fine-grained material under hydrostatic pressure would flow up around the point and jam the retracting mechanism. Because the principal purposes of the sampling program were to determine the thickness of the slope wash and to determine the character of the underlying materials, only a small sample was needed. This small sample was obtained by driving to bedrock, retracting the point only an inch or two, and collecting the sample in the cutting shoe. Jetting the pipe was easier than driving it; consequently, the holes were jetted where water was available from a nearby irrigation ditch or a drain.

Samples of material to be tested in the hydrologic laboratory were collected from eight holes by means of a soil tube and a hand auger. The location of these test holes is shown on plate 2.

During part of the irrigation season, a series of water-level observations were made in temporary wells in an irrigated field to determine the effects of a measured amount of irrigation on the water table. The location of this test plot is shown on plate 1.

Twenty-one samples of water for chemical analysis were collected from wells, drains, the Fort Laramie canal, and holes that were augered to the water table in the farmed area. Samples of water were collected from the augered holes during the irrigation season and again about 1 month after the end of the season in order to determine whether a seasonal change occurs in the chemical composition of the water. One of the samples was from a well that is about half a mile north of the Fort Laramie canal, outside the mapped area.

The geologic and hydrologic field data were recorded on a topographic map prepared by the U. S. Bureau of Reclamation.

The U. S. Bureau of Reclamation furnished data on the soils in the area.

Well-numbering system

In this report, wells and test holes are numbered according to their location within the Bureau of Land Management system of land subdivision. The well number shows the location of the well by township, range, section, and position within the section. A graphic illustration of this well-numbering system is shown by figure 4. The first numeral of a well number indicates the township, the second the range, and the third the section in which the well is located. The lower-case letters following the section number locate the well within the section. The first letter denotes the quarter section, the second, the quarter-quarter section, and the third, the quarter-quarter-quarter section (10-acre tract). The subdivisions of the section are lettered a, b, c, and d in a counterclockwise direction beginning in the northeast quarter. Where more than one well is in a 10-acre tract, consecutive numbers beginning with 1 are added to the well number. Inasmuch as all wells and test holes lie in T. 24 N., R. 62 W., the first two parts of the number are omitted in the geologic sections, plate 3.

Each well was assigned also another number that correlates with a coordinate system established by the U. S. Bureau of Reclamation.

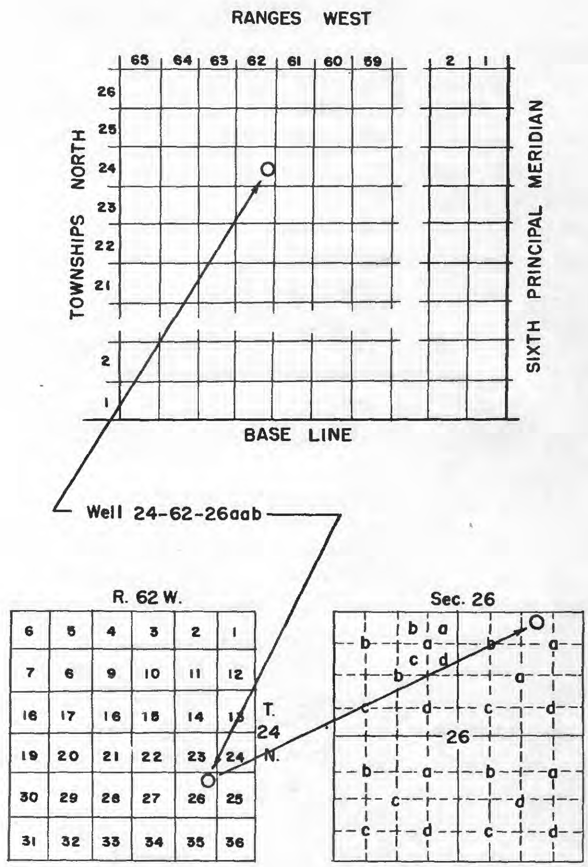

Figure 4.--Sketch showing well-numbering system.

In this system, wells are located by their distance, measured in miles, tenths, and hundredths, north and west from the southeast corner of sec. 36, T. 24 N., R. 62 W.

Climate

The climate of the area is similar to that of other parts of the High Plains section of the Great Plains physiographic province. It is characterized by low precipitation, high evaporation, and a wide range of temperature. The weather is variable from year to year, but usually the summers are mild and the winters are very cold. Torrington, which is about 6 miles northeast of the area, has a normal annual precipitation of 14.32 inches; the highest recorded annual precipitation was 20.91 inches and the lowest was 7.11 inches. The maximum precipitation is during the spring and early summer, and the minimum is during the winter when it usually takes the form of light, dry snow. About 51 percent of the annual precipitation occurs during April, May, and June and only about 11 percent occurs during November, December, January, and February. The summer rains are mostly thunderstorms, which are usually sporadic and are unevenly distributed. Occasionally these storms are accompanied by high winds and hail, which cause considerable damage to crops. The annual precipitation during the period of record and the normal monthly precipitation for the station at Torrington are shown graphically in figure 5. The mean annual temperature at Torrington is 47.5°F and the length of the growing season generally is about 150 days.

and Goshen Hole are separated by a ridge of the Brule formation except where this ridge is cut by the Cherry Creek valley. The area studied is in this part of the Cherry Creek valley; it slopes about 100 feet per mile southward from the Fort Laramie canal to the Cherry Creek drain.

Cherry Creek has cut down through the siltstone of the Brule formation and into the underlying clay of the Chadron formation. At the time of its maximum development the floor of the Cherry Creek valley was cut 50 feet or more below its present level and the Brule and Chadron formations were eroded into a rugged badland topography. The configuration

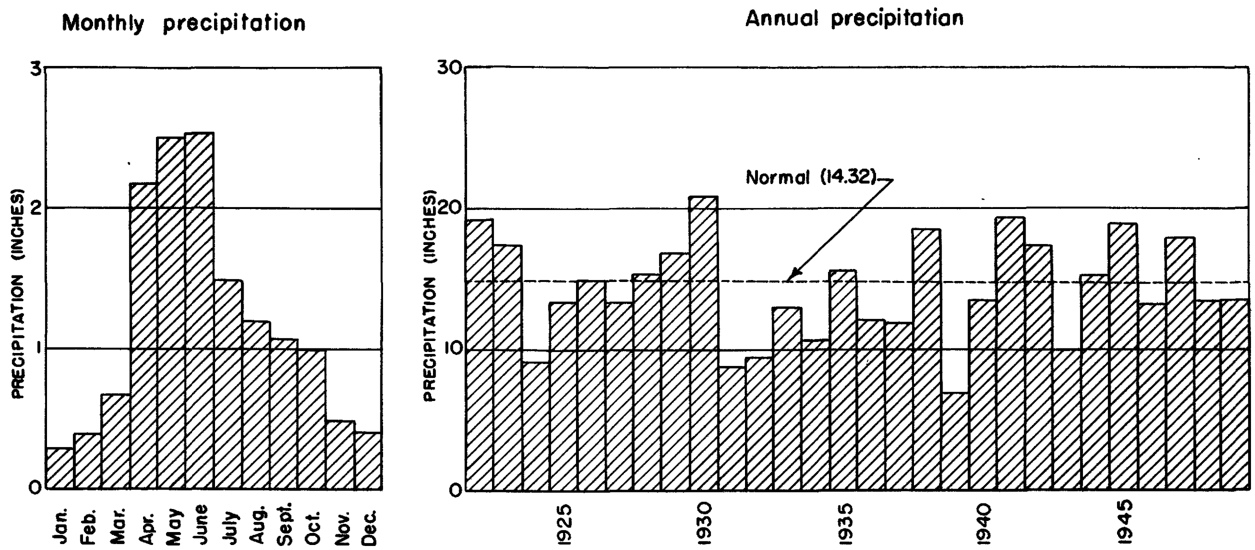

Figure 5.--Precipitation at Torrington, Wyo., 1922-49.

GEOLOGY

Geologic setting

The area is in a deeply dissected section of the northern part of the High Plains and is underlain by the Brule and Chadron formations of Oligocene age. These Tertiary rocks, which are structurally high in this area, were largely eroded away during Pleistocene time by the North Platte River and by other through-flowing streams. Southwest of the North Platte River in the central part of Goshen County, Wyo., this erosion has formed a vast lowland, which has an extent of several hundred square miles and which is called Goshen Hole. The North Platte River valley

of this surface is shown by contour lines on plate 2 and by the diagrammatic geologic sections on plate 3.

Subsequent to this downcutting, Cherry Creek began to aggrade and deposited coarse sand and gravel. Later, as the carrying power of the stream decreased, finer-grained materials were deposited. Ultimately, the flow of the creek decreased to such an extent that it lacked sufficient power or volume to carry away the slope wash from the sides of the main valley. The present floor of the valley was developed at the same time as the second terrace above the North Platte River; at that time, the river was about 50 feet above its present level. The flow of water in the

Cherry Creek valley was so small before the inception of irrigation that the topographers who mapped the area did not show even an intermittent stream in the valley. Subsequently, owing to surface- and ground-water runoff caused by irrigation, Cherry Creek has entrenched itself as much as 35 feet below the adjacent valley floor.

Geologic formations

Tertiary system

Chadron formation.--The Chadron formation is typically a green, brown, buff, or red impervious clay containing a few channel sandstones, especially at the top of the formation. In most places the clay grades upward into the siltstone of the overlying Brule formation. Although the formations are similar in appearance in the contact zone, core samples of the Chadron formation were identified by their tendency to check when drying.

The Chadron formation underlies the entire area, but only the more resistant channel sandstones are exposed. These sandstones crop out in the central and western parts of sec. 26 and in the eastern part of sec. 27. (See pl. 2.)

The channel sandstones of the Chadron formation generally yield water to wells in sufficient quantity and of a suitable quality for domestic and stock use.

Brule formation.--In its typical development, the Brule formation is a pale-buff or flesh-colored sandy limy siltstone of compact texture and massive structure. In the formation are numerous vertical to nearly vertical fractures that range in width from a feather edge to several feet. The Brule is a weak, brittle formation; when placed in compression this material would tend to succumb to induced tension rather than induced shear. The weight of the overlying formations, which have since been removed by erosion, was sufficient to cause vertical fracturing when regional warping reduced the lateral support.

In most of the core holes drilled into the Brule formation the drilling water, which was pumped at a rate of 20 gpm, was entirely absorbed by the fractures. In several of the holes the bit dropped when fractures were encountered; in hole 24-62-23ddd the 3-inch drill bit dropped a foot between the 33 and 34-foot level.

The Brule formation underlies the northern part of the area, where it crops out in several places and is exposed in many of the cuts in the Fort Laramie canal. It ranges in thickness from a feather edge to about 60 feet in the area; however, before erosion, the maximum thickness of the Brule formation was more than 300 feet.

The fine-grained materials of the formation do not readily transmit water. However, fractures in the Brule formation are capable of transmitting large amounts of water and, in adjacent areas, wells develop water from this formation in sufficient quantities for domestic and stock use.

Quaternary system

Sand and gravel.--The sand and gravel that overlies the Chadron formation and underlies the slope wash in the southern part of the area lies in a former channel of Cherry Creek. The sand and gravel consists largely of quartz but includes some pebbles of siltstone that were derived from the Brule formation. Quartz pebbles as large as 1 inch in diameter were brought up in the end of the soil tube. The material probably contains larger pebbles, but these could not be recovered with the 1-inch soil tube. The maximum thickness of these deposits is not known, as in most places, the soil tube did not completely penetrate the material; however, in one probe as much as 20 feet of fine sand was penetrated. Attempts have been made to develop water from this material for domestic and stock use; however, the water is so highly mineralized that it is generally unsuitable.

Slope wash.--The slope wash consists largely of silt and some fine sand. This material is derived from the weathering of the siltstone of the Brule formation, and it is generally indistinguishable from the weathered Brule. All unconsolidated silt and fine sand that was more than a few feet thick was mapped as slope wash. The maximum thickness of the slope wash that was encountered in drilling was 48 feet. The slope wash covers most of the area and constitutes the farmed land. Near its base, the slope wash contains pebbles of siltstone from the Brule formation and it will yield small quantities of water to wells that penetrate a sufficient thickness of these coarser materials. The water generally is too highly mineralized for domestic and stock use.

PHYSICAL AND HYDROLOGIC PROPERTIES OF THE SLOPE WASH

The quantity of water that a material will yield to wells and the rate at which water will move through the material depend upon the physical and hydrologic properties of the material. In order to determine these properties for the slope wash, samples of the material were collected at eight places in the area. (See pl. 2.) In places, samples were collected both in a disturbed condition by means of a soil auger and in a semidisturbed condition by means of the 1-inch soil tube. Some compaction of the material was observed in the samples that were obtained by means of the soil tube; therefore, the porosity and permeability determined for these samples probably are low. Quantitative analyses of the samples were made by A. I. Johnson in the hydrologic laboratory of the U. S. Geological Survey in Lincoln, Nebr. These analyses included mechanical analyses, determination of the coefficient of permeability, the apparent specific gravity, the porosity, the moisture equivalent, the specific retention, and the specific yield. The results of the analyses are summarized in table 1.

Grain size

A mechanical analysis of granular material consists of separating the grains of different sizes into groups and determining, by weight, the percentage of the total sample that each size group constitutes. In preparing for the mechanical analyses, samples were air-dried and placed in a mortar, and adhering lumps of material were gently separated by use of a rubber-covered pestle. Care was taken merely to separate and not crush the individual particles. Grain sizes larger than 0.0625 millimeter were determined by wet-sieve analysis and sizes smaller than 0.0625 millimeter were determined by the hydrometer method of wet analysis. Mechanical analyses were made of four selected samples that were obtained from different test holes in the area. The results of these analyses indicate that the slope-wash material is composed of about 12.5 percent sand, 83.6 percent silt, and 3.9 percent clay.

Permeability

The coefficient of permeability of 25 samples of slope wash was determined with a variable-head permeameter. Laboratory methods employed in determining permeability have been described by V. C. Fishel (in Wenzel, 1942, pp. 59-68).[1] The coefficients of permeability ranged from 0.02 to 6.46 and averaged 1.1. This means that an average of 1.1 gpd of water at 60°F would percolate through a cross section 1 mile wide and 1 foot thick under a hydraulic gradient of 1 foot to the mile.

Porosity

The porosity of a rock or rock aggregate is its property of containing interstices, without regard to size, shape, or arrangement of openings. Porosity is expressed quantitatively as the percentage of the total volume of rock that is occupied by interstices. In a rock that is saturated with water, the porosity is the percentage of the total volume of the rock that is occupied by water. The porosity was determined by subtracting the dry unit weight of a sample of material (apparent specific gravity) from the average unit weight of the solid constituents of the sample (specific gravity) and dividing the resultant by the specific gravity. The porosity of the analyzed samples ranged from 41.2 to 62.3 percent by volume and averaged 55 percent.

Moisture equivalent, specific retention, and specific yield

The moisture equivalent of a water-bearing material is the ratio of (1) the weight of water that the material will retain after saturation against a centrifugal force that is 1,000 times the force of gravity to (2) the weight of the dry material. The moisture equivalent, by volume, is computed by multiplying the moisture equivalent, by weight, by the apparent specific gravity of the material. The specific retention--that is, the quantity of water that a material will retain against the pull of gravity if it is drained after having been saturated--is expressed as the ratio of the retained water to the total volume of material and is determined by adjusting the moisture equivalent by volume by a correction factor that was proposed by Piper (1933, pp. 481-487).

[1] See list of references at end of report.

Table 1.--Physical and hydrologic properties of slope-wash material

Sample number	Depth of sample (feet)		Method of sampling [1]	Grain size (percent by weight)						Apparent specific gravity	Specific gravity	Porosity (percent by volume)	Moisture equivalent (percent by volume)	Specific yield (percent by volume)	Coefficient of permeability
	From	To		Coarse sand (1.0-0.50 mm)	Medium sand (0.50-0.25 mm)	Fine sand (0.25-0.125 mm)	Very fine sand (0.125-0.0625 mm)	Silt (0.0625-0.004 mm)	Clay (less than 0.004 mm)						
24-62-26bdd	10.6	11.0	ST	...	...	...	....	....	...	1.06	2.63	59.7	....	....	
Do.....	15.0	16.6	ST	...	...	...	....	....	...	1.24	2.63	52.9	....	....	1.36
Do.....	16.6	17.0	ST	...	...	...	....	....	...	....	2.63	....	....	....	
Do.....	17.0	17.5	ST	...	...	...	....	....	...	1.42	2.63	46.0	....	19.5	6.46
Do.....	17.5	18.0	ST	...	...	...	....	....	...	....	2.62	....	....	....	
24-62-27abc	1.5	2.0	A	...	...	...	....	....	...	1.07	2.60	58.8	....	....	.43
Do.....	2.0	2.5	A	...	...	...	....	....	...	1.06	2.60	59.2	....	31.7	.53
Do.....	2.5	3.0	A	...	...	...	....	....	...	1.11	2.60	57.3	....	....	.45
Do.....	3.0	4.0	A	...	1.0	0.5	6.5	89.0	3.0	1.16	2.62	55.7	....	29.9	.68
24-62-27acc	.5	1.5	A	...	...	...	....	....	...	1.16	2.60	55.4	....	....	.99
Do.....	1.5	2.0	A	...	...	...	....	....	...	1.15	2.60	55.9	....	....	.95
Do.....	2.0	2.5	A	...	...	...	....	....	...	1.18	2.60	54.6	....	....	1.20
Do.....	2.5	3.0	A	...	...	...	....	....	...	1.19	2.60	54.2	....	....	1.09
Do.....	3.0	3.5	A	...	...	...	....	....	...	1.20	2.60	53.8	....	....	
Do.....	3.5	4.0	A	...	...	...	....	....	...	1.20	2.60	53.8	....	....	1.40
Do.....	4.0	4.5	A	...	...	...	....	....	...	1.17	2.60	55.0	....	....	1.09
Do.....	4.5	5.0	A	...	...	...	....	....	...	1.17	2.60	55.0	....	....	1.84
Do.....	5.0	5.5	A	...	...	...	....	....	...	1.19	2.61	54.4	....	....	1.42
Do.....	5.5	6.0	A	...	...	...	....	....	...	1.17	2.62	55.3	....	....	.98
Do.....	5.5	6.0	ST	1.0	0.5	1.0	7.5	87.5	2.5	1.17	2.60	55.0	....	....	.89
Do.....	6.0	6.5	ST	...	...	...	....	....	...	1.11	2.60	57.3	....	....	
Do.....	6.5	7.0	ST	...	...	...	....	....	...	1.17	2.61	55.2	....	....	1.27
24-62-27add	6.0	6.5	ST	1.0	2.5	7.5	16.0	70.0	3.0	1.32	2.66	50.4	....	30.2	.45
Do.....	6.5	7.0	ST	...	...	...	....	....	...	1.56	2.65	41.1	....	....	.02
24-62-27cbc	1.0	1.2	A	...	...	...	....	....	...	....	....	....	39.9	....	
Do.....	2.0	2.2	A	...	...	...	....	....	...	....	....	....	36.4	....	
Do.....	2.5	2.7	A	...	...	...	....	....	...	....	....	....	40.8	....	
Do.....	3.0	3.2	A	...	...	...	....	....	...	....	....	....	43.9	....	
Do.....	3.8	4.0	A	...	...	...	....	....	...	....	....	....	44.7	....	
Do.....	4.0	4.3	A	...	...	...	....	....	...	....	....	....	46.4	....	
Do.....	4.5	4.8	A	...	...	...	....	....	...	....	....	....	43.8	....	
Do.....	5.0	5.3	A	...	...	1.0	4.0	88.0	7.0	1.17	2.63	55.5	48.7	....	
Do.....	5.8	6.0	A	...	...	...	....	....	...	....	....	....	44.9	....	
24-62-27cbd	1.0	1.3	A	...	...	...	....	....	...	....	....	....	37.9	....	
Do.....	2.0	2.2	A	...	...	...	....	....	...	....	....	....	37.6	....	
Do.....	2.5	2.8	A	...	...	...	....	....	...	....	....	....	43.6	....	
Do.....	3.0	3.2	A	...	...	...	....	....	...	....	....	....	45.6	....	
Do.....	3.5	3.8	A	...	...	...	....	....	...	....	....	....	45.2	....	
Do.....	4.0	4.2	A	...	...	...	....	....	...	....	....	....	45.9	....	
Do.....	4.5	4.8	A	...	...	...	....	....	...	1.15	2.62	56.1	45.6	....	
Do.....	5.0	5.3	A	...	...	...	....	....	...	....	....	....	45.6	....	
Do.....	5.8	6.0	A	...	...	...	....	....	...	....	....	....	46.0	....	
24-62-28dda	3.0	3.5	A	...	...	...	....	....	...	1.13	2.62	56.9	....	....	.52
Do.....	4.5	5.0	A	...	...	...	....	....	...	1.09	2.62	58.4	....	....	.40
Do.....	5.5	6.0	A	...	...	...	....	....	...	.98	2.61	62.5	....	....	1.01
Do.....	6.0	9.0	ST	...	...	...	....	....	...	1.01	2.62	61.5	....	35.6	.93
24-62-33bac	2.0	5.0	ST	...	...	...	....	....	...	1.16	2.62	55.7	....	....	.92
Do.....	3.0	3.5	ST	...	...	...	....	....	...	1.26	2.63	52.1	....	....	.21

[1] Symbols in this column indicate: A, hand auger; ST, soil tube.

The specific yield of a water-bearing material is defined as the ratio of (1) the volume of water that a saturated aquifer will yield by gravity, to (2) its own volume and is numerically equal to the porosity minus the specific retention. The specific yield of the samples ranged from 19.5 to 35.6 percent and averaged 29.4 percent. This indicates that a cubic foot of slope wash, if allowed to drain for a long period, will yield about 0.3 cubic feet of water. A sample of saturated material will not yield its water at once, but the water will drain rather slowly, the rate of draining being somewhat proportional to the permeability of the material. Owing to its fine-grained texture the slope wash yields water slowly; probably, several months to a year or more would be required before the specific yield that was calculated in the laboratory would be reached under natural conditions. Consequently, the quantity of water that is removed from storage by a decline of the water table cannot be calculated from the specific yield that was determined in the laboratory, unless the water table remains at the lower level for a long time. That the seasonal fluctuations of water levels in wells in the slope wash are larger than those in wells penetrating other materials is due, in part, to the incomplete draining of the material during the time that the water table is low, because a considerable period of time may elapse before much water is released from storage.

THE WATER TABLE AND MOVEMENT OF GROUND WATER

The water table is the upper surface of the zone of saturation except where that surface is formed by an impermeable body (Meinzer, 1923, p. 32). It is also the boundary between the zone of saturation and the zone of aeration. The water table is not a static level surface, but rather it is generally a sloping surface with many irregularities caused either by local differences in permeability of thickness of the water-bearing materials or by unequal additions to or withdrawals from the ground-water reservoir at different places.

The movement of ground water depends on the permeability of the material and on the hydraulic gradient of the water table. According to Darcy's law, the velocity of the ground water is directly proportional to the permeability of the water-bearing material and to the hydraulic gradient, and the quantity of ground water that moves through an aquifer depends upon the rate of movement of the water and the cross-sectional area through which the water percolates. The direction of the movement of the ground water can be determined from a map that shows contour lines on the water table. A contour line on the water table is a line along which all points have the same altitude. The maximum difference of hydrostatic head (the hydraulic gradient) is at a right angle to the contour lines; hence, the water moves at a right angle to the contour lines, and the slope or hydraulic gradient of the water table is measured along the direction of this maximum difference in head.

The shape of the water table in the Soil and Moisture Conservation Demonstration Area is shown by the water-table contour lines on plate 1. As a basis for construction of the contour map, the altitude of the water table at the observation wells was determined.

The water table in the demonstration area is near the surface and generally slopes to the southeast except for a few irregularities that are caused by discharge into drains or by changes in the permeability or thickness of the aquifer. In the northern part of the area the contours are closely spaced because of low permeability, and their shape shows that ground water flows into the drains. In the southern part of the area, where the water-bearing material is composed of slope wash and an underlying bed of sand and gravel, the contour lines are more widely spaced because the water table is below the drains and the water-bearing material is more permeable.

The lateral movement of ground water through the slope wash is very slow. The average field coefficient of permeability--that is, the permeability at the prevailing ground-water temperature in the field--is 0.99 gpd per square foot (the 1.1, determined by the laboratory tests, was corrected to 53°F), the effective porosity is assumed to be the same as the average specific yield, or 29.4 percent, and the hydraulic gradient is 100 feet per mile; then the water moves through the slope wash at an average rate of about 3.1 feet per year.

Where the Fort Laramie canal passes through cuts in the Brule formation, the water enters the fractures in the formation and moves downward and outward under the slope wash. The Brule formation thins to a feather edge within a short distance south of the canal;

consequently, the water moving through the fractures in the Brule formation is forced upward under pressure into the less permeable slope wash, in some places reaching the land surface.

FLUCTUATIONS OF THE WATER TABLE

The stage of the water table reflects the quantity of water in storage in the ground-water reservoir in much the same manner as the stage of the water level in a surface reservoir reflects the amount of water in storage. Thus, the changes in the ground-water level indicate changes in the amount of water in the ground-water reservoir. Fluctuations of the water level show the extent to which the ground-water reservoir is replenished by rainfall and irrigation seepage and the extent to which the reservoir is depleted by the withdrawal of water through natural drainage, evapotranspiration, and underflow out of the area. The principal factors contributing to a rise of the water table are seepage from canals and irrigated fields and, to a lesser extent, precipitation. The principal cause of the decline of the water table is evapotranspiration. This subject is discussed in detail in the section on discharge by evapotranspiration. In order to observe the fluctuations of the water table, periodic water-level measurements were made in 87 wells. (See table 4.)

The capillary fringe in the fine-grained silt and clay that comprise the slope wash extends to or near the surface in most of the area. Available data (Meinzer, 1923, pp. 31-38) indicate that, in silt, water will rise by capillary attraction several feet above the water table. When a material contains a large amount of capillary water, a small amount of recharge will cause a comparatively large rise of the water table.

Seepage from the Fort Laramie canal occurs mainly through fractures in the Brule formation and causes a very rapid rise of the water level in wells that penetrate the Brule formation or the slope wash that is underlain by the Brule formation. The hydrographs in figure 6 show that water levels in the wells in the Brule formation rise rapidly soon after water is turned into the canal. The average water level in six wells in the Brule formation rose about 15 feet in 1949 and another 15 feet in 1950. Water levels in wells in the slope wash that is underlain by the Brule formation also rose soon after water was turned into the canal, but they did not rise as high as the water levels in wells in the Brule formation. Farther south, where the slope wash is underlain by the Chadron formation or by the sand and gravel, the water levels were not affected by seepage from the canal. Owing to precipitation and irrigation, the water levels in these areas annually rose an average of about 4 feet; seepage from the irrigated fields caused a rise in water levels shortly after the beginning of irrigation in the spring.

Rises of the water table that are due to precipitation are much more apparent during the nongrowing season because they are not obscured by the much larger fluctuations due to irrigation. Also, during the growing season a large part of the water that enters the ground from precipitation is used by the plant roots and consequently does not penetrate to the water table.

The decline during the irrigation season and the general decline in water levels at the end of the irrigation season are due largely to evapotranspiration.

SOURCE OF GROUND WATER

In the area, recharge to the ground-water reservoir is due to seepage of precipitation and irrigation water, to seepage from irrigation canals and laterals, and to subsurface inflow from areas to the north. Most of the water that is applied to the land is used by the plants and only a part of it reaches the water table. Because of the fine-grained texture of the soil, a large amount of water is held in the soil by capillarity.

Recharge from precipitation

The normal annual precipitation in the area is 14.32 inches, but apparently only a small part of this reaches the zone of saturation. Most of the precipitation that falls on the land is returned to the atmosphere through evaporation and transpiration. This is especially true during the growing season. Although only a small part of the precipitation percolates to the zone of saturation, the amount is sufficient to cause an appreciable rise of the water table in the fine-grained

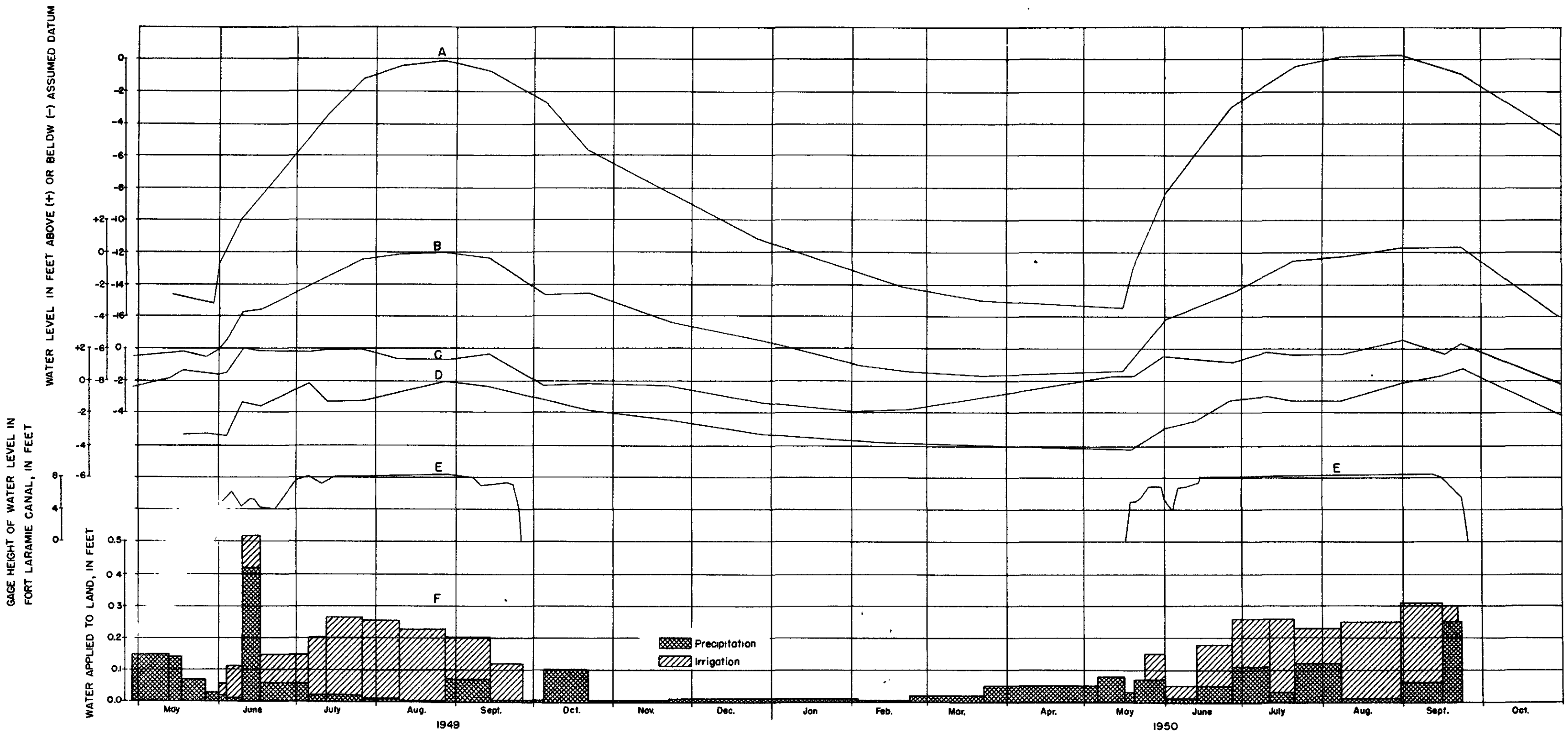

Figure 6.--Hydrographs showing average fluctuations in six wells in (A) the Brule formation, (B) slope wash underlain by Brule, (C) slope wash underlain by the Chadron formation, and (D) slope wash underlain by sand and gravel; (E) the gage height of the water level in the Fort Laramie canal; and (F) the average daily amounts of water applied to the land by irrigation and precipitation.

slope wash. In the area where the slope wash is underlain by the relatively impermeable clay of the Chadron formation, the water level rose an average of about 2 feet in the spring of 1950 (see fig. 6) as a result of recharge from precipitation. In the area where the slope wash is underlain by sand and gravel, which serves as a subdrain, the water levels continued to decline during the period of greatest precipitation and did not rise until after the beginning of irrigation.

Recharge by seepage from irrigation canals and irrigated land

The greatest source of ground-water recharge in the area is from seepage from the canals and laterals and from the irrigation water that is applied to the farm land.

In an attempt to determine the rate of seepage loss from the Fort Laramie canal, the U. S. Bureau of Reclamation made ponding experiments during the fall of 1949. The results of these experiments have been published in a report by the U. S. Bureau of Reclamation (1951, pp. 4-8). The following is taken from this report:

> Seven dikes were constructed in the Fort Laramie Canal, forming six ponds, covering in its entirety the canal between Stations 1911+08 and 2002+84 (miles 36.2 to 38.3). This section of canal is adjacent to the Barthel farm where seepage was great enough to raise the ground water table and inundate the barnyard during the irrigation season. *** The dikes were located at strategic positions along the canal to isolate the various elevations of the contact between the silt and the underlying Brule siltstone. Pond 1 contained a silt-Brule siltstone contact that varied in elevation from 1 foot to over 15 feet below the bottom of the canal. Pond 2, filled to a depth of only 4.1 feet by gravity (no pumping) was formed incidental to the other ponds. In this pond, the Brule siltstone was exposed in the bottom of the canal in several places while in other areas the silt-Brule siltstone contact was more than 15 feet below the canal bottom. Pond 3 had Brule siltstone exposed in the bottom of the canal over the major portion of its length. Pond 4 had a silt cover over the Brule siltstone ranging in thickness from 4 to 12 feet while Pond 5 had a deep cover of silt that exceeded 15 feet in depth. Pond 6 had a silt cover over the Brule siltstone ranging in thickness from 3 to 10 feet. ***
>
> The portland cement pressure grouting in the Fort Laramie Canal *** was installed just prior to the ponding studies while a buried asphalt membrane lining was to be placed in a reach of the Fort Laramie Canal immediately after the completion of the field measurements. ***
>
> Grouting operations were carried out prior to the ponding tests in the areas included in Ponds 1, 2, 3, and 4. An examination of Figure 6 (seepage rate versus depth of water in the ponds) shows that Ponds 1 and 3 with the highest density of grouting had higher seepage rates than Ponds 2 and 4.
>
> In contrast to the higher seepage rates in the areas that were grouted, lower seepage rates were obtained in Ponds 5 and 6. The reach of canal included in Ponds 4, 5, and 6 was lined with buried asphaltic membrane after the completion of these tests.
>
> The lowest seepage rate from a Fort Laramie pond, 0.13 cubic foot per square foot of wetted area per 24 hours, was found in Pond 5. Fifteen or more feet of silt covers the Brule siltstone in this entire reach of canal. The highest seepage rate, 0.57 cubic foot per square foot of wetted area per 24 hours, was obtained in Pond 3 where the Brule siltstone was exposed in the bottom of the canal for practically the entire length of the pond. These data indicate that the silt overlying the Brule siltstone is less conductive to high seepage losses than the Brule siltstone itself.

The water level in wells in the vicinity of the Fort Laramie canal rose immediately after the canal began to carry water in the spring and receded when the amount of water in the canal was reduced in the fall.

Recharge to the area where the slope wash is underlain by the Brule formation is mainly from seepage from the Fort Laramie canal. Water moves away from the canal through fractures and then upward through the slope wash under hydrostatic head. The average water level in six wells (fig. 6) in the slope wash where it is underlain by the Brule formation annually rose nearly 8 feet, mainly as a result of recharge from the canal. The hydrograph of the average water level in these wells shows that a slight rise occurred as a result of the spring rains, but that the main upward trend did not start until after water was turned into the canal in the spring. This upward trend of the water level continued until the end of August 1949 and until the end of September 1950, at which times the amount of water in the canal was reduced.

Recharge to the area where the slope wash is not underlain by the Brule formation is mainly from the seepage of irrigation water that has much of it subsequently is returned to the root zone or the land surface. The water table rises immediately after the application of water and then declines as soon as evaporation and transpiration have removed the excess water in the soil and have begun to withdraw water from the capillary zone. Water moves upward by capillary action to replace the water that was removed and this causes a decline in the water level. The fluctuations of water level caused by irrigation and evapotranspiration are illustrated by figure 7, which is a graph showing the fluctuation of the average water level in eight wells in a

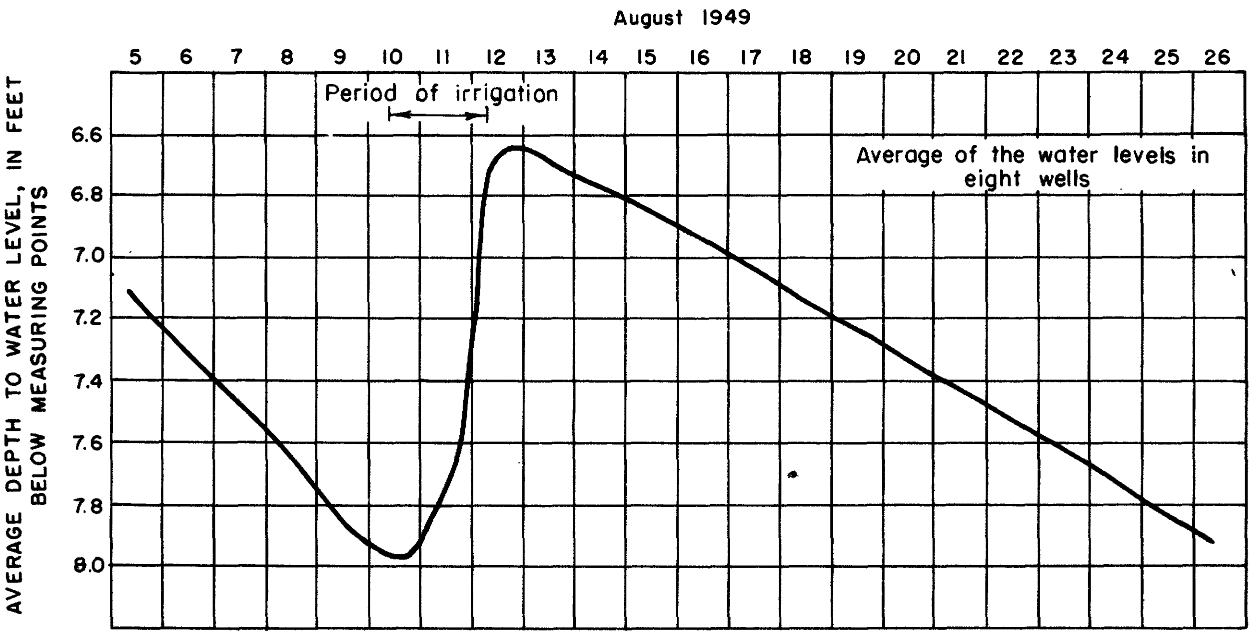

Figure 7.--Hydrograph showing water-level fluctuations cuased by application of 0.23 acre-foot of irrigation water per acre in irrigation test plot. From an average of the water levels in eight wells.

been applied to the land. The water levels in wells in these areas are not affected by recharge from the Fort Laramie canal, but to some extent they reflect recharge from seepage from the laterals that carry water from the main canal to the farms. When irrigation water is applied in excessive amounts, some water may continue downward to the zone of saturation and, hence, cause a rise of the water table. The water table is near the surface in this area and the capillarity of the fine-grained material is so great that, even though some of the water percolates to the water table during periods of irrigation, sugar-beet field. The location of this experimental test plot is shown on plate 1.

Prior to the application of water to the experimental test plot, the water level was declining at an average rate of 0.17 foot a day. As a result of application of 0.23 acre-foot of water per acre, the water level rose 1.32 feet. The water level then declined at an almost uniform rate of 0.10 foot a day. Fourteen days after irrigation, the average water level had declined to about the same position that it had prior to the application of water.

Recharge by inflow from adjacent areas

Precipitation that reaches the water table in the area north of the Fort Laramie canal enters the mapped area as underflow in fractures in the Brule formation. Before water was turned into the canal in the spring of 1950 the water level in well 24-62-28dcb, which is in the Brule formation near the Fort Laramie canal, rose 7.35 feet largely owing to inflow from the north.

Where the Brule formation thins to a feather edge under the slope wash, not all the water moving through fractures in this formation can be transmitted laterally by the fine-grained slope wash; consequently, part is forced upward, causing a rise in the water table. Because of these conditions, a high water table probably existed in part of the area before the construction of the irrigation system.

GROUND-WATER DISCHARGE

Ground water is discharged from the area by evapotranspiration, seepage into drains, and underflow that leaves the area.

Evapotranspiration

Most of the ground water that leaves the area is discharged through evapotranspiration in the irrigated areas and in the areas that are covered with native phreatophytes. Although no tests were made to determine the discharge of water from the area by evapotranspiration, such discharge is apparently sufficient to account for most of the rainfall and irrigation water that is supplied to the land each year and for a large part of the water that is lost by seepage from the Fort Laramie canal.

The amount of evapotranspiration of ground water varies with the season, the depth to water, and with the kind of crop. In general, the evapotranspiration rate is greatest during the growing season when the temperature is highest and where the water table is nearest the surface. In most of the area alfalfa, which begins to transpire ground water as soon as the plants start to grow in the spring, uses ground water throughout the growing season; however, a decrease in the use of water immediately follows each cutting. Sugar beets transpire a little ground water in the spring when the plants are small and reach their peak rate of ground water use toward the end of the growing season when the plants reach their maximum size.

The hydrographs in figure 8 show how the water table is affected by transpiration of plants. Hydrographs of wells 24-62-27acc and 24-62-27dbb, at the edge of a sugar-beet field, show the rise of the water level that was caused by the application of water to the field and the decline of the water level that was caused by transpiration by the beets. The beet field is in a poorly drained area where the slope wash is underlain by the Chadron formation. Owing to precipitation, water levels begin to rise in the late winter and continue to rise until June. By June, the rate of discharge of ground water by evapotranspiration is sufficient to overbalance the recharge due to precipitation and the water levels begin to decline. This decline continues until the beet fields are irrigated, usually at the beginning of July, at which time the water levels begin to rise again. By the end of July 1949 the discharge of water by evapotranspiration was sufficient to overbalance the recharge from irrigation and precipitation, and the water levels began to decline. By this time the sugar beets had become quite large; hence, their consumption of water was great. In the growing season of 1950, which was unusually cold and consequently poor for crop production, the water levels continued to rise during the irrigation season, with only minor declines caused by evapotranspiration. After the end of the irrigation season the water levels declined, owing to evapotranspiration.

The hydrograph of well 24-62-28dda, which is adjacent to an alfalfa field, shows a rise of the water table due to precipitation in the spring. The water table begins to decline as soon as the plants start growing in the spring, and continues to decline during most of the time that irrigation water is applied to the land. When the alfalfa is cut the transpiration rate is greatly reduced, and the water levels rise rapidly as the result of the irrigation that follows the cutting. As the alfalfa grows again, the transpiration rate increases and eventually overbalances the recharge from irrigation and thus again causes a decline of the water level. The hydrograph shows the effects of two cuttings of alfalfa during the 1949

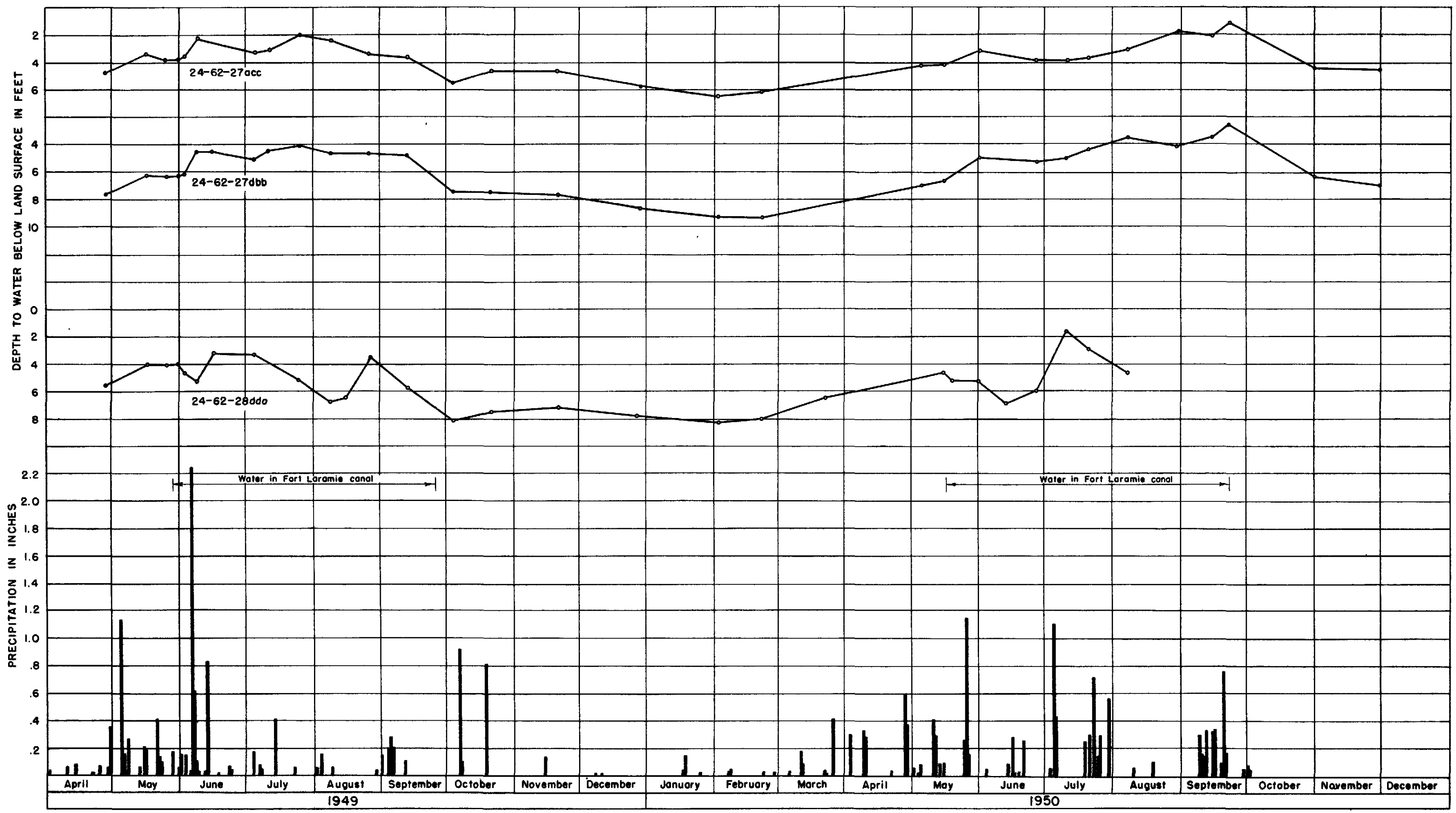

Figure 8.--Graph showing fluctuations of water levels in wells adjacent to irrigated fields. Wells 24-62-27acc and 24-62-27dbb are on the edge of beet fields; well 24-62-28dda is on the edge of an alfalfa field.

irrigation season. The third cutting was in the fall after the irrigation season and apparently had little effect on the water table.

Seepage into drains

Ground water is discharged from the area by seepage into Cherry Creek drain and three of its tributary drains. Most of this discharge seeps into the three tributary drains. Accurate measurement of the amount of ground water that was discharged by the three tributary drains was not possible because the summer flow of the drains was largely derived from surface runoff from the irrigated fields. Discharge measurements were made, however, in the spring before irrigation began, in the fall as soon as irrigation stopped, and during the winter. From these discharge measurements, it was estimated that the three tributary drains annually remove about 500 acre-feet of ground water from the area. Most of the water enters the drains through springs and seeps in that part of the area where the slope wash is underlain by the Brule formation. These seeps and springs are caused by water moving away from the Fort Laramie canal through fractures in the Brule formation and thence upward through the slope wash to the surface. Where the slope wash is not underlain by the Brule formation, very little ground water seeps into the drains through the relatively impermeable slope wash. Also, in many places ground water cannot move into the drains because the drains are above the water table. Therefore, the three tributary drains contribute very little toward draining ground water from the farm lands but mainly serve to carry off part of the water that seeps out of the Fort Laramie canal, and to remove the surplus irrigation water applied to the land.

The Cherry Creek drain is cut largely in relatively impermeable, fine-grained slope wash, and, consequently, only a small amount of ground water from this area is discharged directly into this drain. An approximation of the amount of ground water discharged into the Cherry Creek drain was made by computing the amount of water that moves through the slope-wash material toward the drain. The average coefficient of permeability of the slope wash was computed to be 1.1 gpd per square foot, or 0.99 gpd per square foot corrected to 53°F, the thickness of saturated material is about 30 feet, and the slope of the water table is about 100 feet per mile. From the above data, it was computed that along a 3-mile section of the drain about 10 acre-feet of water moves into the drain in a year.

Underflow

Very little ground water leaves the area as underflow; this discharge probably does not amount to more than 1 acre-foot of water per year. The ground-water contour lines (see pl. 1) show that the downstream component of the water table along the Cherry Creek drain is less than 10 feet per mile and therefore only a small amount leaves the area as underflow.

SEEPAGE

The water table is high throughout much of the area and has caused considerable damage to the farm land. The shallow-lying ground water causes damage by drowning the crops, by depositing harmful salts on and in the soil, and by rendering the land unworkable. Seepage conditions vary according to the character of and the depth to the material that underlies the slope wash. The materials that underlie the slope wash in the area are, from south to north, sand and gravel, clay of the Chadron formation, and siltstone of the Brule formation. (See pl. 2.)

In the part of the area where the slope wash is underlain by sand and gravel, apparently the underdrainage is sufficient to prevent serious damage to the land by the ground water.

In much of the area where the slope wash is underlain by the Chadron formation, the water table is near the surface. Owing to the very low permeability of the slope wash and the underlying Chadron formation, there is very little subsurface drainage in such areas. Consequently, the water table is maintained at a depth where evaporation and transpiration are sufficient to remove the excess water that is recharged to the water table by precipitation and irrigation. Where water is discharged from the area by evaporation and transpiration, most of the dissolved minerals in the water are left behind and cause a gradual increase of minerals in the soil and ground water. Under present conditions, the concentration of minerals will increase with the continued application of irrigation water and eventually will render part of the farm land unfit for production.

In the northern part of the area, where the slope wash is underlain by the Brule formation, many seeps are caused by leakage from the Fort Laramie canal. The seeps persist throughout the year but are more pronounced during the irrigation season, when water flows in the canal. The seepage occurs through fractures in the Brule formation. The ability of the fractures in this formation to transmit water is well demonstrated by an aerial photograph of a section of the canal a few miles upstream from the mapped area. (See fig. 9.) This photograph shows springs and seeps below the canal that are in alignment with extensive fracturing above the canal.

Fractures in the Brule formation apparently transmit water readily; the water levels in many of the wells adjacent to the canal in the Brule formation, and in the slope wash that is underlain by this formation, begin to rise almost as soon as water is turned into the canal. This rise of the water table has caused much of the farm land adjacent to the canal to become waterlogged and to be unfit for cultivation. In some places where it is possible to work the land and plant crops in the spring, the water table rises during the irrigation season, saturates the soil, and makes it impossible to move the farm machinery onto the fields in order to cultivate and harvest the crops.

In an attempt to determine the best method of preventing seepage away from the canal, the U. S. Bureau of Reclamation in the winter of 1949-50 installed an asphalt-membrane lining in the canal from the NE$\frac{1}{4}$ sec. 27, T. 24 N., R. 62 W., to a point downstream about 0.8 mile. Also, two sections of the canal were grouted with portland cement. Several hundred sacks of cement were required to fill the many large fractures encountered in the grouting operation. The grouted and lined sections of the canal are shown on pl. 1.

Several piezometer tubes were installed adjacent to the Fort Laramie canal in order to observe the relation between the water in the canal and the rise of water level in the slope

Figure 9.--Section of the Fort Laramie canal (sec. 36, T. 25 N., R. 63 W.) showing seeps associated with fractures in the Brule formation. The small white dots immediately below the canal in the center of the picture are places where water percolates to the surface. Note the alignment of these dots with fracture lines above the canal.

wash. Measurements were made in these tubes before water was turned into the canal in the spring of 1949 and were continued periodically through the 1950 irrigation season. This series of water-level measurements indicates the trend of the fluctuation of the water levels both before and after the canal was treated. Water levels in the slope wash adjacent to the grouted sections of the canal continued to rise in 1950 at about the same rate and magnitude as they did in 1949 before the canal was treated. In fact, the water level in well 24-62-27aca3 (see fig. 10),

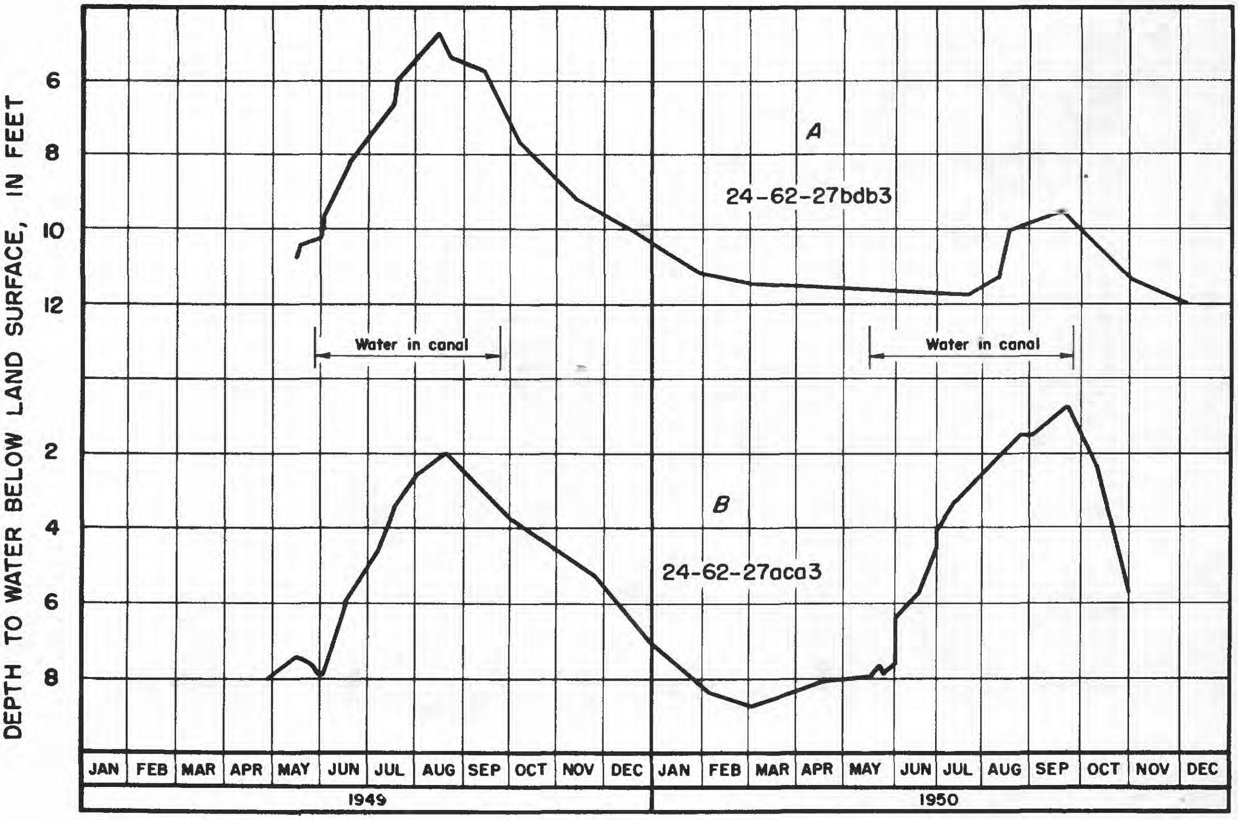

Figure 10.--Hydrographs showing the effects of grouting and lining on the fluctuations of the water level in wells adjacent to the Fort Laramie canal: A, well adjacent to the lined section; B, well adjacent to the grouted section.

adjacent to the grouted section, reached a higher level during the 1950 irrigation season than it did during the 1949 season. Wells adjacent to the section of canal that was treated with the asphalt-membrane lining, however, showed a definite decline of water levels in 1950. The water level in well 24-62-27bdb3, which is in the slope-wash material 300 feet from the lined section of the canal, began to decline almost as soon as water was turned out of the canal in the fall of 1949 and continued to decline until irrigation water was applied to the land in August 1950. The water level in this well rose only about 2 feet during the 1950 irrigation season, whereas it had risen about 6 feet during the previous year before the canal was lined. As a result of the decline of the water table in this area, a nearby field was irrigated for the first time in about 30 years. Previously, the water table had been so near the surface that irrigation water was not needed and considerable difficulty had been encountered in cultivating and harvesting the crops.

In order to study the movement of ground water away from the Fort Laramie canal and to show the effect the lining had on the movement of water, three sets of three piezometer tubes were installed along a line at right angles to the canal. The sets were 100, 200, and 300 feet from the center of the canal and each set consisted of three tubes that were driven to depths of approximately 6, 13, and 20 feet, respectively. The water level in each of these tubes indicated the hydrostatic pressure at the lower end of the tube. From the water-level measurements that were made in these tubes, the equal potential lines were plotted to show their pattern at three periods before the canal was lined: before water was turned into the canal; 1 day after water was turned into the canal; and 58 days after water was turned into the canal. Then, after the canal was lined, the flow lines were plotted to show the pattern 58 days after water was turned into the canal. (See fig. 11.) The movement of water is at right angles to the flow lines and is in the direction of diminishing hydraulic head.

Before water was turned into the canal in 1949, the water table was about 8 feet below the land surface and the direction of ground-water movement was downward and south from the canal. The downward movement of water is due to recharge from the spring rainfall. The first day after water was turned into the canal, the water table rose about 2 feet and the direction of movement of ground water was upward and away from the canal. This indicates that water moves away from the canal, through the Brule formation, and upward through the slope wash under considerable hydraulic pressure. At one time, the water level in the longest tube in each set was more than 1 foot higher than the water level in the shortest tube; this indicates the existence of an upward component to the direction of ground-water movement. After water had been in the canal for 58 days, the water level had risen to the land surface. The movement of water was still upward and south from the canal; however, the upward component was not as great as before because, with the rise in water level, the difference between the elevation of the water table and the level of the water in the canal decreased and, hence, the hydraulic pressure that forced the water upward was less. The water levels in the set of piezometer tubes nearest the canal were above the land surface during the latter part of the irrigation season.

Because of the canal lining the water levels rose much more slowly during the 1950 irrigation season than during the previous season. Fifty-eight days after water was turned into the canal, the water table was about 4 feet below the land surface and ground water was moving upward to some extent. Inasmuch as the line of wells was only about 200 feet from the end of the lined section of the canal, the Brule formation probably transmitted seepage from the unlined portion of the canal to this part of the area. If the lined section of the canal had extended a few hundred feet farther, these wells probably would have shown less rise of the water table.

A comparison of the fluctuations of the water levels in the piezometer tubes both before and after sections of the canal were lined or grouted indicates that the lining is preventing most, if not all, of the canal-seepage loss but that the grouting apparently has little or no effect on the seepage loss.

CHEMICAL QUALITY OF THE WATER

Introduction

The section on chemical quality has been prepared to define the character of water in the canal, wells, and springs in the slope wash and bedrock in the Soil and Moisture Conservation Demonstration Area. The relatively small size of the project area makes chemical-quality data particularly helpful in supporting hydrologic data that relate to direction of ground-water movement, the role of leakage from Fort Laramie canal, and the alterations in the ground water that result from irrigation practices in the area.

The collection of water samples under water-table conditions was made difficult by the sparsity of wells in the immediate area. Several methods of extracting water from the tight slope-wash materials were considered. Of these, it was determined that the most practical method was to hand auger to the water table in selected locations in the area and to bail the slurry or water-mud mixture. Two sets of water samples were collected from each of five shallow hand-augered holes and from three springs in the area. The first set was collected in August 1950, during the irrigation season, and the second set was collected in October 1950, after the end of the irrigation season. Water samples were collected also from the Fort Laramie canal and from two wells, one north of the canal and one outside the irrigated area. The procedure involved some danger of chemical contamination of the samples from such sources as the auger, the dipping container, surface seepage, and leaching of the mud during storage of the sample. However, every possible precaution was taken to insure reliable samples, and for the most part the analytical data indicate that the effort was successful.

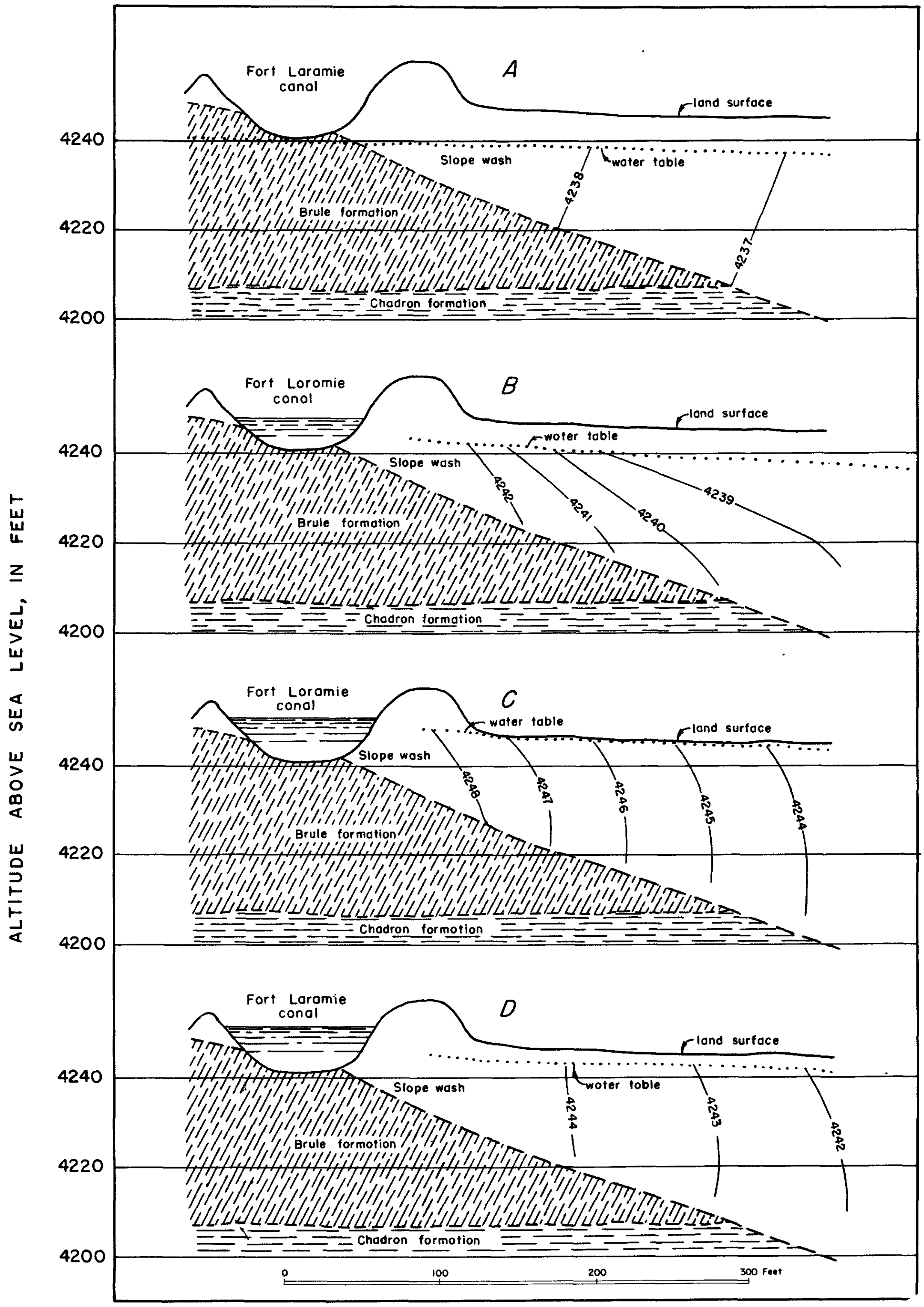

Figure 11.--Flow pattern of ground-water seepage from the Fort Laramie canal; A, Before water was turned into canal May 29, 1949, and before canal was lined; B, 1 day after water was turned into canal May 30, 1949, and before canal was lined; C, 58 days after water was turned into canal July 26, 1949, and before canal was lined; D, 58 days after water was turned into canal July 13, 1950, and after canal was lined.

The 1-liter samples were allowed to stand until the suspended material had settled completely. The chemical analysis was made of the supernatant liquid.

Determinations of total iron were omitted from the analyses of samples from augered holes inasmuch as fine-grained materials in suspension were difficult to remove. Such materials upon acidulation of the sample in preparation for the iron determination would have yielded an abnormally high iron content.

Source of chemical substances in the water

The three principal methods of ground-water recharge in the Soil and Moisture Conservation Demonstration Area are application of irrigation water and leakage from the Fort Laramie canal, direct precipitation, and underflow from the north beneath the canal. Each source provides a water that is appreciably different in chemical character, and the quantities and kinds of minerals in the ground water in the area are determined principally by the quantities of water from the three sources in the admixture. Water that is yielded by the Chadron formation to wells north of Fort Laramie canal probably is representative of the characteristic type found in the area prior to irrigation. Results of analyses of samples collected from two wells that yield water from the Chadron formation (see table 2 and fig. 12) indicate that the water is soft and principally of the sodium bicarbonate type, although the water from well 24-62-22cdd had about equal amounts of sulfate and bicarbonate. Appreciable quantities of chloride were common to both. A single sample from the Chadron formation in Morrill County, Nebr. (Babcock, Visher, and Durum, 1952, p. 50), was of the sodium bicarbonate type but was of lower mineral content (412 ppm) and was harder (112 ppm). Comparison of the three water analyses indicates that, prior to irrigation, waters from the Chadron probably differed considerably in the amounts of dissolved minerals, which ranged from a few hundred to about 1,000 ppm.

Surface-water irrigation in the area has tended to modify the type and character of mineral substances in the water in unconsolidated materials. Comparison of the bar diagrams in figure 12 for canal-water and ground-water samples depicts the magnitude of the changes that have occurred as the comparatively dilute irrigation water spreads across the fields, percolates to the water table, and moves southward toward the Cherry Creek drain. These changes are brought about through solution of mineral substances from the soil and rocks and by evapotranspiration which concentrates the salts in solution and in the soil. The changes are augmented by the low permeability of the water-bearing materials, which results in a high water table and makes flushing of the salts in the soil an extremely slow process. Further alterations in the chemical character of the ground water occur through dilution by precipitation and by canal water that seeps through fractures in the Brule formation and ultimately reappears in the slope-wash materials or at the ground surface. For the most part, the quality of water in the slope wash at a given place is related to the specific bedrock formation that underlies it. It should be noted that the water-table contour lines and bar graphs in figure 12 are based on data collected prior to the lining and grouting of the canal.

Chemical properties of water in the slope wash

The water sampled in the slope wash (of Quaternary age), which overlies the Brule and Chadron formations (of Tertiary age), differed appreciably in composition and in quantity of dissolved solids. The least-mineralized water was from a spring (24-62-27acc), which issues from slope wash overlying Brule formation down slope from the canal. In the sample taken in in August the dissolved-solids content was 464 ppm, and in October the content was 510 ppm. Reference is made again to the bar diagrams in figure 12, in which the combining power or equivalents per million of the cations appear at the left side of each column and of the anions on the right side. The sum of the equivalents of cations and anions equals the total equivalents per million, and this figure appears at the top of each bar. The water from one of the springs (24-62-27acc) is principally of the calcium bicarbonate type, as can be observed readily by the larger proportion of the constituents calcium and bicarbonate.

The most concentrated water was found in one of the augered holes (24-62-33aba) in slope wash that overlies the Chadron formation. The

Table 2.--Chemical analyses of water [Analytical results in parts per million except as indicated]

Location and source	Depth (feet)	Date of collection (1950)	pH	Specific conductance (micromhos at 25°C)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Percent sodium
24-62-26aba, Slope wash over Brule formation................	Spring	8-15	7.7	779	46	....	56	11	107	16	306	155	13	0.7	1.1	0.20	562	186	0	53
		10-22	7.6	693	41	0.02	55	12	84	9.4	258	140	13	.4	1.5	.10	486	186	0	48
24-62-25ccb, Slope wash over sand and gravel (augered hole).......	8	8-15	7.8	1,070	49	....	89	30	114	24	447	198	12	.5	23	.20	774	344	0	40
	6.5	10-23	7.4	1,150	54	....	93	34	127	27	501	208	13	.6	18	.30	826	370	0	41
24-62-27acc, Slope wash over Brule formation................	Spring	8-15	7.2	605	36	....	52	18	56	9.4	206	145	11	.5	.9	.10	464	202	33	36
		10-22	7.2	685	36	.02	58	19	68	9.5	241	148	18	.4	1.2	.20	510	222	24	39
24-62-35bcb, Slope wash over sand and gravel....................	Spring	8-15	7.8	2,700	48	....	56	12	614	16	738	705	129	.9	19	.70	1,960	188	0	86
		10-23	7.7	2,800	45	....	60	13	616	17	715	765	114	.7	24	.50	2,010	202	0	86
24-62-27cbb, Slope wash over Brule formation (augered hole)..	6	8-15	7.3	1,250	48	....	146	54	68	38	521	308	12	.8	.4	.20	964	587	160	19
	7	10-24	7.4	899	45	....	101	34	48	26	380	175	13	.5	3.0	.10	666	393	81	20
24-62-28dda, Slope wash over Chadron formation (augered hole)	5	8-15	7.2	1,720	48	....	209	85	76	66	646	455	55	.4	1.2	.30	1,310	872	342	15
	6	10-23	7.2	1,370	53	....	174	48	69	56	653	258	20	.6	.9	.20	1,000	632	113	18
24-62-28dac, Slope wash over Brule formation (augered hole)..	4	8-14	7.5	1,390	45	....	150	65	61	68	785	180	16	1.3	4.4	.20	980	640	0	15
	7	10-24	7.5	1,480	53	....	188	68	62	52	743	250	34	1.1	.4	.20	1,070	750	141	14
24-62-33aba, Slope wash over Chadron formation (augered hole)	2	8-14	7.4	2,660	36	....	128	18	516	23	708	885	60	.7	1.4	.20	2,020	394	0	73
	2	10-23	7.4	3,170	37	....	194	34	614	27	1,220	810	90	.6	1.0	.10	2,410	622	0	67
24-62-22cda, Chadron formation (drilled well) [1]...............	......	8-15	7.8	920	16	....	8.5	1.2	202	7.7	297	65	114	1.1	.3	.30	580	26	0	92
24-62-22cdd....................	83	8-15	7.8	1,460	50	....	16	4.9	324	11	353	298	99	.6	14	.20	996	60	0	91
Fort Laramie canal, bridge at lower end of area..............	......	8-14	7.6	508	12	.02	54	16	34	4.4	148	130	9.0	.4	.7	.10	354	199	78	27

1 Outside of immediate area of investigation.

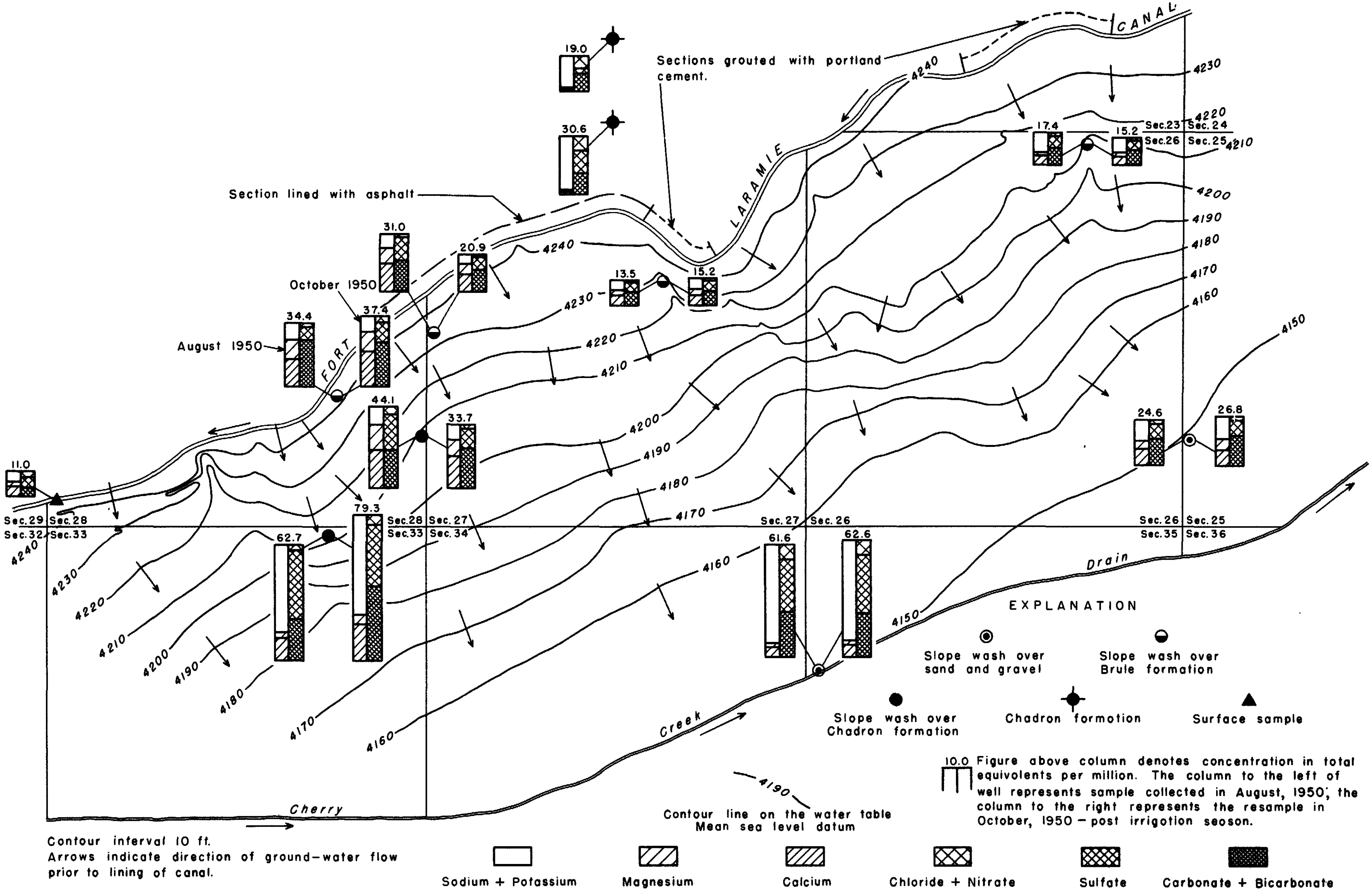

Figure 12.--Location of sampling points and graphic representation of analyses of waters in relation to ground-water movement prior to lining the canal.

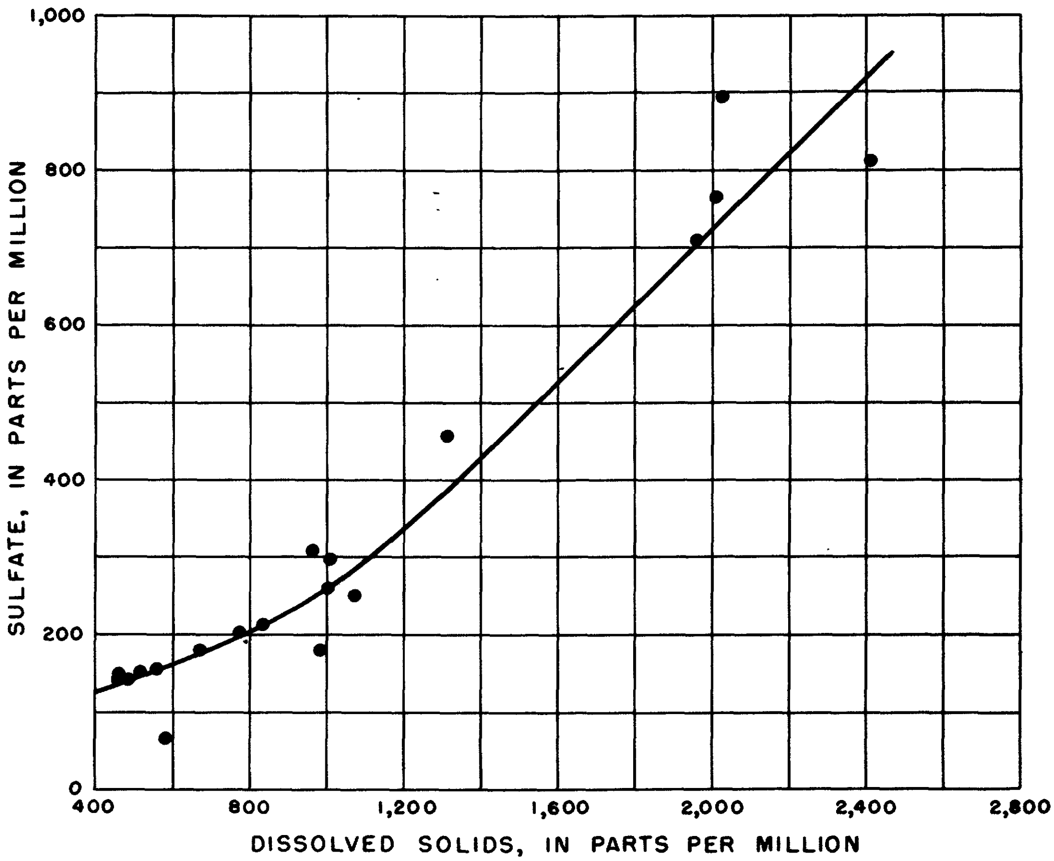

Figure 13.--Relation of sulfate to dissolved solids in ground water.

two samples had 2,020 and 2,410 ppm of dissolved solids and were of the mixed sodium sulfate-sodium bicarbonate type.

Most of the increase in concentration is related to accretion of sulfate and bicarbonate. As shown in figure 13, sulfate plotted against dissolved solids indicates that in the lower concentrations, below about 1,000 ppm, for example, there is an increase of sulfate with increase in dissolved solids, but the rise is less rapid than at higher concentrations. This deviation is explained by the tendency toward alteration in water type at higher concentrations from that of calcium or sodium bicarbonate to that of calcium or sodium sulfate.

The distinction in water types is further illustrated in figure 14, where the sum of calcium and magnesium equivalents is plotted against total equivalents per million (upper diagram), and calcium plus magnesium in parts per million is plotted against dissolved solids in parts per million (lower diagram). The samples of lower concentration, predominantly those in the slope wash over the Brule formation, are grouped in the upper part of the diagram at percentages from about 20 to 40, whereas the percentages of calcium and magnesium in two samples of water collected from the Chadron formation north of the irrigated tracts and for the more highly mineralized waters south of the canal are less than 20. The same grouping is observed in the lower diagram in figure 14, where the scale is in parts per million.

Seasonal changes in chemical substances

The results shown in table 2 and illustrated in figure 12 indicate that, whereas some differences are observed in the quality of water from August to October (respectively, peak of the irrigation season and after irrigation has ceased), the results for the most part are not entirely conclusive. It can be postulated that ground-water samples collected from shallow sources adjacent to or near the

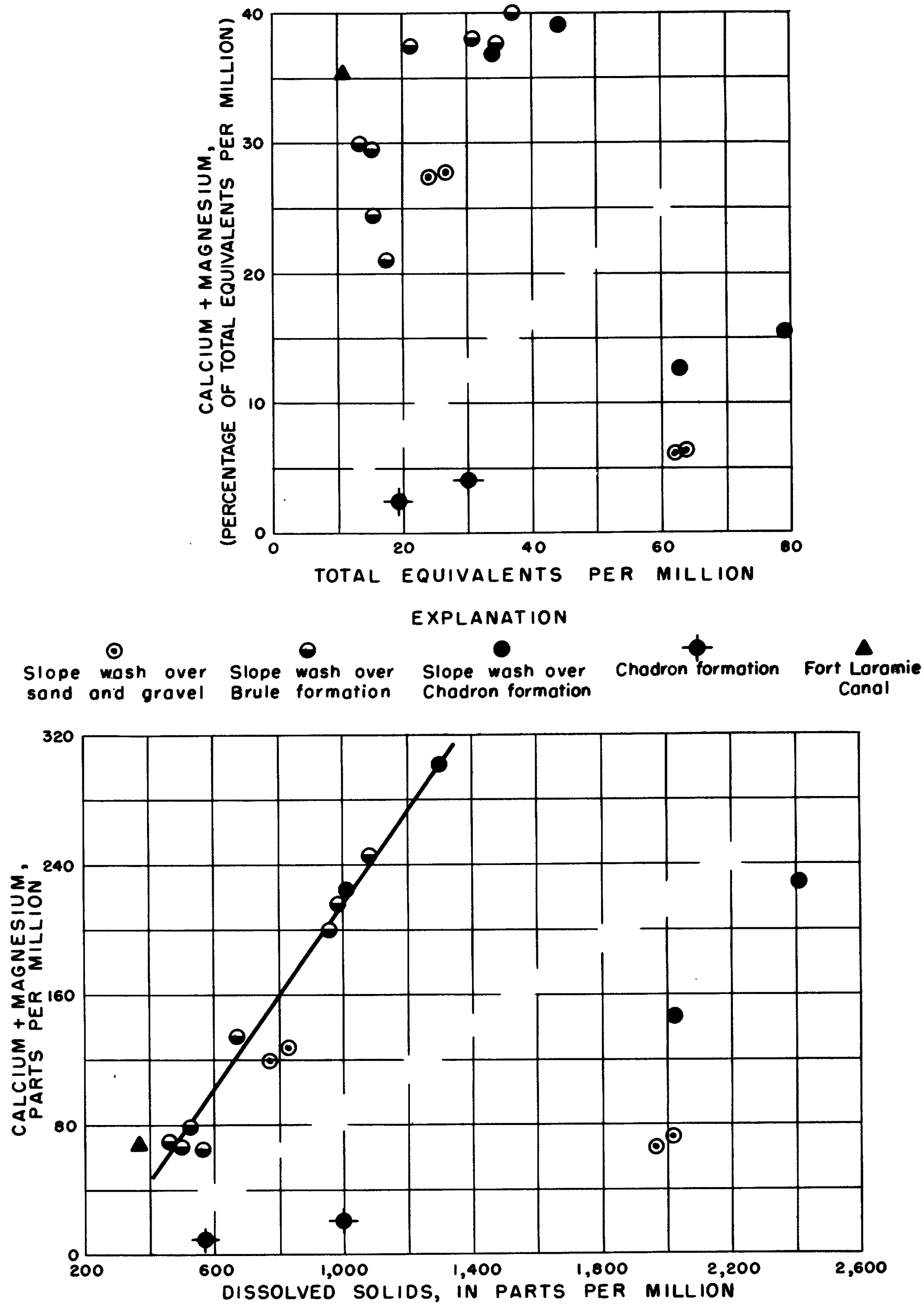

Figure 14.--Relation of calcium and magnesium to dissolved solids in waters.

Fort Laramie canal or irrigation laterals, or that intercept flow from fractures in the Brule formation, are most likely to show seasonal variation in chemical character. Conversely, waters from shallow wells and springs in the lower parts of the irrigated tracts are likely to remain somewhat more uniform in composition and total concentration. This has been demonstrated in other irrigated areas in Wyoming (Morris, Hackett, and Durum, 1951, pp. 61-66). Accordingly, shallow ground water adjacent to the Fort Laramie canal might be expected to increase somewhat in mineral content after the irrigation season, as the ground water then is not being diluted by seepage from the canal. This appears to have occurred at the following locations:

Location	Concentration in equivalents per million: August 1950	Concentration in equivalents per million: October 1950
24-62-28dac....	34.4	37.4
24-62-27acc....	13.5	15.2
24-62-33aba....	62.7	79.3

The most significant change occurred at 24-62-33aba, although the distance from the canal is about 0.3 mile. The mineral content of water from two other wells and one spring near the canal, namely 24-62-27cbb, 24-62-28dda, and 24-62-26aba, lowered during the period, and for the first two this decrease was significantly large. This indicates that either the ground water at these points has not been appreciably affected by seepage from the canal or that the interval of sampling was too short.

Relation of irrigation water to the chemical quality of water in the slope wash

The adequacy of the single sample in representing the concentration of the water in the Fort Laramie canal is to be questioned. However, the analytical data are augmented by the results of analyses of five samples collected in October 1950 and in the spring and summer of 1951 at the upstream face of the Guernsey Reservoir, which controls discharge to the North Platte River a few miles upstream from the intake of the Fort Laramie canal.

Concentrations of irrigation water in the Fort Laramie canal and Guernsey Reservoir, as expressed in equivalents per million and percentage equivalents per million, are given in the table below.

The minimum concentration, which is representative of flow during the spring, is nearly identical in total concentration and

Comparative results of analyses of irrigation water in Fort Laramie canal and releases from Guernsey Reservoir

	Fort Laramie canal		Guernsey Reservoir			
	August 14, 1950		Minimum concentration June 6, 1951		Average five analyses October 1950-June 1951	
	Equivalents per million	Percent	Equivalents per million	Percent	Equivalents per million	Percent
Ca............	2.66	24.2	2.66	25.1	3.83	20.8
Mg............	1.27	11.5	1.03	9.7	2.14	11.6
Na............	1.46	13.3	1.54	14.6	3.13	17.0
K.............	.11	1.0	.06	.6	.12	.6
	5.50		5.29		9.22	
HCO_3..........	2.47	22.4	2.32	21.9	3.19	17.3
SO_4...........	2.75	25.0	2.67	25.2	5.38	29.2
Cl............	.25	2.3	.27	2.6	.60	3.2
F.............	.02	.2	.02	.2	.02	.1
NO_3..........	.01	.1	.01	.1	.03	.2
	5.50		5.29		9.22	
Total equivalents per million	11.0		10.6		18.4	

composition to that of the canal sample. However, releases from the Guernsey Reservoir differed significantly in concentration as shown by difference between minimum and average values for the five samples, but the variation is seasonal; that is, the more highly mineralized water is that released in late fall and winter. In the absence of contrary data it is estimated that water diverted to the canal during the period of this study seldom, if ever, exceeded 600 to 700 ppm or about 20 equivalents per minute (epm).

In those parts of the area where water seeps out of the canal through fractures in the Brule formation and percolates to the slope wash, the character and total concentration of water in the slope wash would be expected to be like that of the irrigation water. The graphic data in figure 12 show that the samples obtained from slope wash that overlies the Brule formation below the canal in secs. 26 and 27 closely resemble the irrigation water in composition and concentration. The samples collected from spring 24-62-26aba in August was of higher mineral content (17.4 epm) than the sample from spring 24-62-27acc (13.5 epm). However, in October the total concentrations were the same (15.2 epm).

By comparison, the chemical character of the water samples collected in slope wash over the Brule formation adjacent to the canal in secs. 27 and 28 yielded waters that were about three times more concentrated than the irrigation water. (See fig. 12.) Accretion of calcium and magnesium carbonate is noticeable, particularly in the samples from 24-62-28dac, which indicates that the water has percolated for a long time through limy materials. Thus, the quality of the water in slope wash over the Brule formation is in a large degree dependent on the ease with which the water moves through the fractures of the Brule formation in the area under consideration.

Down gradient from the area where slope wash overlies the Brule formation, in the hole penetrating slope wash above the Chadron formation, the water resembles that of the Brule formation except that it is more concentrated and has a higher proportion of sulfate. Inasmuch as the sample was collected near the contact between the Brule and Chadron formations, the water should tend to be like that of the Brule waters. Water more typical of the Chadron formation is found in sec. 33 (24-62-33aba) and was characterized by a high percentage of sodium, predominantly as sodium sulfate, and was the most highly mineralized of all waters analyzed for this study. It was observed that waters having higher concentrations of dissolved minerals also contained bicarbonate in excess of calcium together with magnesium (equivalents per million). This "residual" sodium carbonate characteristic is considered by authorities as a potential source of danger to soil structure when the water is in contact with the soil.

Quality of water as related to effects on the soil

Soils of the Soil and Moisture Conservation Demonstration Area have developed under semiarid conditions. Therefore, they may be somewhat calcareous at the surface and more strongly calcareous in the lower horizons. The soils are fertile but, because of the climate, irrigation is needed to produce the maximum yields of which the soils are capable. The main soil types in the area are the Bridgeport silt loam, Keota silt loam, Cherry silty clay loam, and Buffington silty clay loam, and the minor soil types are the Epping silt loam, Bridgeport silty clay loam, Orella clay, and Colby silt loam. All these soils develop on young terraces and alluvial fans. A soil map of the area is shown in figure 15.

Four profiles of the Bridgeport silt loam were sampled in an area adjacent to the canal that was waterlogged by canal seepage. (See fig. 15.) The sampling was done by J. L. Doyle, U. S. Bureau of Reclamation, and the analyses were made by personnel of the U. S. Bureau of Reclamation in the laboratory at Denver, Colo. The analytical data are presented in table 3. These data indicate conditions for one soil type in a relatively small area and may not be representative of soil conditions in other parts of the Soil and Moisture Conservation Demonstration Area from which no samples were collected. However, in correspondence, J. N. Spencer, U. S. Bureau of Reclamation, stated that the soils that were sampled were predominantly saline (the neutral-salt or white-alkali type of salinity) and that the salts could be readily leached if the water table could be lowered.

On the basis of the pH, exchangeable-sodium percentage, and specific conductance of the saturation extract, all the samples of soil

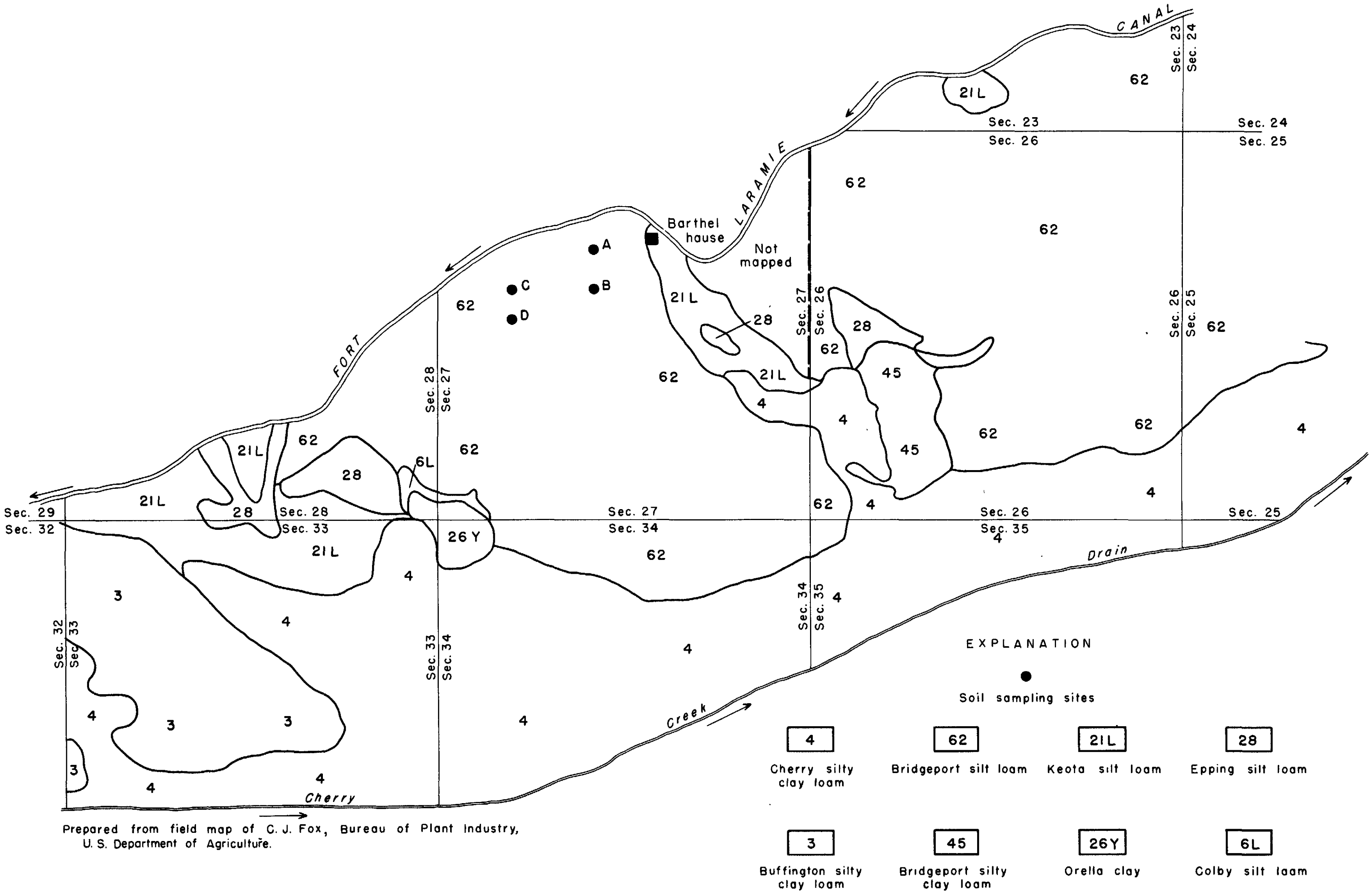

Figure 15.--Soil map (preliminary) of the Soil and Moisture Conservation Demonstration Area.

Table 3.--Analyses of soils [Analyses by U. S. Bureau of Reclamation, Denver, Colo.]

Profile number	Depth (inches)	Insoluble carbonates (percent)	Gypsum me/100 g of soil	pH of saturated paste	pH of 1/10 mixture	Saturation percentage	Exchangeable sodium me/100 g soil	Exchange capacity me/100 g of soil[1]	Exchangeable sodium percentage	Conductivity of saturation extract $Kx10^3$	Soluble sodium percentage	Soluble sodium me/100 g of soil	Remarks
A	0-12	11.6	0.00	7.5	8.5	49.0	1.68	26.0	6.46	4.13	38.0	0.77	Area leveled and irrigated with sump pump. Three-inch hard layer at 14 inches.
	12-24	12.0	.00	7.5	8.7	48.0	1.27	23.6	5.38	1.34	38.4	.25	
	24-36	12.7	.00	7.5	8.6	45.0	1.09	21.9	4.98	1.56	33.8	.24	
	36-48	11.0	.00	7.5	8.7	45.0	1.19	23.6	5.04	1.11	38.0	.19	
	48-60	6.51	.00	7.7	8.7	45.0	1.17	29.2	4.01	1.05	43.6	.21	
B	0-12	10.2	.00	7.7	8.5	48.0	1.24	23.9	5.19	3.06	36.8	.54	Water table at 36 inches. Three-inch dense layer at 54 inches.
	12-24	9.10	.00	7.5	8.9	44.0	2.31	30.0	7.70	.62	99.7	.27	
	24-36	6.69	.00	7.8	8.9	44.0	2.10	30.2	6.95	1.59	68.7	.48	
	36-48	7.99	.00	7.7	8.7	48.0	1.93	27.1	7.12	2.06	53.1	.52	
	48-60	12.4	.00	7.8	9.0	43.0	2.19	29.4	7.45	.92	67.2	.26	
C	0-12	7.19	.00	7.6	8.2	55.0	3.26	28.5	11.4	7.72	40.6	2.59	Six-inch dense layer at 18 inches. Water table at 44 inches.
	12-24	17.7	.00	8.0	9.3	43.0	3.93	26.4	14.9	1.86	84.4	.67	
	24-36	15.2	.00	7.9	9.2	42.0	2.61	24.2	10.8	1.75	70.6	.52	
	36-48	10.9	.00	7.8	9.2	44.0	2.60	28.5	9.1	.86	67.7	.26	
	48-60	11.5	.00	7.6	9.1	41.0	2.42	30.5	7.93	3.48	49.6	.71	
D	0-12	6.32	.00	7.8	8.9	52.0	2.51	29.7	8.45	2.67	63.9	.89	
	12-24	11.62	.00	7.8	8.9	48.0	2.91	30.5	9.54	1.08	95.1	.49	
	24-36	12.85	.00	7.8	9.0	45.0	2.67	30.9	8.64	1.54	47.9	.33	
	36-60	10.78	.00	7.8	8.9	48.0	2.46	29.7	8.28	1.83	61.5	.54	

[1] Exchange capacity increased by 10 percent when insoluble carbonates are 1 percent or more.

would be classed according to Israelsen (1950) as normal arid soils except the samples from 0-12 inches of profiles A and C, which are classed as saline. When the chemical analyses of the water samples collected at 24-62-27acc and 24-62-27cbb are compared with that of the sample from 24-62-35bcb down slope near the Cherry Creek drain, the data show that the water percolating through the subsoils has increased two to five times in specific conductance, percentage of sodium, and dissolved solids. The water increased markedly in the amount of sodium, bicarbonate, chloride, and sulfate (mainly white-alkali salts). That only the surface soils in profiles A and C were classed as saline shows that the build-up of alkali salts in the soils has not been as great as might be expected. At least for the limited area of soil sampling, the movement of water out of the soil through the many seeps has prevented an excessive accumulation of alkali salts. Thus it may be concluded that the soils in the area of sampling have not been seriously damaged.

SUMMARY AND CONCLUSIONS

The Soil and Moisture Conservation Demonstration Area is underlain largely by fine-grained slope-wash material. All the irrigated land in the area is underlain by this material. The Brule formation, a fractured siltstone, underlies the slope wash in the northern part of the area; the Chadron formation, predominantly a tight clay, underlies the slope wash in the central part of the area; and coarse sand and gravel underlies the slope wash in the southern part of the area. Shallow, unconfined ground water is contained in the slope wash within about 10 feet of the land surface in most of the area.

Water is recharged to the water table through seepage from the canals and laterals, from irrigation water applied to the land, and from precipitation. In the part of the area adjacent to the Fort Laramie canal, where the slope wash is underlain by the Brule formation, seepage from the canal is the source of considerable recharge. Water moves away from the canal through the fractures in the Brule formation and thence upward through the slope wash under hydrostatic pressure, which in some places is sufficient to force the water to the surface.

Transpiration by plants and evaporation from the land surface are the main means of ground-water discharge in the area. Some ground water is discharged through drains in the area; however, most of the water enters the drains near the Fort Laramie canal and, hence, the drains serve mainly to remove part of the ground water that seeps from the canal. In most of the area, the capillary fringe extends to the root zone of the plants, and in many places in the area, it reaches the land surface. Where water is discharged through evaporation and transpiration, the dissolved materials in the water are left behind; this causes an increase in the minerals in the soil and ground water and, if excessive, decreases the productivity of the soil. In places, the evaporation of water has left deposits of harmful salts on the land surface. The continued application of irrigation water causes an increase in the mineralization of the ground water and, if present conditions continue, eventually will render a large part of the land unfit for cultivation. As the irrigation water is the main source of the harmful salts, the productive life of the soil could be increased by decreasing the amount of water applied to the land.

In order to reclaim land that has been damaged by the high water table, adequate subsurface drainage would have to be provided to lower the water table sufficiently to prevent the capillary fringe from extending to the land surface. However, a system of drains that would remove the excess ground water or that would lower the water table sufficiently to prevent the deposition of harmful salts on the land surface probably could not be installed economically.

Seeps in the area adjacent to the Fort Laramie canal are due to water leaking out of the canal through fractures in the Brule formation. Attempts to prevent leakage from the canal apparently were successful only in the experimental section that was lined with an asphalt membrane. Where the canal was grouted with portland cement, the water continued to leak out of the canal at about the same rate as it did prior to the grouting.

Preventing leakage from the Fort Laramie canal would reduce seepage only in the part of the area that is underlain by the Brule formation and would not appreciably affect the level of the water table in the rest of the area.

Chemical-quality reconnaissance in the area indicates that surface-water irrigation has tended to modify the type and character of mineral substances of water found under water-table conditions. These changes occur as the comparatively dilute irrigation water is spread across the fields, percolates to the water table, and moves laterally toward the Cherry Creek drain. Solution of mineral substances from the soil and rocks is facilitated by the low permeability of and resulting slow movement of water in the slope wash, the Brule formation, and the Chadron formation. A high water table and evapotranspiration have facilitated the concentration of salts in ground water at shallow depths in parts of the area.

Water from the slope wash and bedrock differed widely in composition and in quantity of dissolved solids. The least mineralized was a spring water (464 ppm of dissolved solids) of the calcium bicarbonate type, whereas the most mineralized water was from an augered test hole (2,410 ppm of dissolved solids) and was of the mixed sodium sulfate-sodium bicarbonate type.

Most of the increase in concentration is related to accretion of sulfate and bicarbonate; a plot of sulfate against dissolved solids shows proportionally higher sulfate at higher concentration levels than at lower levels.

Ground-water samples collected from shallow sources down slope from the unlined section of the canal are likely to show seasonal variation in chemical character, and conversely ground water at shallow depths in the lower parts of the irrigated tracts is likely to remain relatively uniform in composition and total concentration.

In those parts of the area where water seeps out of the canal through fractures in the Brule formation and percolates up through the slope wash, the character and total concentration of the water resemble those of the irrigation water. Where the Brule formation is only slightly fractured, the shallow ground water in the overlying slope wash shows a substantially higher content of dissolved minerals.

Soils that were sampled at four places in the area were predominantly saline (of the neutral salt or white alkali type) and are classed as normal arid soils except for the top 12-inch sample in two profiles.

Periodic water-level measurements should be continued in a few selected wells in order to determine the long-range effects of the lining and grouting on the water levels. Also, if additional sections of the canal are lined, wells should be installed and periodic water-level measurements should be made at least a year prior to and for at least a year after treatment. Thus, the effects of the lining could be observed.

Samples of the ground water for chemical analysis should be collected periodically in this and other similar areas in order to determine the rate of increase of minerals in the ground water. More extensive sampling of water diverted to the Fort Laramie canal is needed to correlate properly the chemical quality of the irrigation water with the water that moves through fractures in the Brule formation. Also, soil samples should be tested periodically to determine the rate of increase of minerals.

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Table 4.--Water levels in observation wells, in feet above or below land-surface datum

[All measurements are below land surface unless preceded by (+)]

Date	Water level	Date	Water level	Date	Water level	Date	Water level
			24-62-22cdd				
May 25, 1949	27.09	Sept.20, 1949	22.64				
			24-62-23cdc				
May 26, 1949	15.36	July 12, 1949	5.95	Feb. 22, 1950	13.43	May 21, 1950	13.83
29 (3:09pm)	15.38	26	3.55	Mar. 22	14.38	31	10.65
29 (4:50pm)	15.37	Aug. 9	2.18	May 5	15.34	June 12	8.75
29 (9:17pm)	15.25	27	1.49	15	15.53	26	5.70
30 (8:45am)	14.95	Sept.13	1.76	16	15.53	July 10	3.78
30 (3:35pm)	14.83	Oct. 4	5.04	17 (8:33am)	15.42	20	2.35
31	14.44	21	4.68	17 (4:14pm)	15.39	Aug. 7	1.13
June 1	14.16	Nov. 21	7.89	18	15.04	30	.73
3	14.45	Dec. 27	10.46	19	14.57	Sept.22	1.27
9	11.77	Feb. 2, 1950	12.48	20	14.29	Oct. 30	7.37
July 5	7.07						
			24-62-23dad				
May 13, 1949	44.22	July 12, 1949	30.34	Aug. 27, 1949	27.10	Oct. 21, 1949	34.25
June 3	41.02	26	27.77	Sept.13	28.73	Nov. 21	41.39
9	34.77	Aug. 9	27.50	Oct. 4	33.84	Dec. 27	43.43
July 5	31.59						

Table 4.--Water levels in observation wells--Continued

Date	Water level	Date	Water level	Date	Water level	Date	Water level
24-62-23dbd							
May 13, 1949	37.05	July 5, 1949	25.62	Feb. 22, 1950	35.00	May 31, 1950	30.28
26	37.30	12	23.55	Mar. 22	35.22	June 12	26.72
29 (3:53pm)	37.37	26	19.59	May 5	37.42	26	21.74
29 (4:30pm)	37.37	Aug. 9	17.45	15	37.63	July 10	18.33
29 (9:10pm)	37.37	29	16.75	16	37.65	20	16.90
30 (8:40am)	37.25	Sept.13	17.39	17 (8:27am)	37.33	Aug. 7	16.03
30 (3:20pm)	37.15	Oct. 4	21.20	17 (4:04pm)	37.21	30	15.92
31	36.75	21	23.13	18	36.86	Sept.22	17.40
June 1	36.40	Nov. 21	26.77	19	36.26	Oct. 30	26.24
3	35.39	Dec. 27	30.97	20	35.88	Nov. 30	29.98
9	32.87	Feb. 2, 1950	33.82	21	35.25		
24-62-23dcb1							
Apr. 28, 1949	28.25	June 3, 1949	26.98	Nov. 21, 1949	19.87	May 18, 1950	28.54
May 11	28.55	9	24.67	Dec. 27	23.31	19	28.00
17	28.67	July 5	18.26	Feb. 2, 1950	25.89	20	27.73
26	29.14	12	16.46	22	26.93	21	27.22
29 (3:02pm)	29.06	26	13.60	Mar. 22	27.99	31	22.50
29 (4:40pm)	29.07	Aug. 9	12.27	May 5	29.09	June 12	19.34
29 (9:12pm)	29.06	27	12.09	15	29.26	26	14.85
30 (8:45am)	28.78	Sept.13	12.58	16	29.26	July 10	12.46
30 (3:35pm)	28.59	Oct. 4	15.37	17 (8:30am)	29.08	20	11.65
31	28.19	21	16.62	17 (4:13pm)	28.88	Aug. 7	11.30
June 1	27.83						
24-62-23dcb2							
May 13, 1949	19.12	July 26, 1949	21.03	Sept.13, 1949	19.05	Nov. 21, 1949	28.21
26	28.37	Aug. 9	19.02	Oct. 4	22.89	Dec. 27	32.20
July 5	26.97	27	18.40	21	24.65	Feb. 2, 1950	34.28
12	24.96						
24-62-23dcb3							
July 26, 1949	8.29	Oct. 4, 1949	10.53	July 17, 1950	6.50	Aug. 24, 1950	5.40
Aug. 9	6.65	June 22, 1950	11.75	20	6.26	30	5.18
27	6.15	30	9.97	Aug. 2	5.60	31	5.12
Sept.13	7.76	July 7	8.06	7	5.43	Sept.22	6.91
24-62-23dcb4							
July 26, 1949	11.12	Sept.13, 1949	8.93	July 20, 1950	8.45	Aug. 30, 1950	7.69
Aug. 9	8.97	Oct. 4	12.42	Aug. 7	7.64	Sept.22	9.08
27	8.28						
24-62-23ddb1							
May 13, 1949	36.52	June 3, 1949	33.62	Oct. 4, 1949	25.07	May 17, 1950	
26	37.47	9	32.54	21	26.66	(4:08pm)	29.74
29 (3:47pm)	37.86	July 5	26.20	Nov. 21	30.77	18	29.76
29 (4:20pm)	37.81	12	23.48	Dec. 27	34.65	19	30.05
29 (9:00pm)	32.11	26	20.68	Feb. 2, 1950	36.34	20	30.79
30 (8:40am)	29.67	Aug. 9	19.69	22	37.30	21	31.43
30 (3:20pm)	29.68	27	19.42	May 16	37.23	31	30.39
31	30.84	Sept.13	20.69	17 (8:27am)	29.74	June 12	28.27
June 1	31.29					26	23.53

Table 4.--Water levels in observation wells--Continued

Date	Water level	Date	Water level	Date	Water level	Date	Water level
			24-62-23ddb2				
May 13, 1949	38.47	July 5, 1949	22.39	Feb. 2, 1950	35.36	May 21, 1950	35.14
26	38.70	12	19.70	22	36.13	31	28.67
29 (2:45pm)	38.81	26	17.30	Mar. 22	37.57	June 12	22.88
29 (4:15pm)	38.78	Aug. 9	16.28	May 5	38.92	26	19.93
29 (9:57pm)	38.57	27	16.15	15	39.14	July 10	17.47
30 (8:35am)	38.10	Sept.13	17.70	16	39.08	20	16.25
30 (3:15pm)	37.88	Oct. 4	22.50	17	38.23	Aug. 7	15.60
31	37.19	21	23.71	18	37.33	30	15.67
June 1	36.89	Nov. 21	28.55	19	36.55	Sept.22	17.70
3	35.60	Dec. 27	32.41	20	36.14	Oct. 30	27.86
9	32.21						
			24-62-23ddb3				
July 26, 1949	8.27	Sept.13, 1949	7.26	Aug. 7, 1950	9.33	Sept.22, 1950	8.34
Aug. 9	7.24	Oct. 4	8.46	30	8.93	Oct. 30	9.35
27	7.24	21	8.45				
			24-62-23ddb4				
July 26, 1949	5.08	Oct. 4, 1949	9.72	July 17, 1950	5.32	Aug. 30, 1950	4.46
Aug. 9	4.81	21	11.36	Aug. 2	4.70	31	4.58
27	4.77	June 22, 1950	9.70	7	4.42	Sept.22	5.95
Sept.13	5.16	July 7	6.48	24	4.36		
			24-62-23ddb5				
Aug. 9, 1949	5.01	Aug. 27, 1949	4.74	Sept.13, 1949	Dry		
			24-62-23ddd				
Apr. 28, 1949	21.87	July 5, 1949	20.97	Dec. 27, 1949	18.70	June 26, 1950	18.89
May 11	22.02	12	19.38	Feb. 2, 1950	19.88	July 10	18.55
17	22.11	26	17.26	22	20.55	20	17.88
26	22.52	Aug. 9	16.27	Mar. 22	21.30	Aug. 7	17.48
29	22.71	27	14.88	May 5	22.47	30	16.12
30	22.73	Sept.13	15.14	15	22.69	Sept.15	15.65
31	22.78	Oct. 4	15.64	19	22.82	22	15.86
June 3	22.88	21	16.66	31	22.06	Oct. 30	17.34
9	22.17	Nov. 21	17.65	June 12	20.82		
			24-62-24cbc				
May 26, 1949	49.30	May 31, 1949	49.27	July 26, 1949	30.55	Nov. 21, 1949	29.17
29 (2:37pm)	49.36	June 1	49.24	Aug. 9	29.52	Dec. 27	31.04
29 (4:05pm)	49.27	3	49.14	27	28.60	Feb. 2, 1950	33.15
29 (8:50pm)	49.26	9	48.60	Sept.13	28.27	22	34.01
30 (8:30am)	49.27	July 5	34.25	Oct. 4	28.16	Mar. 22	34.98
30 (3:14pm)	49.27	12	30.86	21	28.42	May 15	37.23
			24-62-25bcd				
July 12, 1949	16.78	Aug. 27, 1949	14.67	Oct. 21, 1949	14.26	Feb. 2, 1950	16.47
26	16.06	Sept.13	14.07	Nov. 21	14.17	22	16.87
Aug. 9	15.19	Oct. 4	14.52	Dec. 27	15.45		
			24-62-25ccb				
Apr. 28, 1949	9.30	July 12, 1949	4.62	Feb. 2, 1950	8.81	July 10, 1950	5.62
May 12	9.38	26	6.10	22	9.24	20	6.62
17	9.39	Aug. 9	5.49	Mar. 22	9.72	Aug. 7	6.21
26	8.24	27	4.16	May 5	10.21	30	4.98
31	9.59	Sept.13	2.87	15	10.29	Sept.15	5.22
June 3	9.56	Oct. 4	4.34	19	10.35	22	3.61
9	5.84	21	5.37	31	8.46	Oct. 30	6.89
16	5.99	Nov. 21	6.67	June 12	8.16	Nov. 30	7.97
July 5	3.27	Dec. 27	7.83	26	4.60		

Table 4.--Water levels in observation wells--Continued

Date	Water level	Date	Water level	Date	Water level	Date	Water level
24-62-26aab1							
May 26, 1949	13.10	Sept.13, 1949	6.64	May 5, 1950	8.97	July 10, 1950	7.78
31	10.54	Oct. 4	7.34	15	9.00	20	6.67
June 3	10.11	Nov. 21	7.95	19	9.12	Aug. 7	6.42
9	9.22	Dec. 27	8.49	31	8.63	30	6.83
July 26	7.68	Feb. 2, 1950	8.75	June 12	8.69	Sept.22	6.06
Aug. 9	7.41	22	8.85	26	8.45	Oct. 30	7.60
27	7.10	Mar. 22	8.92				
24-62-26aab2							
May 11, 1949	9.99	May 26, 1949	10.43	June 3, 1949	10.71	July 5, 1949	10.22
17	10.13	31	10.61	9	9.82	12	8.58
24-62-26abb1							
May 11, 1949	5.88	July 26, 1949	2.10	Feb. 2, 1950	5.20	June 26, 1950	3.16
17	6.16	Aug. 9	.49	22	5.39	July 10	.92
26	6.70	27	.32	Mar. 22	5.80	20	.61
31	7.15	Sept.13	.21	May 5	6.33	Aug. 7	.31
June 3	6.49	Oct. 4	1.30	15	6.63	30	.21
9	4.28	21	1.28	19	6.81	Sept.22	.14
July 5	3.77	Nov. 21	2.19	31	4.65	Oct. 30	2.14
12	3.63	Dec. 27	3.59	June 12	3.79		
24-62-26abb2							
May 11, 1949	5.78	Aug. 9, 1949	0.56	Dec. 27, 1949	3.60	May 15, 1950	6.56
17	6.12	27	.45	Feb. 2, 1950	5.17	31	4.58
June 9	4.25	Sept.13	.31	22	5.38	June 12	3.85
July 5	3.67	Oct. 4	1.24	Mar. 22	5.80	26	3.12
12	3.66	21	1.25	May 5	6.39	July 10	.96
26	2.12	Nov. 21	2.21				
24-62-26ada1							
Apr. 28, 1949	5.14	July 26, 1949	3.33	Feb. 2, 1950	6.09	June 26, 1950	3.97
May 11	4.17	Aug. 9	3.50	22	5.75	July 10	4.39
17	4.25	27	3.86	Mar. 22	5.50	20	4.82
26	4.80	Sept.13	3.31	May 5	5.34	Aug. 7	5.45
31	5.22	Oct. 4	4.15	15	5.49	30	4.81
June 3	5.39	21	3.65	19	5.87	Sept.15	4.47
9	2.50	Nov. 21	4.29	31	3.45	22	3.10
July 5	3.83	Dec. 27	5.24	June 12	3.82	Oct. 30	5.30
12	4.38						
24-62-26ada2							
Apr. 28, 1949	5.14	July 26, 1949	3.34	Feb. 2, 1950	6.10	June 26, 1950	4.00
May 11	4.19	Aug. 9	3.52	22	5.76	July 10	4.42
17	4.16	27	3.86	Mar. 22	5.52	20	4.84
26	4.88	Sept.13	3.33	May 5	5.39	Aug. 7	5.48
31	5.23	Oct. 4	4.18	15	5.34	30	4.83
June 3	5.44	21	3.67	19	5.79	Sept.15	4.54
9	2.52	Nov. 21	4.36	31	3.45	22	3.07
July 5	3.96	Dec. 27	5.25	June 12	3.85	Oct. 30	5.32
12	4.44						
24-62-26ada3							
Apr. 28, 1949	5.58	July 12, 1949	4.45	Dec. 27, 1949	5.25	June 26, 1950	3.99
May 11	4.20	26	3.33	Feb. 22, 1950	5.76	July 10	4.41
17	4.28	Aug. 9	3.59	Mar. 22	5.51	20	4.82
26	4.30	27	3.81	May 5	5.39	Aug. 7	5.49
31	5.17	Sept.13	3.33	15	5.44	30	4.81
June 3	5.45	Oct. 4	4.14	19	5.77	Sept.15	4.52
9	2.52	21	3.64	31	3.45	22	3.05
July 5	3.98	Nov. 21	4.29	June 12	3.83	Oct. 30	5.30

Table 4.--Water levels in observation wells--Continued

Date	Water level	Date	Water level	Date	Water level	Date	Water level
			24-62-26bad				
May 17, 1949	1.58	July 5, 1949	2.24	Sept.13, 1949	1.87	May 15, 1950	1.85
26	1.75	12	2.27	Oct. 4	2.19	19	2.17
31	1.76	26	1.95	21	1.44	31	1.73
June 3	1.76	Aug. 9	2.39	Nov. 21	1.43	June 12	1.95
9	1.01	27	2.29				
			24-62-26bbb1				
June 3, 1949	9.01	July 26, 1949	2.95	Oct. 21, 1949	6.25	July 10, 1950	3.17
9	6.99	Aug. 9	3.26	Nov. 21	10.51	20	2.58
16	6.30	27	3.29	May 31, 1950	5.68	Aug. 7	2.89
July 5	3.87	Sept.13	4.37	June 12	4.09	30	3.30
12	3.88	Oct. 4	8.32	26	3.76	Sept.22	4.70
			24-62-26bbb2				
July 5, 1949	3.92	Aug. 9, 1949	3.14	Sept.13, 1949	4.29	June 26, 1950	3.77
12	3.92	27	3.21	June 12, 1950	4.13	July 10	3.18
26	2.75						
			24-62-26bdd				
July 5, 1949	10.60	Aug. 27, 1949	4.10	Nov. 21, 1949	8.53	May 31, 1950	13.41
12	9.53	Sept.13	3.98	May 15, 1950	13.71	June 12	12.12
Aug. 9	5.61	Oct. 4	5.02	19	13.79		
			24-62-26cbb				
Apr. 28, 1949	5.10	July 26, 1949	4.23	Feb. 2, 1950	4.93	June 26, 1950	4.38
May 17	4.68	Aug. 9	4.68	22	4.92	July 10	4.34
25	4.74	27	4.71	Mar. 22	4.71	20	4.20
31	4.59	Sept.13	4.22	May 5	4.26	Aug. 7	4.30
June 3	4.74	Oct. 4	4.46	15	4.22	30	4.13
9	4.24	21	4.44	19	4.31	Sept.15	4.04
16	4.28	Nov. 21	4.59	31	4.14	22	3.86
July 5	4.73	Dec. 27	4.82	June 12	4.30	Oct. 30	4.27
12	4.73						
			24-62-26ccc				
May 26, 1949	11.90	Aug. 9, 1949	8.43	Feb. 22, 1950	12.57	July 10, 1950	8.95
31	11.94	27	6.54	Mar. 22	12.58	20	8.65
June 3	11.91	Sept.13	7.30	May 5	12.24	Aug. 7	8.08
9	10.64	Oct. 4	8.23	15	12.11	30	7.45
16	9.80	21	9.25	19	12.14	Sept.15	6.53
July 5	9.49	Nov. 21	10.30	31	10.83	22	6.29
12	8.96	Dec. 27	11.34	June 12	9.67	Oct. 30	9.54
26	8.98	Feb. 2, 1950	12.28	26	9.40		
			24-62-26daa				
July 5, 1949	20.01	Oct. 21, 1949	16.24	May 15, 1950	22.79	July 20, 1950	20.32
12	19.17	Nov. 21	17.93	19	22.79	Aug. 7	19.93
26	17.83	Dec. 27	19.03	31	22.20	30	19.16
Aug. 9	17.46	Feb. 2, 1950	20.52	June 12	21.42	Sept.15	18.23
27	16.18	22	21.07	26	20.09	22	17.70
Sept.13	15.17	Mar. 22	21.77	July 10	20.10	Oct. 30	18.82
Oct. 4	14.47	May 5	22.54				

Table 4.--Water levels in observation wells--Continued

Date	Water level	Date	Water level	Date	Water level	Date	Water level
			24-62-26dcd				
Apr. 29, 1949	6.90	July 26, 1949	5.96	Feb. 2, 1950	8.35	June 26, 1950	5.76
May 17	8.11	Aug. 9	5.06	22	8.58	July 10	4.70
26	7.94	27	3.55	Mar. 22	8.82	20	4.96
31	7.99	Sept.13	4.19	May 5	9.07	Aug. 7	5.30
June 3	8.00	Oct. 4	5.52	15	9.99	30	5.66
9	3.97	21	6.24	19	9.02	Sept.15	4.72
16	5.43	Nov. 21	7.07	31	8.51	22	4.45
July 5	2.90	Dec. 27	7.61	June 12	6.41	Oct. 30	7.13
12	4.60						
			24-62-27aad1				
Apr. 28, 1949	5.25	July 12, 1949	5.20	Feb. 2, 1950	5.65	June 26, 1950	5.73
May 12	4.92	26	1.06	22	5.93	July 10	2.26
17	5.00	Aug. 9	1.74	Mar. 22	5.83	20	1.74
26	5.51	27	1.98	May 5	6.01	Aug. 7	1.65
31	5.48	Sept.13	1.56	15	6.10	30	1.48
June 3	4.96	Oct. 4	2.15	19	6.32	Sept.15	1.56
9	4.26	21	1.91	31	5.47	22	1.54
16	4.59	Nov. 21	3.11	June 12	5.91	Oct. 30	3.36
July 5	5.33	Dec. 27	4.44				
			24-62-27aad2				
May 12, 1949	4.97	July 26, 1949	2.07	Sept.13, 1949	1.61	Nov. 21, 1949	3.17
June 9	4.30	Aug. 9	1.79	Oct. 4	2.16	Dec. 27	4.49
16	4.65	27	2.03	21	1.87		
			24-62-27abc1				
Apr. 28, 1949	8.40	June 9, 1949	2.60	Oct. 4, 1949	5.03	May 20, 1950	7.62
May 12	8.28	16	2.33	Nov. 21	6.17	21	7.13
17	8.11	July 5	+.15	Dec. 27	7.83	31	4.69
26	8.59	12	+.48	Feb. 2, 1950	8.79	June 12	4.01
29 (3:35pm)	8.70	15	+.57	22	9.07	26	3.31
29 (4.50pm)	8.70	26	+.66	Mar. 22	9.21	July 10	2.79
29 (9:47pm)	7.99	Aug. 5	+.75	May 5	9.24	13	2.78
30 (9:10am)	6.75	9	+.81	15	9.20	20	2.50
30 (4:00pm)	6.35	27	+.79	16	9.25	Aug. 7	2.17
31	5.43	Sept.13	+.35	17	9.00	30	1.80
June 1	4.72	14 (1:50pm)	+.18	18	8.37	Sept.22	2.46
3	3.70	14 (8:34pm)	+.15	19	7.89	Oct. 30	7.22
			24-62-27abc2				
Apr. 28, 1949	8.34	June 9, 1949	2.52	Nov. 21, 1949	6.08	May 21, 1950	6.97
May 12	8.28	16	2.26	Dec. 27	7.81	31	4.48
17	8.08	July 5	+.10	Feb. 2, 1950	8.75	June 12	3.83
26	8.50	12	+.43	22	9.06	26	3.12
29 (3:37pm)	8.64	26	+.74	Mar. 22	9.11	July 10	2.52
29 (5:54pm)	8.60	Aug. 5	+.67	May 5	9.21	13	2.55
29 (9:46pm)	8.70	9	+.75	15	9.13	20	2.37
30 (9:10am)	6.78	27	+.56	16	9.18	Aug. 7	2.01
30 (4:00pm)	6.40	Sept.13	+.15	17	8.78	30	1.66
31	5.49	14 (1:49pm)	+.12	18	8.16	Sept.22	2.32
June 1	4.78	14 (8:35pm)	+.11	19	7.68	Oct. 30	7.17
3	3.70	Oct. 4	4.96	20	7.49		
			24-62-27abc3				
June 3, 1949	4.09	July 26, 1949	+0.19	Sept.14, 1949		July 20, 1950	2.49
9	2.70	Aug. 5	+.27	(1:48pm)	+0.21	Aug. 7	2.14
16	2.37	9	+.32	14 (8:36pm)	+.17	30	1.77
July 5	.23	Sept.13	+.23	Oct. 4	1.48	Sept.22	2.41
12	+.09			July 13, 1950	2.67		

Table 4.--Water levels in observation wells--Continued

Date	Water level	Date	Water level	Date	Water level	Date	Water level
			24-62-27abc4				
Apr. 28, 1949	7.68	June 9, 1949	2.28	Dec. 27, 1949	5.92	May 21, 1950	6.20
May 12	7.55	16	1.81	Feb. 2, 1950	7.03	31	3.43
17	7.49	July 5	.44	22	7.31	June 12	2.87
26	7.87	12	.13	Mar. 22	7.35	26	2.44
29 (3:40pm)	8.03	26	+.02	May 5	7.17	July 10	1.95
29 (5:57pm)	8.10	Aug. 9	+.05	15	7.09	13	1.99
29 (9:48pm)	7.92	27	.02	16	7.10	20	1.72
30 (9:10am)	7.20	Sept.13	.17	17	7.10	Aug. 7	1.34
30 (4:00pm)	6.88	14	.17	18	7.09	30	1.06
31	6.05	Oct. 4	3.19	19	6.90	Sept.22	1.24
June 1	5.50	Nov. 21	4.28	20	6.69	Oct. 30	6.57
3	4.32						
			24-62-27abc5				
Apr. 28, 1949	7.66	June 3, 1949	5.02	Nov. 21, 1949	3.31	May 20, 1950	7.88
May 12	7.76	9	2.48	Dec. 27	5.16	21	7.87
17	5.41	16	1.97	Fèb. 2, 1950	6.61	31	3.70
26	7.69	July 5	.64	22	7.21	June 12	3.59
29 (3:40pm)	7.95	12	.29	Mar. 22	7.21	26	2.48
29 (5:57pm)	7.98	26	.08	5	7.85	July 10	2.31
29 (9:49pm)	7.95	Aug. 9	+.04	15	7.87	13	2.29
30 (9:10am)	7.93	27	.02	16	7.87	20	2.19
30 (4:00pm)	7.84	Sept.13	.27	17	7.87	Aug. 7	1.77
31	7.28	14	.19	18	7.88	30	1.63
June 1	6.55	Oct. 4	2.63	19	7.87	Sept.22	1.27
			24-62-27abc6				
June 9, 1949	2.48	Aug. 9, 1949	0.15	June 12, 1950	3.10	July 20, 1950	1.92
16	2.04	27	.23	26	2.64	Aug. 7	1.55
July 5	.66	Sept.13	.41	July 10	2.07	30	1.23
12	.35	14 (1:51pm)	.43	13	2.19	Sept.22	1.58
26	.20	14 (8:39pm)	.47				
			24-62-27abc7				
Apr. 28, 1949	7.87	June 9, 1949	3.24	Dec. 27, 1949	7.85	May 21, 1950	6.37
May 12	7.90	16	2.79	Feb. 2, 1950	8.75	31	3.90
17	7.58	July 5	1.89	22	9.03	June 12	3.58
26	8.06	12	1.56	Mar. 22	8.90	26	3.27
29 (3:43pm)	8.22	26	1.39	May 5	8.77	July 10	2.88
29 (5:00pm)	8.23	Aug. 9	1.36	15	8.62	13	2.91
29 (9:51pm)	8.06	27	1.45	16	8.70	20	2.82
30 (9:10am)	7.54	Sept.13	1.43	17	8.13	Aug. 7	2.23
30 (4:00pm)	7.27	14	1.45	18	7.51	30	1.91
31	6.65	Oct. 4	4.58	19	7.02	Sept.22	2.09
June 1	6.29	Nov. 21	6.04	20	6.86	Oct. 30	7.06
3	5.36						
			24-62-27abc8				
Apr. 28, 1949	7.74	June 9, 1949	3.13	Dec. 27, 1949	7.73	May 21, 1950	6.43
May 12	7.64	16	2.67	Feb. 2, 1950	8.70	31	3.84
17	7.42	July 5	1.81	22	8.88	June 12	3.51
26	7.88	12	1.43	Mar. 22	8.71	26	3.21
29 (3:58pm)	8.06	26	1.27	May 5	8.62	July 10	2.81
29 (5:01pm)	8.09	Aug. 9	1.22	15	8.50	13	2.88
29 (9:50pm)	7.98	27	1.33	16	8.58	20	2.72
30 (9:10am)	7.57	Sept.13	1.36	17	8.16	Aug. 7	2.15
30 (4:00pm)	7.43	14	1.41	18	7.56	30	1.80
31	6.76	Oct. 4	8.54	19	7.10	Sept.22	1.90
June 1	6.39	Nov. 21	5.99	20	6.94	Oct. 30	6.93
3	5.44						

Table 4.--Water levels in observation wells--Continued

Date	Water level	Date	Water level	Date	Water level	Date	Water level
24-62-27abc9							
June 9, 1949	2.92	July 26, 1949	1.10	Sept.14, 1949	1.09	Aug. 7, 1950	2.30
16	2.45	Aug. 9	1.09	Oct. 4	2.66	30	1.92
July 5	1.66	27	1.17	July 13, 1950	2.99	Sept.22	1.71
12	1.25	Sept.13	1.88	20	2.89		
24-62-27aca1							
June 9, 1949	11.05	Aug. 9, 1949	3.94	Dec. 27, 1949	10.87	Aug. 7, 1950	3.93
16	10.45	27	3.17	June 12, 1950	9.99	30	3.30
July 5	8.25	Sept.13	2.39	26	8.55	Sept.22	2.44
12	6.85	Oct. 4	5.24	July 10	7.20	Oct. 30	7.32
26	4.82	Nov. 21	8.40	20	6.48		
24-62-27aca2							
July 26, 1949	4.09	Aug. 9, 1949	3.58	Aug. 27, 1949	2.96	Sept.13, 1949	2.28
24-62-27aca3							
Apr. 28, 1949	7.89	June 9, 1949	6.81	Feb. 22, 1950	8.69	June 30, 1950	4.26
May 13	7.55	16	5.96	Apr. 18	8.02	July 10	3.44
17	7.59	July 5	4.49	May 5	7.96	17	3.11
26	7.75	12	3.60	15	7.83	20	2.99
29 (3:25pm)	7.86	26	2.68	17	7.87	Aug. 2	2.44
29 (5:15pm)	7.88	Aug. 9	2.31	24	7.68	7	2.27
29 (9:35pm)	7.86	27	1.94	31	6.68	24	1.69
30 (9:00am)	7.90	Oct. 4	3.82	June 9	6.07	30	1.72
30 (3:50pm)	7.82	Nov. 21	5.27	12	5.85	31	1.76
31	7.86	Dec. 27	7.08	13	5.81	Sept.22	.95
June 1	7.85	Feb. 2, 1950	8.37	26	4.59	Oct. 30	5.77
3	7.73						
24-62-27aca4							
July 5, 1949	4.39	July 26, 1949	2.70	Aug. 27, 1949	1.92	Oct. 4, 1949	3.82
12	3.49	Aug. 9	2.11	Sept.13	1.03		
24-62-27acb							
May 11, 1949	20.11	June 9, 1949	12.74	Dec. 27, 1949	20.25	May 21, 1950	12.52
17	19.78	16	12.78	Feb. 2, 1950	21.25	31	11.81
26	20.48	July 5	9.97	22	21.41	June 12	10.38
29 (3:38pm)	20.86	12	9.99	Mar. 22	21.40	26	9.96
29 (5:23pm)	19.80	26	10.02	May 5	21.15	July 10	9.29
29 (9:40pm)	16.54	Aug. 5	9.60	15	21.16	20	8.65
30 (9:05am)	14.78	9	9.61	16	18.40	Aug. 7	7.85
30 (3:50pm)	14.40	27	9.79	17	14.12	30	9.05
31	13.20	Sept.13	10.69	18	13.18	Sept.22	11.28
June 1	13.07	Oct. 4	16.19	19	12.85	Oct. 30	19.29
3	12.30	Nov. 21	18.45	20	12.79	Nov. 30	20.52
24-62-27acc1							
Apr. 28, 1949	4.65	July 26, 1949	2.57	Dec. 27, 1949	5.75	June 26, 1950	3.80
May 11	3.50	Aug. 9	3.10	Feb. 2, 1950	6.62	July 10	3.93
17	3.36	27	3.31	22	6.34	20	3.90
26	3.75	Sept.13	3.72	Mar. 22	5.43	Aug. 7	3.13
31	3.83	14 (2:00pm)	3.76	May 5	4.27	30	1.85
June 3	3.52	14 (8:30pm)	3.83	15	4.13	Sept.15	2.08
9	2.24	Oct. 4	5.51	19	4.10	22	1.12
16	2.48	21	4.64	31	3.12	Oct. 30	4.43
July 5	3.33	Nov. 21	4.64	June 12	3.48	Nov. 30	4.55
12	3.15						

Table 4.--Water levels in observation wells--Continued

Date	Water level	Date	Water level	Date	Water level	Date	Water level
24-62-27acc2							
Apr. 28, 1949	4.80	July 5, 1949	3.38	Oct. 4, 1949	5.63	May 15, 1950	4.23
May 13	3.65	12	3.19	21	4.76	19	4.10
17	3.45	26	2.08	Nov. 21	4.76	31	3.16
26	3.87	Aug. 9	2.45	Dec. 27	5.89	June 12	3.51
31	3.86	27	3.51	Feb. 2, 1950	6.66	26	3.90
June 3	3.72	Sept.13	3.71	22	6.35	July 10	3.98
9	2.35	14 (2:01pm)	3.79	Mar. 22	5.50	20	3.76
16	2.66	14 (5:31pm)	3.84	May 5	4.35		
24-62-27acc3							
Apr. 28, 1949	4.74	June 16, 1949	2.54	Sept.14, 1949 (1:52pm)	3.47	June 26, 1950	3.90
May 11	3.75	July 5	3.50	14 (8:32pm)	3.51	July 10	4.00
17	3.60	12	3.41	May 15, 1950	4.15	20	3.79
26	3.67	26	1.18	19	4.01	Aug. 7	2.24
31	3.94	Aug. 9	2.07	31	3.04	30	1.66
June 3	3.79	27	2.97	June 12	3.53	Oct. 30	4.08
9	2.19	Sept.13	3.32				
24-62-27adb							
May 11, 1949	23.27	June 3, 1949	18.09	Feb. 2, 1950	25.22	May 21, 1950	22.09
17	23.57	9	16.98	22	27.29	31	18.02
26	24.63	16	16.68	Mar. 22	28.16	June 12	17.15
29 (3:15pm)	25.33	July 12	13.17	May 5	25.33	26	15.20
29 (5:00pm)	25.36	26	12.31	15	24.84	July 10	13.80
29 (9:00pm)	25.19	Aug. 27	12.41	16	24.79	20	13.35
30 (8:55am)	23.56	Sept.13	12.72	17	24.72	Aug. 7	12.74
30 (3:45pm)	22.62	Oct. 4	18.40	18	24.28	30	12.08
31	20.55	Nov. 21	21.52	19	23.49	Sept.22	11.90
June 1	19.32	Dec. 27	23.62	20	22.94	Oct. 30	17.18
24-62-27add							
Apr. 28, 1949	5.68	June 16, 1949	5.95	Oct. 4, 1949	5.99	Mar. 22, 1950	6.00
May 12	5.96	July 5	5.95	21	6.00	May 15	6.03
17	5.95	12	6.01	Nov. 21	5.99	19	6.02
26	5.93	26	5.99	Dec. 27	5.99	31	6.01
31	5.89	Aug. 9	6.00	Feb. 2, 1950	5.99	June 12	6.01
June 3	5.95	29	6.14	22	6.00	26	6.02
9	5.95	Sept.13	5.99				
24-62-27bad							
Apr. 28, 1949	7.80	June 3, 1949	5.93	Feb. 2, 1950	8.58	May 21, 1950	7.70
May 11	7.45	9	4.23	22	8.80	31	6.31
17	7.64	16	3.53	Mar. 22	8.76	June 12	5.75
26	7.74	July 5	2.29	May 5	8.92	26	5.27
29 (3:57pm)	7.94	12	1.64	15	8.74	July 10	4.92
29 (5:05pm)	7.90	26	1.28	16	8.82	20	4.83
29 (9:55pm)	7.73	Aug. 9	.97	17	8.40	Aug. 7	4.07
30 (9:30am)	7.40	27	.93	18	8.12	30	3.56
30 (4:00pm)	7.18	Oct. 4	4.26	19	7.94	Sept.22	4.12
31	6.78	Nov. 21	5.68	20	8.00	Oct. 30	7.23
June 1	6.44	Dec. 27	7.50				
24-62-27bca							
May 13, 1949	8.32	May 30, 1949 (9:45am)	7.59	June 16, 1949	4.09	Sept.13, 1949	2.56
17	8.10	30 (4:15pm)	7.40	July 5	2.69	Oct. 4	6.38
26	8.55	31	6.89	12	2.37	21	5.57
29 (4:09pm)	8.76	June 1	6.57	26	2.56	Nov. 21	7.71
29 (5:43pm)	8.59	3	6.09	Aug. 9	2.48	Dec. 27	8.83
29 (10:16pm)	8.10	9	4.42	27	2.51		

Table 4.--Water levels in observation wells--Continued

Date	Water level	Date	Water level	Date	Water level	Date	Water level
			24-62-27bdb1				
June 9, 1949	10.13	July 12, 1949	6.62	Aug. 9, 1949	5.46	Sept.13, 1949	5.28
16	9.23	26	5.97	27	5.17	Oct. 4	8.45
July 5	7.16						
			24-62-27bdb2				
Apr. 28, 1949	7.19	May 30, 1949		June 16, 1949	8.66	Sept.13, 1949	5.31
May 13	8.49	(9:35am)	11.32	July 5	7.26	Oct. 4	7.44
17	8.77	30 (4:13pm)	11.28	12	6.71	Nov. 21	8.47
26	11.30	31	10.93	26	6.26	Dec. 27	9.26
29 (4:01pm)	11.35	June 1	10.80	Aug. 9	5.48	Feb. 2, 1950	10.22
29 (5:38pm)	11.33	3	10.52	27	5.32	22	10.77
29 (10:11pm)	11.36	9	9.56				
			24-62-27bdb3				
May 13, 1949	10.76	June 1, 1949	10.04	Aug. 27, 1949	5.24	Aug. 2, 1950	11.55
17	10.55	3	9.90	Sept.13	5.28	7	11.37
26	10.50	9	9.15	Oct. 4	7.68	24	9.94
29 (4:03pm)	10.45	16	8.17	Nov. 21	8.95	30	9.93
29 (4:40pm)	10.46	July 5	6.99	Dec. 27	10.19	31	9.94
29 (10:13pm)	10.47	12	6.75	Feb. 2, 1950	11.15	Sept.22	9.79
30 (9:40am)	10.44	26	5.91	22	11.35	Oct. 30	11.33
30 (4:13pm)	10.36	Aug. 9	4.72	July 20	11.66	Nov. 30	11.90
31	10.16						
			24-62-27cad1				
Apr. 28, 1949	8.58	July 26, 1949	3.10	Dec. 27, 1949	8.47	June 26, 1950	3.60
May 13	7.71	Aug. 9	3.48	Feb. 2, 1950	9.35	July 10	3.55
17	7.89	27	2.63	22	9.50	13	2.47
26	7.70	Sept.13	3.97	Mar. 22	9.09	20	3.05
31	7.45	14 (1:54pm)	4.06	May 5	7.93	Aug. 7	3.33
June 3	5.89	14 (8:25pm)	4.13	15	7.64	30	3.44
9	3.65	Oct. 4	5.80	19	7.06	Sept.15	2.68
16	4.39	21	6.35	31	4.80	22	2.24
July 5	3.18	Nov. 21	7.27	June 12	3.68	Oct. 30	6.49
12	2.44						
			24-62-27cad2				
Apr. 28, 1949	8.55	July 26, 1949	2.95	Dec. 27, 1949	8.37	June 26, 1950	3.40
May 13	7.80	Aug. 9	3.33	Feb. 2, 1950	9.25	July 10	3.39
17	7.78	27	2.31	22	9.44	13	2.20
26	7.63	Sept.13	3.82	Mar. 22	8.96	20	2.84
31	7.47	14 (1:55pm)	3.91	May 5	7.85	Aug. 7	3.14
June 3	5.94	14 (8:26pm)	3.98	15	7.72	30	3.30
9	3.52	Oct. 4	5.68	19	6.97	Sept.15	2.54
16	4.48	21	6.25	31	4.68	22	2.12
July 5	3.02	Nov. 21	7.19	June 12	3.49	Oct. 30	6.43
12	2.24						
			24-62-27cad3				
June 9, 1949	4.24	Aug. 9, 1949	3.19	May 31, 1950	4.52	July 20, 1950	2.64
16	4.06	27	2.01	June 12	3.33	Aug. 7	2.95
July 5	2.87	Sept.13	3.65	26	3.29	30	3.16
12	2.02	14 (1:56pm)	3.78	July 10	3.23	Sept.15	2.39
26	2.87	14 (8:27pm)	3.83	13	1.95	22	1.90

Table 4.--Water levels in observation wells--Continued

Date	Water level	Date	Water level	Date	Water level	Date	Water level
			24-62-27dbb				
Apr. 28, 1949	7.75	July 12, 1949	4.51	Feb. 2, 1950	9.39	July 10, 1950	5.01
May 11	6.59	26	4.19	22	9.37	20	4.33
17	6.35	Aug. 9	4.77	Mar. 22	8.45	Aug. 7	3.50
26	6.39	27	4.71	May 5	6.98	30	4.05
31	6.35	Sept.13	4.86	15	6.67	Sept.15	3.41
June 3	6.22	Oct. 4	7.43	19	6.33	22	2.55
9	4.54	21	7.52	31	5.08	Oct. 30	6.26
16	4.55	Nov. 21	7.64	June 12	5.11	Nov. 30	6.89
July 5	5.14	Dec. 27	8.71	26	5.26		
			24-62-27dda1				
May 12, 1949	1.79	July 12, 1949	1.90	Nov. 21, 1949	1.72	May 19, 1950	1.39
17	1.62	26	1.77	Dec. 27	2.09	31	.91
26	1.50	Aug. 9	2.14	Feb. 2, 1950	2.89	June 12	.76
31	1.71	27	1.67	22	3.04	26	1.70
June 3	1.95	Sept.13	.75	Mar. 22	2.08	July 10	.97
9	1.04	Oct. 4	1.64	May 5	1.31	20	.86
16	.85	21	1.40	15	1.14	Aug. 7	1.36
July 5	1.55						
			24-62-27dda2				
Apr. 28, 1949	2.80	July 12, 1949	0.79	Feb. 2, 1950	3.03	June 26, 1950	2.17
May 12	1.61	26	1.51	22	2.97	July 10	.77
17	1.16	Aug. 9	2.29	Mar. 22	1.95	20	.47
26	1.56	27	1.88	May 5	1.24	Aug. 7	1.57
31	1.96	Sept.13	1.03	15	1.34	30	1.35
June 3	2.17	Oct. 4	1.79	19	1.75	Sept.15	1.06
9	.60	21	1.03	31	.50	22	.82
16	.92	Nov. 21	1.65	June 12	.58	Oct. 30	2.53
July 5	1.59	Dec. 27	2.23				
			24-62-28add				
Apr. 28, 1949	7.70	May 29, 1940		June 9, 1949	3.59	Aug. 27, 1949	1.69
May 13	6.69	(10:20pm)	7.01	16	3.17	Sept.13	3.19
17	6.54	30	6.36	July 5	1.92	Oct. 4	5.88
26	7.02	31	6.13	12	1.49	21	6.22
29 (4:14pm)	7.29	June 1	5.93	26	1.98	Nov. 21	7.96
29 (5:47pm)	7.27	3	5.46	Aug. 9	1.93		
			24-62-28ccc				
June 9, 1949	6.23	July 12, 1949	3.80	Aug. 27, 1949	3.10	Oct. 4, 1949	6.88
16	5.58	26	3.60	Sept.13	3.07	21	8.00
July 5	4.32	Aug. 9	3.29				
			24-62-28dac				
Apr. 28, 1949	8.20	June 3, 1949	6.37	Nov. 21, 1949	7.03	May 20, 1950	7.86
May 13	7.58	9	4.11	Dec. 27	8.72	21	7.49
17	7.34	16	3.44	Feb. 2, 1950	10.04	31	5.29
26	7.40	July 5	3.44	22	10.25	June 12	5.22
29 (4:17pm)	7.59	12	3.04	Mar. 22	10.18	26	4.08
29 (5:50pm)	7.58	26	3.05	May 5	9.18	July 10	2.98
29 (10:25pm)	7.51	Aug. 9	2.72	15	8.81	20	2.78
30 (9:50am)	7.32	27	1.74	16	8.92	Aug. 7	1.87
30 (4:35pm)	7.19	Sept.13	2.43	17	8.57	30	1.39
31	6.89	Oct. 4	4.27	18	8.17	Sept.22	.24
June 1	6.68	21	5.06	19	7.93	Oct. 30	5.46

Table 4.--Water levels in observation wells--Continued

Date	Water level	Date	Water level	Date	Water level	Date	Water level
			24-62-28dcb				
May 13, 1949	10.52	July 5, 1949	0.87	Feb. 2, 1950	16.73	May 21, 1950	3.73
17	9.31	12	.79	22	17.24	31	2.37
29 (5:53pm)	10.42	26	.74	Mar. 22	16.87	June 12	1.75
29 (10:30pm)	5.26	Aug. 9	.69	May 5	11.15	26	1.55
30 (9:55am)	4.36	27	1.07	15	9.89	July 10	1.07
30 (4:45pm)	4.28	Sept.13	2.21	16	10.13	20	.73
31	3.92	Oct. 4	7.28	17	4.96	Aug. 7	.75
June 1	3.26	21	7.71	18	4.30	30	1.18
3	3.42	Nov. 21	12.34	19	4.02	Sept.22	3.41
9	3.60	Dec. 27	15.06	20	3.88	Oct. 30	10.11
16	3.65						
			24-62-28dda				
Apr. 28, 1949	5.60	July 12, 1949	4.04	Nov. 21, 1949	7.27	May 19, 1950	5.25
May 13	4.40	26	5.24	Dec. 27	7.87	31	5.26
26	4.08	Aug. 9	6.72	Feb. 2, 1950	8.30	June 12	6.94
31	4.02	16	6.56	22	8.03	26	5.97
June 3	4.69	27	3.53	Mar. 22	6.59	July 10	1.58
9	5.27	Sept.13	5.76	May 5	5.08	20	2.85
16	3.22	Oct. 4	8.17	15	4.71	Aug. 7	4.59
July 5	3.29	21	7.57				
			24-62-32aaa				
Apr. 28, 1949	7.25	July 12, 1949	2.42	Feb. 2, 1950	9.13	June 26, 1950	2.77
May 12	6.59	26	2.19	22	9.38	July 10	3.74
17	6.23	Aug. 9	2.22	Mar. 22	9.28	20	2.58
26	6.66	27	2.60	May 5	8.85	Aug. 7	2.90
31	6.64	Sept.13	2.40	15	8.32	30	2.43
June 3	6.24	Oct. 4	5.28	19	7.70	Sept.22	2.31
9	3.75	21	5.22	31	4.36	Oct. 30	6.39
16	3.85	Nov. 21	6.84	June 12	2.84	Nov. 30	6.90
July 5	3.10	Dec. 27	8.09				
			24-62-33aad				
Apr. 28, 1949	7.01	July 12, 1949	5.46	Dec. 27, 1949	6.59	June 12, 1950	6.50
May 13	5.50	26	5.10	Feb. 2, 1950	7.47	26	5.40
17	6.05	Aug. 9	3.29	22	7.65	July 10	4.68
26	6.33	27	2.60	Mar. 22	7.64	20	3.80
31	6.52	Sept.13	4.70	May 5	7.39	Aug. 7	3.57
June 3	6.69	Oct. 4	4.95	15	7.43	30	2.75
9	4.84	21	5.44	19	7.41	Sept.22	2.22
16	4.87	Nov. 21	5.88	31	6.55	Oct. 30	4.39
July 5	5.52						
			24-62-33aba				
Apr. 28, 1949	5.69	July 12, 1949	3.44	Dec. 27, 1949	4.72	June 12, 1950	5.88
May 13	5.19	26	3.48	Feb. 2, 1950	5.83	26	5.52
17	5.08	Aug. 9	3.47	22	6.23	July 10	5.23
26	4.89	27	3.45	Mar. 22	6.58	20	5.04
31	5.08	Sept.13	3.41	May 5	6.63	Aug. 7	4.70
June 3	4.80	Oct. 4	3.51	15	6.42	30	4.50
9	4.25	21	3.49	19	6.40	Sept.22	4.09
16	3.95	Nov. 21	4.81	31	6.01	Oct. 30	2.97
July 5	3.53						
			24-62-33acc				
July 5, 1949	13.44	Sept.13, 1949	8.16	Dec. 27, 1949	12.54	May 5, 1950	14.85
12	11.48	Oct. 4	8.77	Feb. 2, 1950	13.30	15	14.95
26	10.75	21	10.57	22	13.68	19	15.02
Aug. 9	8.47	Nov. 21	11.65	Mar. 22	14.20	31	15.02
27	8.54						

Table 4.--Water levels in observation wells--Continued

Date	Water level	Date	Water level	Date	Water level	Date	Water level
24-62-33adc							
July 5, 1949	3.97	Sept.13, 1949	3.79	Dec. 27, 1949	4.72	May 5, 1950	7.44
12	10.89	Oct. 4	3.78	Feb. 2, 1950	5.80	15	7.41
26	7.98	21	3.68	22	6.30	19	7.49
Aug. 9	3.92	Nov. 21	4.06	Mar. 22	7.03	31	7.05
27	3.86						
24-62-33bab							
Apr. 28, 1949	5.94	July 5, 1949	6.29	Dec. 27, 1949	6.59	June 26, 1950	1.85
May 13	5.53	26	2.96	Feb. 2, 1950	7.40	July 10	4.60
17	5.37	Aug. 9	2.36	Mar. 22	6.93	20	1.59
26	5.67	27	1.48	May 5	6.02	Aug. 7	1.70
31	5.77	Sept.13	3.36	15	5.85	30	1.50
June 3	5.96	Oct. 4	4.18	19	5.70	Sept.22	2.99
9	4.70	21	5.26	31	5.23	Oct. 30	5.33
16	5.23	Nov. 21	5.94	June 12	5.34		
24-62-33bac							
May 13, 1949	2.49	June 3, 1949	3.54	July 12, 1949	3.02	Aug. 27, 1949	2.65
17	2.09	9	1.51	26	1.78	Sept.13	2.67
26	2.55	16	2.00	Aug. 9	2.07	Oct. 4	5.00
31	3.13	July 5	2.47				
24-62-34abc							
May 26, 1949	16.54	Aug. 9, 1949	14.06	Feb. 22, 1950	16.89	July 10, 1950	16.09
31	16.48	27	14.01	Mar. 22	17.14	20	15.34
June 3	16.53	Sept.13	13.55	May 5	17.22	Aug. 7	14.79
9	16.09	Oct. 4	13.71	15	17.24	30	13.04
16	15.41	21	14.33	19	17.22	Sept.15	11.77
July 5	15.60	Nov. 21	14.95	31	17.24	22	12.09
12	15.86	Dec. 27	15.63	June 12	17.07	Oct. 30	13.68
26	14.96	Feb. 2, 1950	16.52	26	16.58		
24-62-34bab							
May 26, 1949	18.50	Aug. 9, 1949	7.47	Feb. 22, 1950	13.74	June 26, 1950	12.11
31	16.49	27	6.45	Mar. 22	14.06	July 10	11.84
June 3	15.77	Sept.13	8.38	May 5	13.65	20	11.45
9	13.75	Oct. 4	9.00	15	13.42	Aug. 7	9.84
16	12.24	21	10.27	19	13.38	30	8.02
July 5	11.69	Nov. 21	11.45	31	13.37	Sept.22	5.20
12	11.19	Dec. 27	12.47	June 12	13.39	Oct. 30	7.08
26	7.67	Feb. 2, 1950	13.37				
24-62-34bcc							
May 26, 1949	10.64	Aug. 9, 1949	6.92	Feb. 22, 1950	11.09	July 10, 1950	6.00
31	10.51	27	6.64	Mar. 22	11.25	20	6.54
June 3	10.55	Sept.13	8.08	May 5	11.25	Aug. 7	5.94
9	9.03	Oct. 4	8.20	15	11.22	30	4.99
16	8.62	21	9.05	19	11.21	Sept.22	5.50
July 5	7.27	Nov. 21	9.87	31	10.98	Oct. 30	8.52
12	7.92	Dec. 27	10.47	June 12	9.25	Nov. 30	9.53
26	7.56	Feb. 2, 1950	10.90	26	8.22		
24-62-34cbc							
May 26, 1949	11.10	Aug. 9, 1949	10.41	Feb. 22, 1950	11.70	June 26, 1950	10.67
31	11.34	27	9.97	Mar. 22	11.72	July 10	10.40
June 3	11.55	Sept.13	10.54	May 5	11.75	20	10.13
9	10.73	Oct. 4	10.64	15	11.76	Aug. 7	10.23
16	10.92	21	11.04	19	11.72	30	9.28
July 5	10.64	Nov. 21	11.40	31	11.37	Sept.22	9.78
12	10.49	Dec. 27	11.54	June 12	11.24	Oct. 30	10.81
26	10.52	Feb. 2, 1950	11.67				

Table 4.--Water levels in observation wells--Continued

Date	Water level	Date	Water level	Date	Water level	Date	Water level
24-62-35baa							
May 12, 1949	6.02	July 12, 1949	5.60	Dec. 27, 1949	6.06	June 12, 1950	6.05
17	5.82	26	6.02	Feb. 2, 1950	6.29	26	6.97
26	6.14	Aug. 9	5.26	22	6.08	July 10	5.76
31	6.05	27	3.97	Mar. 22	9.42	20	5.30
June 3	6.09	Sept.13	4.99	May 5	6.11	Aug. 30	6.09
9	6.06	Oct. 4	6.05	15	6.10	Sept.15	5.16
16	6.10	21	6.05	19	6.08	22	5.57
July 5	4.70	Nov. 21	6.06	31	6.08	Oct. 30	6.11
24-62-35bba							
Apr. 28, 1949	8.90	July 12, 1949	4.90	Dec. 27, 1949	8.68	June 26, 1950	5.45
May 12	8.87	26	4.10	Feb. 2, 1950	9.19	July 10	4.44
17	8.27	Aug. 9	3.72	22	9.27	20	4.96
26	8.80	27	3.73	May 5	9.23	Aug. 7	6.23
31	8.31	Sept.13	4.77	15	9.14	30	2.58
June 3	7.60	Oct. 4	6.15	19	8.89	Sept.15	3.50
9	6.29	21	6.80	31	6.13	22	4.04
16	6.54	Nov. 21	7.82	June 12	5.45	Oct. 30	7.53
July 5	4.46						
24-62-35bbc1							
May 12, 1949	5.55	July 26, 1949	4.64	Feb. 2, 1950	6.78	June 26, 1950	4.82
17	5.65	Aug. 9	3.57	22	6.93	July 10	4.86
26	5.75	27	3.45	Mar. 22	6.86	20	5.03
31	5.83	Sept.13	4.01	May 5	6.67	Aug. 7	4.59
June 3	5.90	Oct. 4	4.34	15	6.54	30	3.80
9	4.66	21	5.03	19	6.57	Sept.15	1.52
16	4.67	Nov. 21	5.60	31	6.24	22	.86
July 5	3.85	Dec. 27	6.16	June 12	6.37	Oct. 30	5.11
12	4.60						
24-62-35bbc2							
June 9, 1949	4.65	July 12, 1949	3.47	Aug. 9, 1949	3.99	Sept.13, 1949	4.16
16	4.72	26	4.77	27	3.56	Oct. 4	4.50
July 5	3.92						
24-62-35bcb							
May 26, 1949	8.33	Aug. 9, 1949	6.53	Feb. 22, 1950	8.82	July 10, 1950	7.05
31	8.39	27	6.17	Mar. 22	8.71	20	6.90
June 3	8.46	Sept.13	6.41	May 5	8.76	Aug. 7	6.65
9	7.00	Oct. 4	6.89	15	8.41	30	6.11
16	7.06	21	7.43	19	8.54	Sept.15	4.58
July 5	6.47	Nov. 21	7.86	31	8.32	22	4.08
12	6.33	Dec. 27	8.48	June 12	8.18	Oct. 30	7.44
26	6.92	Feb. 2, 1950	8.80	26	7.27		
24-62-36bbb							
May 31, 1949	12.75	Aug. 27, 1949	10.07	Mar. 22, 1950	13.63	July 10, 1950	9.75
June 3	12.84	Sept.13	9.73	May 5	13.77	20	9.29
9	12.20	Oct. 4	9.91	15	13.77	Aug. 7	9.95
16	11.33	21	10.34	19	13.80	30	9.60
July 5	10.61	Nov. 21	12.01	31	12.91	Sept.15	9.56
12	10.10	Dec. 27	12.71	June 12	11.74	22	9.62
26	10.07	Feb. 2, 1950	13.19	26	11.12	Oct. 30	11.71
Aug. 9	9.31	22	13.44				

Table 5.--Water level at noon for well 24-62-27bda, in feet below land-surface datum, 1949-50
(From recorder charts)

Day	1949							1950								
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	9.35	7.69	....	5.52	....	....	....	....	....	.....	....	....	....	9.13	....	5.48
2	9.30	7.69	....	5.66	....	....	....	....	....	.....	....	....	....	9.18	9.14	5.35
3	9.11	7.68	....	5.60	....	....	....	....	....	10.35	....	....	....	9.72	....	5.44
4	9.05	7.73	....	....	7.02	....	....	....	....	.....	....	....	....	9.18	....	6.00
5	8.72	7.76	....	....	7.01	....	....	....	....	.....	....	9.90	....	9.20	....	6.30
6	8.35	7.71	....	....	7.19	....	....	....	....	.....	....	....	....	9.08	....	....
7	8.15	7.60	....	....	7.07	....	....	....	....	.....	....	....	....	9.04	8.65	....
8	7.88	7.35	....	....	6.78	....	....	....	....	.....	....	....	....	9.08	....	....
9	7.81	7.30	....	....	6.92	....	....	....	....	.....	....	....	9.02	9.20	....	....
10	7.79	7.34	5.07	....	7.01	....	....	....	....	.....	....	....	....	9.26	....	....
11	7.72	7.35	....	....	7.00	....	....	....	....	.....	....	9.73	....	9.20	....	....
12	7.67	7.43	5.40	....	7.14	....	....	....	....	.....	....	9.64	8.93	9.26	....	....
13	7.58	7.40	5.55	5.30	7.05	....	....	....	....	.....	....	9.69	8.99	9.40	....	....
14	7.54	7.35	5.62	5.32	6.99	6.82	....	....	9.12	.....	....	9.66	8.93	9.26	....	....
15	7.58	7.35	5.07	5.50	7.00	....	7.75	....	....	.....	....	9.61	8.88	9.36	4.77	....
16	7.58	7.49	5.28	5.63	6.90	....	....	....	....	.....	....	9.70	8.77	9.42	4.99	....
17	7.50	7.46	4.74	5.96	6.46	....	....	....	....	.....	....	9.67	8.51	9.50	5.04	....
18	7.56	7.51	3.46	....	....	....	....	....	....	.....	9.87	9.59	8.55	9.44	5.35	....
19	7.63	7.55	3.53	....	....	....	....	....	....	.....	....	9.72	8.53	9.43	4.89	.....
20	7.61	6.97	3.91	....	....	....	....	....	....	.....	9.87	9.72	8.52	9.45	4.49	....
21	7.66	6.81	4.01	....	....	7.19	....	....	....	8.92	....	9.72	8.52	9.51	4.45	....
22	7.62	6.95	4.27	....	....	....	....	....	....	.....	....	9.73	8.55	9.38	4.05	....
23	7.70	6.80	4.50	....	....	....	....	....	....	.....	....	9.69	8.66	9.37	4.37	....
24	7.72	....	4.81	....	....	....	....	....	....	.....	....	9.77	8.74	....	....	....
25	7.73	....	4.92	....	....	....	....	....	....	.....	....	9.74	8.92	....	....	....
26	7.60	6.81	5.20	....	....	....	....	....	....	.....	....	9.56	9.08	....	....	....
27	7.55	6.85	5.35	....	....	....	....	....	....	.....	....	9.22	9.02	....	....	....
28	7.67	6.48	5.32	....	....	....	....	....	....	.....	....	8.93	9.20	....	....	6.85
29	7.72	....	5.42	....	....	....	....	....	....	.....	....	8.94	9.12	....	....	....
30	7.70	....	5.46	....	....	....	8.95	....	....	.....	....	8.85	9.10	....	5.96	....
31	....	....	5.58	....	....	....	....	....	....	9.20	....	8.85	....	....	5.74	....

Table 6.--Records of wells in the Soil and Moisture Conservation Demonstration Area, Goshen County, Wyo.

Well number: See page 6 for description of well-numbering system.
Well location: See page 6 for description of well-location system.
Depth of well: Measured depths are given in feet and tenths below land-surface datum; reported depths are given in feet below land-surface datum.
Type of well: All wells $\frac{1}{2}$ inch in diameter are piezometer tubes installed by the U. S. Geological Survey. All wells $1\frac{1}{4}$ inches in diameter were drilled by the U. S. Bureau of Reclamation using a rotary drill. Wells more than $1\frac{1}{2}$ inches in diameter were drilled with cable tools or dug.
Measuring point: Measuring point is top of casing for all wells except well 24-62-27bda, for which the measuring point is the top of the recorder platform.

Well number	Location	Depth of well (feet)	Diameter of well (inches)	Measuring point: Distance above land surface (feet)	Measuring point: Altitude above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement (1949)
24-62-22cdd	2.00 N.-2.51 W.	83	4	0.5	....	23.14	9-20
23cdc	2.12 N.-1.72 W.	20.0	.5	1.0	4,241.41	2.76	9-13
23dad	2.28 N.-1.05 W.	45.9	1.25	1.1	4,269.89	29.83	9-13
23dbd	2.27 N.-1.31 W.	44.5	1.25	2.5	4,258.24	19.89	9-13
23dcb1	2.17 N.-1.50 W.	41.0	1.25	1.0	4,248.29	13.58	9-13
23dcb2	2.24 N.-1.41 W.	34.6	1.25	2.4	4,259.42	21.45	9-13
23dcb3	2.23 N.-1.40 W.	13.2	.5	.8	4,247.50	8.56	9-13
23dcb4	2.22 N.-1.39 W.	13.0	.5	1.0	4,245.40	9.93	9-13
23ddb1	2.25 N.-1.20 W.	39.7	1.25	2.3	4,260.30	22.99	9-13

Table 6.--Records of wells in the Soil and Moisture Conservation Demonstration Area, Goshen County, Wyo.--Continued

Well number	Location	Depth of well (feet)	Diameter of well (inches)	Measuring point: Distance above land surface (feet)	Measuring point: Altitude above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement (1949)
24-62-23ddb2	2.25 N.-1.14 W.	45.0	1.25	1.7	4,257.31	19.40	9-13
23ddb3	2.24 N.-1.25 W.	12.8	.5	1.15	....	8.41	9-13
23ddb4	2.22 N.-1.25 W.	13.1	.5	.9	4,243.23	6.06	9-13
23ddb5	2.22 N.-1.25 W.	6.1	.5	.9	4,243.19	5.64	8-27
23ddd	2.01 N.-1.00 W.	29.2	1.25	.8	4,234.00	15.94	9-13
24cbc	2.30 N.- .96 W.	51.1	1.25	1.9	4,271.45	30.17	9-13
25bcd	1.50 N.- .75 W.	19.4	.5	1.6	4,166.17	15.67	9-13
25ccb	1.25 N.-1.00 W.	12.8	.5	1.2	4,152.68	4.07	9-13
26aab1	2.00 N.-1.23 W.	18.8	.5	2.2	4,217.87	8.84	9-13
26aab2	2.00 N.-1.23 W.	11.4	.5	1.6	4,217.95	10.18	7-12
26abb1	2.00 N.-1.48 W.	9.9	.5	1.1	4,226.07	1.31	9-13
26abb2	2.00 N.-1.48 W.	6.9	.5	1.1	4,226.13	1.41	9-13
26ada1	1.75 N.-1.00 W.	19.8	.5	1.2	4,188.76	4.51	9-13
26ada2	1.75 N.-1.00 W.	11.7	.5	1.3	4,188.83	4.63	9-13
26ada3	1.75 N.-1.00 W.	6.9	.5	1.1	4,188.60	4.43	9-13
26bad	1.82 N.-1.50 W.	6.2	.5	.8	4,215.24	2.67	9-13
26bbb1	1.95 N.-2.00 W.	11.5	.5	1.5	4,246.36	5.87	9-13
26bbb2	1.95 N.-2.00 W.	7.1	.5	.9	4,245.76	5.19	9-13
26bdd	1.50 N.-1.50 W.	19.9	.5	1.1	4,192.65	5.08	9-13
26cbb	1.39 N.-2.00 W.	15.0	1.25	1.0	4,191.54	5.22	9-13
26ccc	1.00 N.-2.00 W.	19.8	.5	1.2	4,166.93	8.50	9-13
26daa	1.50 N.-1.00 W.	36.7	.5	5.3	4,171.64	20.47	9-13
26dcd	1.00 N.-1.25 W.	12.5	.5	1.5	4,154.03	5.69	9-13
27aad1	1.75 N.-2.00 W.	13.0	.5	1.0	4,234.72	2.56	9-13
27aad2	1.75 N.-2.00 W.	6.0	.5	1.0	4,234.64	2.61	9-13
27abc1	1.80 N.-2.47 W.	19.8	.5	1.2	4,248.57	.85	9-13
27abc2	1.80 N.-2.47 W.	12.8	.5	1.2	4,248.40	1.05	9-13
27abc3	1.80 N.-2.47 W.	6.0	.5	1.0	4,248.34	.77	9-13
27abc4	1.78 N.-2.47 W.	19.7	.5	1.3	4,246.81	1.47	9-13
27abc5	1.78 N.-2.47 W.	12.9	.5	1.1	4,246.72	1.37	9-13
27abc6	1.78 N.-2.47 W.	6.2	.5	.8	4,246.44	1.21	9-13
27abc7	1.76 N.-2.47 W.	19.8	.5	1.2	4,246.18	2.63	9-13
27abc8	1.76 N.-2.47 W.	13.2	.5	.8	4,245.62	2.16	9-13
27abc9	1.76 N.-2.47 W.	6.1	.5	.9	....	2.78	9-13
27aca1	1.64 N.-2.33 W.	13.0	.5	1.0	4,239.00	3.39	9-13
27aca2	1.64 N.-2.33 W.	6.1	.5	.9	4,238.80	3.18	9-13
27aca3	1.62 N.-2.33 W.	13.0	.5	1.0	4,234.25	2.94	8-27
27aca4	1.62 N.-2.33 W.	6.0	.5	1.0	4,234.12	2.03	9-13
27acb	1.74 N.-2.37 W.	30.6	1.25	1.4	4,258.62	12.09	9-13
27acc1	1.51 N.-2.50 W.	19.5	.5	1.5	4,226.26	5.22	9-13
27acc2	1.51 N.-2.50 W.	12.7	.5	1.3	4,226.06	5.01	9-13
27acc3	1.51 N.-2.50 W.	5.9	.5	1.1	4,225.79	4.42	9-13
27adb	1.67 N.-2.22 W.	37.8	1.25	4.2	4,262.53	16.92	9-13
27add	1.50 N.-2.00 W.	12.4	.5	1.6	4,212.00	7.59	9-13
27bad	1.78 N.-2.51 W.	30.0	1.25	1.0	4,247.43	1.93	8-27
27bca	1.71 N.-2.80 W.	12.0	.5	2.0	4,248.78	4.56	9-13
27bda	1.73 N.-2.53 W.	10.8	8	2.3	....	7.60	9-13
27bdb1	1.75 N.-2.65 W.	13.1	.5	.9	4,249.83	6.18	9-13
27bdb2	1.73 N.-2.65 W.	13.2	.5	.8	4,247.02	6.11	9-13
27bdb3	1.71 N.-2.65 W.	13.1	.5	.9	4,245.46	6.18	9-13
27cad1	1.25 N.-2.50 W.	19.7	.5	1.3	4,207.23	5.27	9-13
27cad2	1.25 N.-2.50 W.	12.9	.5	1.1	4,206.92	4.92	9-13
27cad3	1.25 N.-2.50 W.	5.9	.5	1.1	4,206.76	4.75	9-13
27dbb	1.40 N.-2.50 W.	16.8	.5	2.2	4,216.50	7.06	9-13
27dda1	1.25 N.-2.00 W.	10.1	.5	1.9	4,174.70	2.65	9-13
27dda2	1.25 N.-2.00 W.	5.6	.5	1.4	4,174.18	2.43	9-13
28add	1.55 N.-3.00 W.	12.6	.5	1.4	4,245.05	4.59	9-13

Table 6.--Records of wells in the Soil and Moisture Conservation Demonstration Area, Goshen County, Wyo.--Continued

Well number	Location	Depth of well (feet)	Diameter of well (inches)	Measuring point: Distance above land surface (feet)	Measuring point: Altitude above mean sea level (feet)	Distance to water level below measuring point (feet)	Date of measurement (1949)
24-62-28ccc	1.08 N.-4.00 W.	10.0	0.5	4.0	4,254.63	7.07	9-13
28dac	1.35 N.-3.25 W.	12.7	.5	1.3	4,247.45	3.73	9-13
28dcb	1.22 N.-3.47 W.	28.9	1.25	3.1	4,251.43	5.31	9-13
28dda	1.25 N.-3.00 W.	11.6	.5	2.4	4,217.26	8.16	9-13
32aaa	1.00 N.-4.00 W.	11.8	.5	2.2	4,245.84	4.60	9-13
33aad	.75 N.-3.00 W.	13.1	.5	.9	4,179.92	5.60	9-13
33aba	1.00 N.-3.25 W.	12.5	.5	1.5	4,217.63	4.91	9-13
33acc	.50 N.-3.50 W.	19.0	.5	2.0	4,186.83	10.16	9-13
33adc	.50 N.-3.20 W.	13.4	.5	.6	4,169.74	4.39	9-13
33bab	1.00 N.-3.75 W.	12.5	.5	1.5	4,230.27	4.86	9-13
33bac	.75 N.-3.75 W.	5.9	.5	1.1	4,213.36	3.77	9-13
34abc	.85 N.-2.50 W.	18.4	.5	2.6	4,177.84	16.15	9-13
34bab	1.00 N.-2.75 W.	20.0	.5	1.0	4,195.50	9.39	9-13
34bcc	.50 N.-3.00 W.	19.3	.5	1.7	4,167.83	9.78	9-13
34cbc	.27 N.-3.00 W.	13.0	.5	1.0	4,166.07	11.54	9-13
35baa	1.00 N.-1.50 W.	12.9	.5	1.1	4,156.55	6.09	9-13
35bba	1.00 N.-1.75 W.	12.9	.5	1.1	4,157.44	5.87	9-13
35bbc1	.75 N.-2.00 W.	12.4	.5	1.6	4,158.16	5.61	9-13
35bbc2	.75 N.-2.00 W.	5.5	.5	1.5	4,158.01	5.66	9-13
35bcb	.65 N.-1.98 W.	....	4	.0	4,157.91	6.41	9-13
36bbb	1.00 N.-1.00 W.	17.7	.5	3.3	4,156.39	13.03	9-13

Table 7.--Logs of drilled test holes [1]

24-62-23dad. Ground altitude, 4,269 feet.

	Thickness (feet)	Depth (feet)
Silt and sand	36	36
Siltstone, broken and creviced; lost circulation at 37 feet	4	40
Siltstone	6	46

24-62-23dbd. Ground altitude, 4,256 feet.

	Thickness (feet)	Depth (feet)
Silt and sand	15	15
Silt and sand; fragments of siltstone	20	35
Silt	5	40
Siltstone, soft and broken	5	45
Siltstone, broken	8	53

24-62-23dcb1. Ground altitude, 4,247 feet.

	Thickness (feet)	Depth (feet)
Silt and sand	24	24
Siltstone, weathered	3	27
Siltstone, broken; encountered cavity at 43 feet and lost circulation	29	56
Clay	11	67

24-62-23dcb2. Ground altitude, 4,257 feet.

	Thickness (feet)	Depth (feet)
Silt and sand	20	20
Siltstone, broken and creviced; lost circulation at 23 feet	15	35

[1] Thirteen of these test holes were cased and used as observation wells.

Table 7.--Logs of drilled test holes--Con.

24-62-23ddb1. Ground altitude, 4,258 feet.

	Thickness (feet)	Depth (feet)
Silt and sand	25	25
Siltstone, weathered	2	27
Siltstone	13	40

24-62-23ddb2. Ground altitude, 4,256 feet.

	Thickness (feet)	Depth (feet)
Silt and sand	35	35
Siltstone, broken and creviced; lost circulation at 37 feet	10	45

24-62-23ddd. Ground altitude, 4,233 feet.

	Thickness (feet)	Depth (feet)
Silt and sand	26	26
Siltstone; encountered 1-foot cavity at 34 feet and lost circulation	18	44
Clay	6	50

24-62-24cbc. Ground altitude, 4,270 feet.

	Thickness (feet)	Depth (feet)
Silt and sand	54	54
Siltstone, broken and creviced; lost circulation at 55 feet	7	61

24-62-26cbb. Ground altitude, 4,191 feet.

	Thickness (feet)	Depth (feet)
Clay, hard	5	5
Clay	11	16

Table 7.--Logs of drilled test holes--Con.

	Thickness (feet)	Depth (feet)
24-62-27acb. Ground altitude, 4,257 feet.		
Silt and sand	19	19
Siltstone, broken; encountered cavity at 21 feet and lost circulation	5	24
Siltstone	7	31
24-62-27adb. Ground altitude, 4,258 feet.		
Silt and sand	2	2
Siltstone	35	37
Sandstone (Chadron formation)	7	44
24-62-27bad. Ground altitude, 4,246 feet.		
Silt and sand	35	35
Sand and clay balls	5	40
Clay	10	50
24-62-27cdd. Ground altitude, 4,186 feet.		
Silt and sand	48	48
Clay	12	60
24-62-28dcb. Ground altitude, 4,248 feet.		
Sand and silt	5	5
Siltstone	23	28
Clay	2	30

Table 8.--Records of soil-tube test holes

Test hole number: See explanation of numbering system in text, page 6.
Location: See explanation of location system in text, page 6.
Material encountered at bottom of hole: Where possible, test holes were driven or jetted to bedrock and a sample was collected.

Test hole number	Location	Ground altitude above mean sea level, feet	Depth (feet)	Material encountered at bottom of hole
24-62-23cdc	2.12 N.-1.72 W.	4,245	45	Silt
25ccb	1.25 N.-1.00 W.	4,152	47	Sand and gravel
26aab	2.00 N.-1.23 W.	4,218	34	Clay
26abb	2.00 N.-1.48 W.	4,224	11	Siltstone
26acd	1.50 N.-1.25 W.	4,180	18	Clay
26ada	1.75 N.-1.00 W.	4,187	31	Do.
26add	1.50 N.-1.12 W.	4,171	47	Sand
26bad	1.75 N.-1.50 W.	4,208	44	Silt and clay
26bbb	1.95 N.-2.00 W.	4,244	12	Siltstone
26bdd	1.50 N.-1.50 W.	4,195	35	Clay
26cad	1.25 N.-1.50 W.	4,164	28	Do.
26ccc	1.00 N.-2.00 W.	4,164	40	Sand
26daa	1.50 N.-1.00 W.	4,166	42	Do.
26ddc	1.00 N.-1.25 W.	4,153	44	Gravel
26ddd	1.12 N.-1.00 W.	4,151	46	Sand
27aad	1.80 N.-2.12 W.	4,250	38	Siltstone
27abc1	1.80 N.-2.47 W.	4,247	21	Do.
27abc2	1.78 N.-2.47 W.	4,245	37	Silt and clay
27acc	1.51 N.-2.50 W.	4,223	34	Do.
27add	1.50 N.-2.00 W.	4,207	27	Siltstone
27bdc	1.50 N.-2.75 W.	4,231	27	Do.
27dbb	1.40 N.-2.50 W.	4,212	43	Silt
27dda	1.25 N.-2.00 W.	4,174	14	Clay
28add	1.55 N.-3.00 W.	4,244	10	Siltstone
32aaa	1.00 N.-4.00 W.	4,244	32	Do.
33aad	.75 N.-3.00 W.	4,178	24	Clay
33aba	1.00 N.-3.25 W.	4,214	9	Do.
33abb	1.00 N.-3.50 W.	4,218	4	Do.
33acc	.50 N.-3.50 W.	4,184	38	Do.
33adc	.50 N.-3.20 W.	4,270	18	Do.
33bab	1.00 N.-3.75 W.	4,228	17	Do.
33bac	.75 N.-3.75 W.	4,211	29	Do.
33bcb	.75 N.-4.00 W.	4,218	10	Do.
33bcc	.50 N.-4.00 W.	4,184	8	Do.
33bdc	.50 N.-3.75 W.	4,199	19	Silt and clay
34aba	1.00 N.-2.25 W.	4,178	25	Silt
34abc	.85 N.-2.50 W.	4,176	40	Silt and sand

Table 8.--Records of soil-tube test holes--Continued

Test hole number	Location	Ground altitude above mean sea level, feet	Depth (feet)	Material encountered at bottom of hole
24-62-34bab	1.00 N.-2.75 W.	4,194	26	Clay
34bbb	.90 N.-3.00 W.	4,192	10	Do.
34bcc	.50 N.-3.00 W.	4,166	29	Sand and gravel
34cbc	.27 N.-3.00 W.	4,164	16	Sand, fine
35baa	1.00 N.-1.50 W.	4,154	37	Gravel
35bba	1.00 N.-1.75 W.	4,152	52	Clay and sand
35bbc	.75 N.-2.00 W.	4,152	27	Gravel
36bbb	1.00 N.-1.00 W.	4,152	42	Clay

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