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Hydrologic Conditions in the Wheatland Flats Area, Platte County Wyoming

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GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1783

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

Hydrologic Conditions in the Wheatland Flats Area, Platte County Wyoming

By EDWIN P. WEEKS

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By Edwin P. Weeks

ABSTRACT

Wheatland Flats, an area of about 100 square miles in Platte County, Wyo., is bounded on the east by Chugwater Creek, on the north by the Laramie River, and on the west by Sybille Creek. The southern boundary is approximately the southernmost limit of the terrace deposits. About 50,000 acres of land in the area is irrigated with water supplied by the Wheatland Irrigation District. Adequate supplies of water for irrigation are available only in years when stream runoff is above normal; for the years 1945–56, annual water shortages averaged about 0.5 acre-foot per acre of irrigated land.

The area is underlain by rocks of Precambrian, Tertiary, and Quaternary age. The principal water-bearing formations include the Arikaree Formation of Tertiary age and terrace deposits of Quaternary age. The terrace deposits, which are very permeable, absorb and hold large quantities of water during the irrigation season. Much of the water is transmitted through the Arikaree Formation to the major streams bounding the area, which lie at a lower altitude than the terrace deposits. A considerable head decline associated with the downward movement of water exists in the area, and the piezometric level for water at depth in the Arikaree Formation is lower than the water table in most places.

Underflow to and from the area is limited by deeply entrenched streams on the west, north, and east sides and by relatively impermeable beds on the south side. The ground-water reservoir is recharged almost entirely by seepage from irrigation and by precipitation. Recharge by seepage from irrigation was 45 to 50 percent of the water applied in 1959 and 35 to 40 percent of the water applied in 1960. The difference between recharge rates for the 2 years probably is caused partly by inaccuracies in interpreting the data and partly by changes in irrigation practices during the 2 years. From 5 to 10 percent of the precipitation in the area is estimated to be recharged to the ground-water reservoir.

Discharge from the ground-water reservoir is by seepage to streams, springs, and drains, by evapotranspiration, and by pumping from wells. About 23,000 acre-feet of water is discharged to the major streams by seepage from the Arikaree Formation. Some ground water is discharged from the terrace deposits and the upper part of the Arikaree Formation to minor streams, drains, seeps, and springs. The annual amount of water thus discharged is dependent on the amount of surface water applied for irrigation and on the amounts of precipitation.

From 60 to 65 percent of the surface water applied for irrigation and 90 to 95 percent of the precipitation in the area is discharged by evapotranspiration. About 2,500 acre-feet is transpired by nondesirable hydrophytes and phreatophytes.

About 4,000 acre-feet of ground water was pumped for municipal, domestic and stock, and irrigation uses in 1959, and about 7,700 acre-feet was pumped in 1960.

On the basis of aquifer tests and specific-capacity data, the coefficient of transmissibility for the terrace deposits ranges from about 10,000 to about 120,000 gpd (gallons per day) per ft, and the coefficient of permeability ranges from about 500 to 5,000 gpd per sq ft. The average values for the coefficients of trans-

missibility, storage, and vertical permeability for the Arikaree Formation are about 5,700 gpd per ft, 5.4×10^{-4}, and 0.48 gpd per sq ft, respectively. On the basis of the accretion component of head and the accretion rate to the Arikaree Formation, the coefficient of transmissibility is about 10,000 gpd per ft. The figure of 10,000 gpd per ft probably is more accurate for the formation than the figure determined by the aquifer tests, because the aquifer tests were made at the sites of partly penetrating wells and do not indicate conditions for the aquifer as a whole.

A minimum value for the vertical permeability based on the difference in head between the water table and the piezometric surface and the accretion rate to the Arikaree Formation at depth is about 0.06 gpd per sq ft. The maximum recharge to the formation, based on this value, is about 400 acre-feet per day, considerably more than the recharge of 165 acre-feet per day needed to maintain ground-water supplies for the pumping project proposed by the U.S. Bureau of Reclamation.

Under the proposed Bureau of Reclamation's pumping plan, about 15,600 acre-feet of ground water would be pumped annually to supplement surface-water supplies. About 12,000 acre-feet of additional surface water would be made available by increasing storage space and by lining some canals outside the project area. New equilibrium levels for the water table and the piezometric surface produced by pumping 18,000 acre-feet annually from the Arikaree Formation for several years would be from 5 to 10 feet and from 25 to 30 feet lower, respectively, than at present. About 9,000 acre-feet of water would be captured from increased recharge resulting from the additional supply of water made available under the plan, and the remaining 9,000 acre-feet would be salvaged from water that would be discharged by seepage to streams and by evapotranspiration under present conditions. Streamflow in the Laramie River below its confluence with Chugwater Creek eventually might be diminished by as much as 7,000 acre-feet a year.

If all the water were pumped from the Arikaree Formation, average pumping lifts for water pumped under the project plan would be from 185 to 190 feet.

INTRODUCTION

PURPOSE AND SCOPE

This investigation was made by the U.S. Geological Survey in cooperation with the U.S. Bureau of Reclamation to determine the availability of ground water in the Wheatland Flats area for supplemental irrigation supplies. Water for irrigation is diverted from the Laramie River, but in many years the supply is inadequate for crop requirements. The Bureau of Reclamation is studying the feasibility of constructing ground-water pumping facilities to alleviate the problem. The study requires detailed quantitative data from which an estimate can be made of the effects of an increased draft on the ground-water reservoir. This report is based on field investigations carried out between July 1958 and June 1961. Investigations included inventory of most small-discharge wells and all large-discharge wells, examination of drill cuttings of the Arikaree Formation, periodic measurements of water levels in selected wells, compilation of pumpage inventories, and several aquifer tests on the Arikaree Formation.

Much of the material for this paper was adapted from previous reports, especially the report by Morris and Babcock (1960), to avoid duplication of effort.

The work was done under the supervision of Ellis D. Gordon, district geologist for the Ground Water Branch of the U.S. Geological Survey in Wyoming.

LOCATION AND EXTENT OF THE AREA

Wheatland Flats includes an area of about 100 square miles in Platte County, Wyo., bounded on the east by Chugwater Creek, on the north by the Laramie River, and on the west by Sybille Creek. The southern boundary is indefinite; it is considered to lie along the southernmost limit of the terrace deposits in the Wheatland Flats area. The area described in this report includes the Wheatland Flats and adjacent areas in Tps. 23, 24, and 25 N., Rs. 67, 68, and 69 W., (Pl. 1; fig. 1).

METHODS OF INVESTIGATION

The irrigation-well inventory of Morris and Babcock (1960) was brought up to date. Data were obtained on 42 wells tapping the Arikaree Formation of Tertiary age and 63 wells tapping the terrace deposits of Quaternary age that had been constructed to supply water for irrigation, municipal, or industrial use. Morris and Babcock's inventory of small-discharge wells tapping the Arikaree Formation also was brought up to date. The depth to water was measured in most of the wells that were visited, and reported depths were obtained from the owners or tenants for wells that could not be measured. The discharges and drawdowns of most of the large-discharge wells were measured, and logs of as many wells as possible were obtained.

Periodic measurements of water levels were begun in May 1958 in 19 observation wells tapping the Arikaree Formation and 33 observation wells tapping the terrace deposits. In addition, periodic measurement of water levels in 13 observation wells installed by the Bureau of Reclamation was assumed by the Geological Survey in November 1960.

The Bureau of Reclamation drilled five test holes, four of which were finished as observation wells, in the area to obtain lithologic data on the Arikaree Formation. The Bureau also drilled 10 observation wells in the vicinity of well 23–68–4abc to facilitate making an aquifer test at that site.

The Geological Survey drilled eight observation wells tapping the Arikaree Formation to be used in aquifer tests at the sites of five irrigation wells. Stratigraphic data were collected at these sites. In 1953, the Geological Survey drilled 73 test holes to the base of the terrace deposits (Morris and Babcock, 1960, p. 113).

During this investigation, aquifer tests were made at the sites of

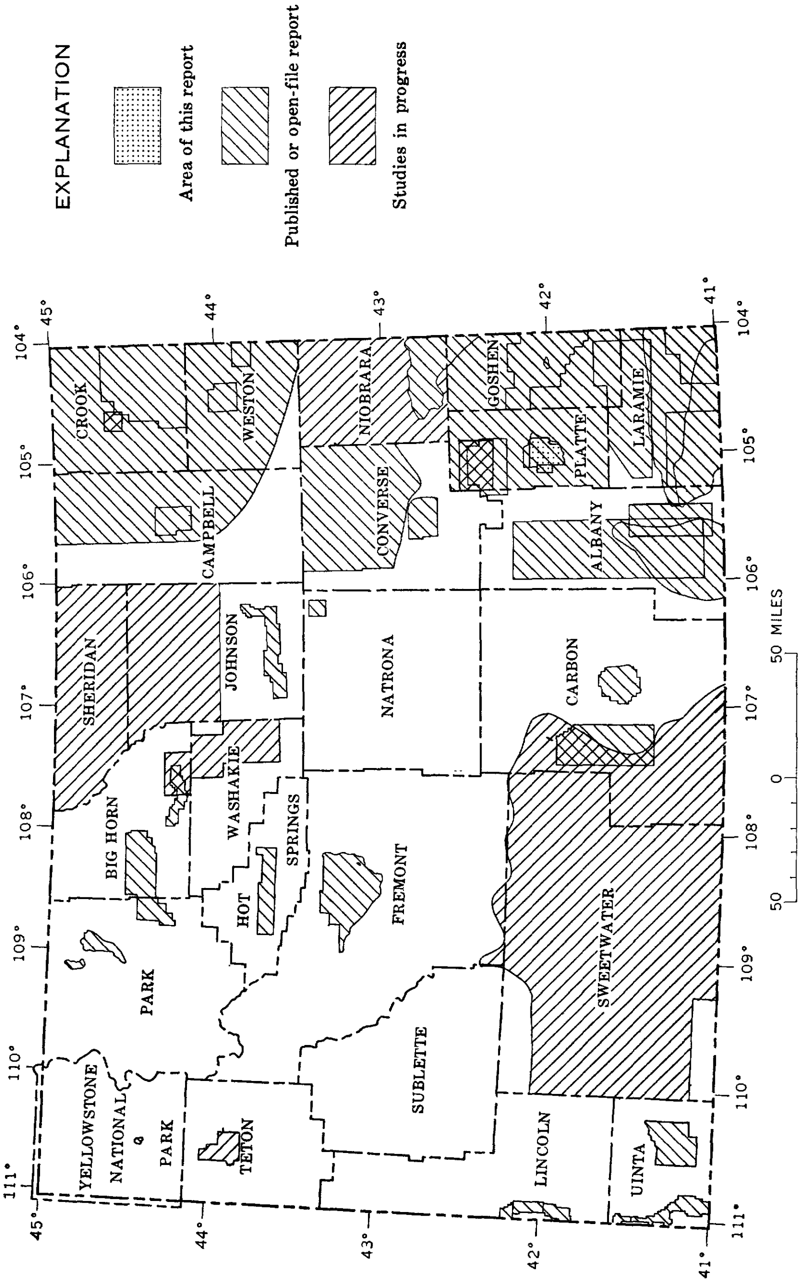

FIGURE 1.—Map of Wyoming showing the area described in this report and other areas for which ground-water reports have been released or where studies are in progress.

eight irrigation wells tapping the Arikaree Formation. One test was made on the Arikaree Formation and three were made on the terrace deposits by Morris and Babcock (1960, p. 52–54) during their investigation.

Locations and altitudes of wells were determined from Geological Survey topographic maps of the 1:24,000 series. Altitudes of Geological Survey and Bureau of Reclamation test holes were determined by spirit leveling.

Maps were prepared showing the location of wells, contours on the top of the bedrock, contours on the water table and the piezometric surface, the saturated thickness of the terrace deposits, depth to the water table below the land surface, and the difference in head between the piezometric surface and the water table. The geologic map was taken from Morris and Babcock (1960, pl. 2).

A detailed study of the hydrology was made. The head of water at depth in the Arikaree Formation was broken down into two components—that due to the aquifer boundaries and that due to accretion—by means of an electrical analog apparatus. Estimates of recharge to the ground-water reservoir were made from water-level measurements and streamflow gains; deep percolation losses were estimated from a flow-net analysis of streamflow gains, and the aquifer coefficients were determined by aquifer tests and other methods.

WELL-NUMBERING SYSTEM

The wells are numbered according to their location within the U.S. Bureau of Land Management's system of land subdivision. All wells are in the sixth principal meridian and baseline system. The well number shows the location of the well by township, range, section, and position within the section. A graphical illustration of the well-numbering system is shown by figure 2. 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 lowercase letters following the section number indicate the position of the well within the section. The first letter denotes the quarter section, the second the quarter-quarter section, and third the quarter-quarter-quarter section (10-acre tract). The subdivisions of the sections are lettered a, b, c, and d in a counterclockwise direction, beginning in the northeast quarter. If more than one well is listed in a 10-acre tract, consecutive numbers beginning with 1 are added to the well number. Locations of wells and test holes in the area are shown on figure 3.

This numbering system was used also to designate the test holes and springs and to designate flow-measuring stations on the major streams.

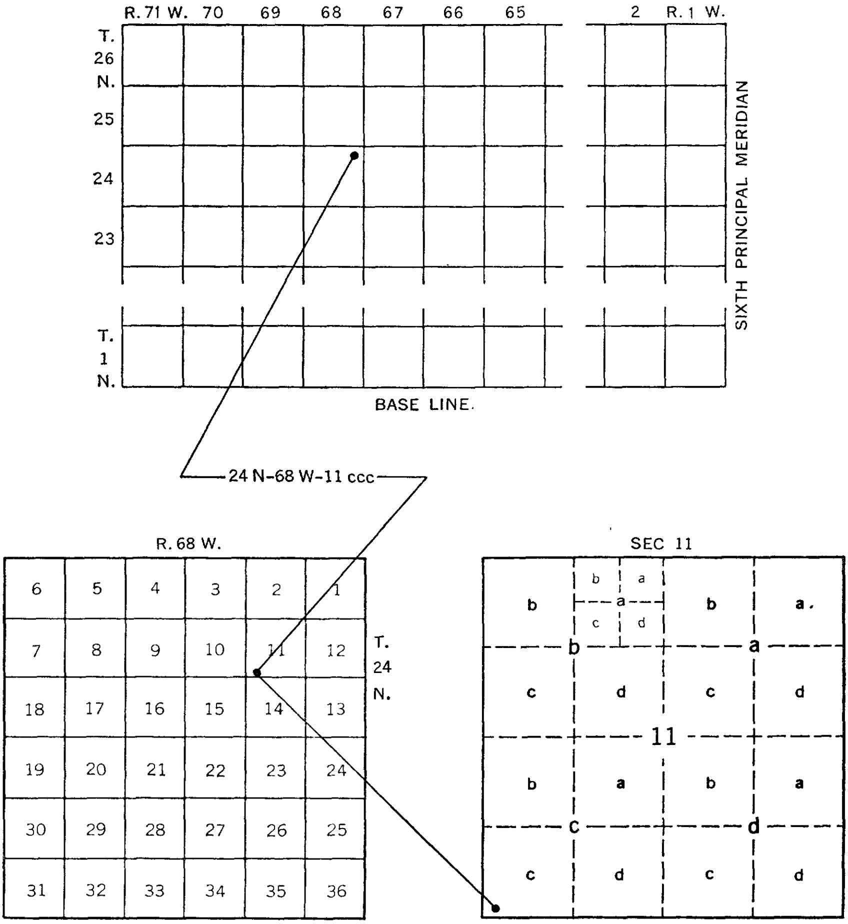

FIGURE 2.—Sketch showing well-numbering system.

PREVIOUS INVESTIGATIONS

The first published report on ground water in the area is one by Edwards (1941) on the ground-water resources in the valleys of Chugwater Creek and Laramie and North Laramie Rivers. R. T. Littleton (1950) made a reconnaissance of the ground-water resources in the area, giving special emphasis to water losses from canals to the terrace deposits. Morris and Babcock (1960) made a comprehensive study of the ground-water resources of Platte County, with emphasis on the Wheatland Flats area.

ACKNOWLEDGMENTS

The writer is indebted to the many persons who contributed information and assistance. Messrs. Clarence Galusha and Robert Mor-

dahl furnished information on wells they had drilled in the area. Residents in the Wheatland Flats area supplied information on their wells and gave permission for various measurements and tests to be made on their property.

The free exchange of ideas between the author and Messrs. Robert Cross and Dale Raitt of the Bureau of Reclamation contributed a great deal to this report, as did the whole-hearted cooperation of many other Bureau of Reclamation personnel.

HISTORY OF IRRIGATION IN THE AREA

Approximately 40,000 to 50,000 acres of land is irirgated in the Wheatland Flats area with water supplied by the Wheatland Irrigation District. The principal crops grown on the irrigated acreage are corn, sugar beets, beans, hay, barley, oats, and pasture. Livestock feeding is a major enterprise.

Irrigation was begun in the area in 1883 with irrigation water obtained directly from streamflow. About 30,000 to 40,000 acres of land was settled and irrigated under this program. Supplies of surface water from streamflow were ample for irrigation in the spring and early summer, when runoff from snowmelt was high, but late in the growing season supplies generally were insufficient. Therefore, two reservoirs were constructed to store water during periods of high streamflow and during the nonirrigation season, under a charter providing for the irrigation of 63,500 acres of land. In 1896, Reservoir No. 1, having a usable capacity of 5,300 acre-feet, was completed in secs. 5 and 6, T. 23 N., R. 68 W.; and, in 1901, Reservoir No. 2, having a usable capacity of about 60,000 acre-feet, was completed on the Laramie River, about 24 miles west of the project area. The height of the dam for Reservoir No. 2 was raised in the 1930's, and the capacity of the reservoir was thus increased to 99,000 acre-feet (M. J. Greer, written communication, 1962).

Irrigated acreage is much smaller than the 63,500 acres provided for under the charter; it varies from year to year, depending on the amount of water available and market conditions. The average acreage irrigated during the period 1930–46 was about 43,000 acres. The area has sufficient water for irrigation only in years when stream runoff is above normal. In the period 1945–56, annual water shortages averaged about 0.5 acre-foot per acre of irrigated land (U.S. Bureau of Reclamation, 1958, p. 23). Thus, water shortages constitute a major problem to agriculture in the area.

GEOLOGY

Igneous and metamorphic rocks of Precambrian age and sedimentary rocks of Tertiary and Quaternary age crop out in the Wheatland Flats area. The geology of the Wheatland Flats is shown in plate 1.

ROCKS OF PRECAMBRIAN AGE

Rocks of Precambrian age crop out a short distance west of the Wheatland Flats. The rocks consist of granite, gneiss, and schist that have been intruded by pegmatite dikes. These igneous rocks are genetically related to the rock mass of the Laramie Range (Littleton, 1950, p. 10). These rocks do not yield water to wells in the Wheatland Flats area.

ROCKS OF TERTIARY AGE

The rocks of Tertiary age that crop out in the Wheatland Flats area include the Brule Formation of Oligocene age, the Arikaree Formation of Miocene age, and undifferentiated alluvial deposits of probable Tertiary age. The ages of the Oligocene and Miocene deposits have been determined by study of vertebrate fossils found in them and by their lithology and stratigraphic sequence. No fossils were found in the undifferentiated alluvial deposits, and their age has been estimated from lithologic characteristics and stratigraphic position (Morris and Babcock, 1960, p. 38).

BRULE FORMATION

The Brule Formation consists of white to buff-orange, moderately hard brittle argillaceous, bentonitic blocky siltstone or silty claystone (Morris and Babcock, 1960, p. 32). The formation is middle to late Oligocene in age and correlates with the upper unit of the White River Group in other areas in Wyoming, South Dakota, Nebraska, and northern Colorado (Wood and others, 1941, p. 1).

The permeability of the rocks is very low. The formation is of no importance as an aquifer in the area of this report, although it does yield small quantities of water to numerous domestic and stock wells a few miles east of the Wheatland Flats.

ARIKAREE FORMATION

The deposits of Miocene age in the area constitute a fairly homogeneous, mappable unit; however, detailed geologic and paleontologic work in western Nebraska and in the Greyrocks area, Platte County, Wyo., indicate that the Miocene deposits may be divided into smaller mappable units.

McGrew (unpublished master's thesis, University of Wyoming, 1953) recognized and subdivided the Arikaree Formation in the Greyrocks area, 10 to 12 miles east of the Wheatland Flats. Although the formations recognized by McGrew probably are present in the Wheatland Flats area, the scope of this report did not warrant the detailed study necessary to subdivide the sandstones of Miocene age. They have been grouped under the Arikaree Formation in this report.

Lithology.—The Arikaree Formation is composed chiefly of fine to very fine quartz sand and sandstone containing muscovite and biotite grains. In many places in Platte County, the formation consists of two distinct lithologic units, a basal conglomeratic unit and an upper sandy unit. The basal unit has not been observed in the Wheatland Flats area, but it may be present at depth locally. The basal conglomerate was deposited in stream channels and lies unconformably on the Brule Formation (Morris and Babcock, 1960, p. 33–34).

Morris and Babcock (1960, p. 34) described the basal unit as consisting of loosely to well-cemented red to gray coarse to very coarse sandstone interbedded with lenses of well-cemented conglomerate containing fine to very coarse gravel and boulders. These materials have been derived from the Laramie Range and other structurally high areas and include quartzite, felsic rocks, mafic rocks, sandstone, limestone, and chert.

The upper unit is composed, for the most part, of light-gray to tan very fine to fine-grained silty sandstone interbedded with thin lenses of white to light-tan fine-grained sandstone very tightly cemented with concretionary lime. Individual concretions are numerous in many places. Some of these concretions are spherical and others are cylindrical. The cylindrical concretions, called "pipy concretions" by Darton (1903, p. 23–29), seem to be much more numerous than the spherical ones. The cylindrical concretions have been described by Wenzel, Cady, and Waite (1946, p. 72–75).

The uppermost part of the upper sandy unit in the Wheatland Flats area is very poorly cemented and contains fewer limy concretions than zones lower in the unit. The upper zone does not stand as open hole when drilled and is known by drillers in the area as quicksand. The zone is poorly defined and is inconsistent between wells as to thickness or altitude of the bottom of the zone. It is difficult to complete wells in this poorly consolidated material, and in most of the wells the top part of the upper unit has been cased off.

Some wells penetrate lenticular deposits of coarse sand to fine gravel in the upper unit. The deposits are poorly sorted, subangular to subrounded, and contain a predominance of orthoclase and andesine(?) plagioclase grains. These coarse lenticular deposits may have been deposited in stream channels. Five wells (24–68–34bbc1, 24–68–27acc1, –27acc2, 24–68–22acc1, and –22acc2) tapped a considerable thickness of the coarse deposits. These wells lie in a northward-trending line and indicate a continous channel in this area. The wells yield much more water than others in the area. Thin white beds of silty limestone were penetrated in several wells and test holes, and beds of hard green claystone were tapped in USBR test hole 5 (fig. 4). Samples of cuttings from wells 24–68–22aac1, 24–68–27aac2.

24–68–27bdd, and 24–67–7acd all contained some sand composed of rounded frosted quartz grains that appear to be aeolian in origin.

Particle-size distribution analyses of the Arikaree Formation were made on eight core samples taken from USBR test hole 1 by the Bureau of Reclamation. The results of these analyses are given in table 1. The first four samples were taken from unconsolidated deposits in the upper part of the formation and are composites of the material recovered in the depth intervals shown. The last four samples are continuous cores of consolidated material taken at the indicated depths. The mean grain size of five of the eight samples is in the very fine sand range (0.0625–0.125mm). In two samples, the mean grain size is in the fine sand range (0.125–0.250mm); and in one sample, the mean grain size is in the silt size range (0.005–0.0625mm). Clay content for the samples ranges between 4.4 and 26.2 percent.

TABLE 1.—*Particle-size percentage distribution of core samples of the Arikaree Formation from U.S. Bureau of Reclamation test hole 1 (well 24–68–33aba)*

[Analyses by U.S. Bureau of Reclamation]

Sample	Depth interval from which sample was taken (feet)	Particle size, in millimeters							
		Clay size (<0.005)	Silt size (0.005–0.0625)	Sand size					Gravel size (+2.00)
				Very fine (0.0625–0.125)	Fine (0.125–0.250)	Medium (0.250–0.500)	Coarse (0.500–1.00)	Very coarse (1.00–2.00)	
1	42–44	26.2	26.1	40.8	1.1	1.7	2.5	1.2	0.2
2	83–85	4.4	.6	18.3	30.8	21.1	22.7	2.0	.1
3	153–164	12.2	5.2	33.8	40.6	4.3	1.8	.2	----------
4	184–194	12.4	8.8	14.6	30.3	23.4	10.3	.1	.2
5	226	7.8	25.2	45.2	15.9	3.1	2.7	.1	----------
6	259	8.4	2.8	44.5	34.6	8.1	1.5	----------	----------
7	320	7.8	34.0	26.3	12.8	7.4	10.8	1.3	.1
8	346	5.4	20.7	47.7	20.5	2.7	2.7	.5	----------

Electric and gamma-ray logs of five test holes drilled by the Bureau of Reclamation and of five observation wells drilled by the Geological Survey were obtained. No definite correlation of strata could be established between well sites from these logs, but the electric logs, in conjunction with the lithologic logs, were useful in determining the lithologic sequence at each test-hole site. Plate 2 is a detailed columnar section showing the relation between the lithologic characteristics of the rocks penetrated by U.S. Bureau of Reclamation test hole 5 and their electric properties, as shown on the electric log. The middle third of the section has a higher resistivity than the upper and lower parts. The higher resistivity might indicate that less clay occurs in that part of the section and that it might be more permeable than the other zones.

Thickness and extent.—The Arikaree Formation is present throughout most of the project area, being absent only in the areas of outcrop of rocks of Precambrian age and south of the Wheatland Fault where the Brule Formation and undifferentiated alluvial deposits of probable Tertiary age crop out. The Arikaree strata in the Wheatland Flats area are almost flat-lying and were deposited on an erosion surface of considerable relief. The formation ranges in thickness from 0 to about 1,100 feet. It is 1,080 feet thick in USBR test hole 1. The extent and thickness of the basal unit is not known. It is absent in USBR test hole 1.

The formation is cut by several faults of the Wheatland and Whalen fault systems near the eastern and southern boundaries of the area. Total displacement along the fault systems is not known; however, the total throw on the fault system may be several hundred feet.

Water-bearing properties.—The basal unit of the Arikaree Formation is deeply buried or absent in the area, and its potential as an aquifer has not been tested. However, in the vicinity of Chugwater, about 11 miles south of the project area, the unit is very tightly cemented, and a laboratory test made on a sample from this outcrop indicates that the permeability of the unit is very low in that locality.

The upper unit yields small quantities of water to many domestic and stock wells in the area and from 150 to 700 gpm (gallons per minute) to several irrigation and public-supply wells. The wells of large discharge penetrate a considerable thickness of the formation, many being as much as 500 feet deep.

Bedrock topography.—The Arikaree Formation has been extensively eroded, and its upper surface is very irregular. It is covered in most of the area with a veneer of terrace sand and gravel deposits. A contour map of the top of the formation has been made from data obtained from logs of test holes and wells that penetrate the Arikaree Formation and from altitudes of its outcrop. The contours are shown on the geologic map (pl. 1).

DEPOSITS OF TERTIARY(?) AGE, UNDIFFERENTIATED

Gray to red, loosely consolidated sand, gravel, and arkosic conglomerate crop out in the southernmost part of the area. The deposits are interbedded or mixed with clayey sand and tuffaceous clay. The sediments were deposited as alluvial fans, but subsequent erosion has dissected them to form deep valleys and pediment surfaces. The deposits range in thickness from 0 to 200 feet.

The deposits are unfossiliferous, and their time of deposition cannot be determined. Their stratigraphic position indicates that they may be of Tertiary age, and they have been mapped as Tertiary(?) undivided (Morris and Babcock, 1960, p. 37–38).

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The beds are topographically high and well drained in most places and are of minor hydrologic importance. However, they yield water to springs and probably contribute to the flow of Antelope and Hunton Creeks in areas where these streams are entrenched below the water table.

ROCKS OF QUATERNARY AGE

Quaternary deposits in the Wheatland Flats area include terrace and flood-plain deposits and alluvial-fan deposits. The alluvial-fan deposits are areally small and generally lie above the water table. Only the terrace and flood-plain deposits are discussed in this report.

TERRACE DEPOSITS

Thickness and extent.—Terrace deposits underlie the seven terraces (Morris and Babcock, 1960, p. 39) that form the Wheatland Flats. The deposits also underlie the extensions of the terraces across the major stream valleys from the Wheatland Flats. The deposits range in thickness from 0 to 50 feet; differences in thickness are great because of the irregularity of the erosion surface (pl. 1) on which they were deposited. Only the terrace deposits underlying the Wheatland Flats contain significant quantities of ground water, and they are the only ones discussed in this report.

Lithology.—The deposits consist of subangular to rounded unsorted unconsolidated sand, gravel, cobbles, and boulders, interbedded with lenses of clay and silt. The cobbles and boulders are igneous and metamorphic rocks and are subrounded to subangular. The sand grains are predominantly quartz, orthoclase, and plagioclase. They range in grain size from fine to coarse and are subrounded to well rounded. Source rocks for the deposits are from the Laramie range and from local sources (Morris and Babcock, 1960, p. 39–40).

Water-bearing properties.—Water in the terrace deposits is under water-table conditions. The deposits yield small to moderate quantities of water to numerous domestic and stock wells. Irrigation wells in the area generally yield 100 to 700 gpm; however, one well fed by radiating tile drain lines yields more than 800 gpm.

A summary of data on the terrace deposits on the Flats is given in table 2 (Morris and Babcock, 1960, table 3).

FLOOD-PLAIN DEPOSITS

The deposits that underlie the flood plains of the Laramie River and Sybille and Chugwater Creeks are principally fine to very coarse sand and gravel containing lenses and beds of fine sand, silt, and clay, and cobbles and boulders derived from sedimentary, metamorphic, and igneous rocks (Morris and Babcock, 1960, p. 41).

The thickness of the flood-plain deposits probably ranges from 0 to about 30 feet. The Geological Survey drilled six test holes in the

TABLE 2.—*Terraces on Wheatland Flats*

Terrace	Approximate height above parent stream (feet)	Average thickness of deposits (feet)	Evaluation of terrace deposits as source of irrigation water	Remarks
7	160	40	Good in N½ of T. 23 N., R. 68 W.	Depth to water is more than 40 ft except in approximately the N½ T. 23 N., R. 68 W., where it is less.
6	140	50	Poor	Terrace is of small areal extent; depth to water generally is more than 40 ft.
5	120	25	Good	Depth to water under much of the terrace is less than 20 ft.
4	90	15	Fair to poor	Depth to water under much of the terrace is less than 10 ft.
3	70	25	Poor	Depth to water under most of the terrace is 20 ft or more.
2	40	20	do	Do.
1	25	10	do	Terrace is of very small areal extent.

valley of the Laramie River between its confluence with Sybille Creek and its confluence with Chugwater Creek that penetrated from 9 to 28 feet of alluvial material. In general, the deposits range from about a quarter of a mile to half a mile in width.

The flood-plain deposits seem to be very permeable and probably can transmit moderately large quantities of water. The scope of this investigation did not include a quantitative analysis of the hydraulic properties of the flood-plain deposits, but data on the hydraulic properties of deposits in adjoining areas have been published (Morris and Babcock, 1960, p. 58).

GROUND-WATER HYDROLOGY

The Wheatland Flats area is bounded on the west, north, and east by deeply entrenched streams, which act as ground-water drains and prevent significant quantities of ground water from moving into or from the area as underflow. Rocks of relatively low permeability occur in the southernmost part of the area and limit underflow to or from the south. The ground-water reservoir is recharged almost entirely by seepage from irrigation water and from precipitation. The reservoir loses water to wells, to streams, and through evapotranspiration.

The terrace deposits and the Arikaree Formation are the principal aquifers in the area. The terrace deposits form a thin blanket over the Arikaree Formation and readily absorb water from precipitation and irrigation. Water in the terrace deposits moves slowly downward into the less permeable Arikaree Formation and from there to the major streams, which are at a much lower altitude than the terrace deposits. The Arikaree Formation cannot transmit all the water available from the terrace deposits, and water rejected by the Arikaree Formation is discharged to minor streams, springs, drains, and seeps tapping the terrace deposits.

THE WATER TABLE

The water table is defined as the upper surface of the zone of saturation except where that surface is formed by an impermeable boundary (Meinzer, 1923b, p. 22).

The water table lies within the terrace deposits throughout most of the area, except in that part of terrace 7 (pl. 1) lying east of Rock Creek and that part along the high area lying in sec. 4, T. 23 N., R. 68 W., and secs. 33 and 34, T. 24 N., R. 68 W. In these areas the terrace deposits are topographically high and drained. Plate 3 shows the configuration of the water table based on altitudes of water levels in shallow wells and altitudes of ponds and seeps. The contour lines are drawn on the perched water table where it occurs along the major streams. In places where the terrace deposits are not saturated, the contour lines have been interpolated from nearby saturated areas.

The zone of saturation is continuous between the terrace deposits and the Arikaree Formation in much of the area, but near the edges of the flats, the zone may be discontinuous, as indicated by springs at the contact of the two formations (pl. 1) in a few places along the cliffs bounding the area. In these areas, a lower zone of saturation in the Arikaree Formation, which contains the main water table, lies below a perched zone of saturation in the terrace deposits. Figure 3 shows the probable relation between the main water table and the zone of perched water in the terrace deposits.

Ground-water moves downslope in a direction approximately perpendicular to the contour lines of the water table, and almost everywhere in the Wheatland Flats it moves to the north and northeast

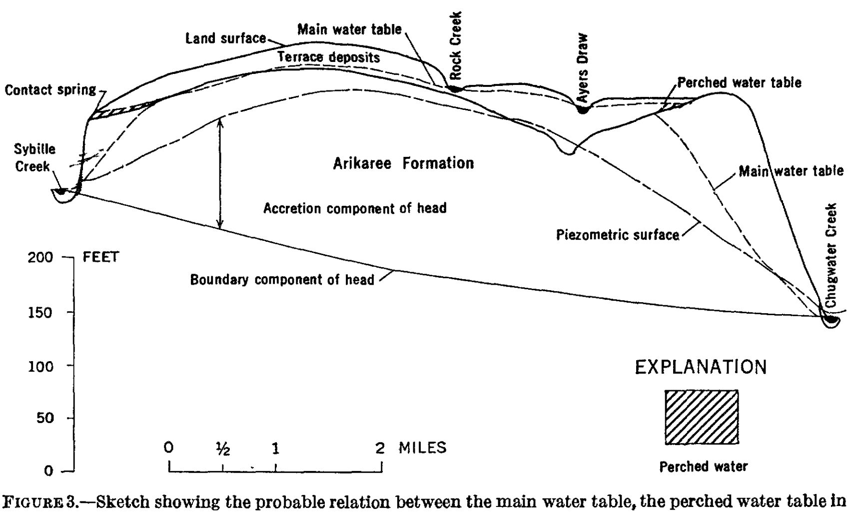

FIGURE 3.—Sketch showing the probable relation between the main water table, the perched water table in the terrace deposits near the major streams, the piezometric surface of the Arikaree Formation, and the boundary and accretion components of head for the piezometric surface.

in the direction of the slope of the land surface. The slope of the water table, as represented by the spacing of the contours (pl. 3), is uneven. The slope is dependent on the permeability and thickness of the water-bearing materials and on the amount of water being transmitted. The terrace deposits are much more permeable than the Arikaree Formation; therefore, the slope of the water table varies inversely with the thickness of the saturated part of the terrace deposits. The terrace deposits differ greatly in thickness in short distances (pl. 4) because they were deposited on the highly irregular erosional surface of the Arikaree Formation. At many places where the terrace deposits are thin or absent, seeps appear at the land surface because the underlying Arikaree Formation is not sufficiently permeable to transmit the water available from the terrace deposits.

The average slope of the water table is greater in the part of terrace 7 lying in T. 23 N., R. 68 W., than in the terrace deposits in other parts of the area, although the saturated thickness is greater here than in most of the rest of the area. The deposits underlying terrace 7 transmit no more water than the deposits farther north, and they probably are less permeable than those beneath the other terraces. Examination of drill cuttings from several wells on this terrace reveals that the deposits contain more clay and silt than those beneath the other terraces. This high clay and silt content probably is responsible for the relatively low permeability.

THE PIEZOMETRIC SURFACE

When water moves through an aquifer, a decline in piezometric head, which is proportional to the rate of flow divided by the permeability of the aquifer, occurs along the path of flow. Because water moves downward from the terrace deposits and horizontally through the Arikaree Formation to the major streams, a considerable decline in head with depth occurs in much of the area. The head decline caused by vertical flow is comparatively high because the Arikaree Formation is lenticular and its vertical permeability is much less than its horizontal permeability. Static water levels in observation wells installed by the Bureau of Reclamation in the vicinity of well 23–68–4abc (fig. 4) demonstrate this decline.

Water levels in wells tapping the Arikaree Formation represent a piezometric surface much different from the water table because of the decline in head with depth. Plate 5 shows the configuration of this piezometric surface based on altitudes of water levels in the wells and altitudes along the major streams. Most of the wells are open or screened in the zone lying a few feet below the poorly consolidated part of the upper sandy unit of the Arikaree Formation. This zone coincides roughly with the plane described by connecting points of equal

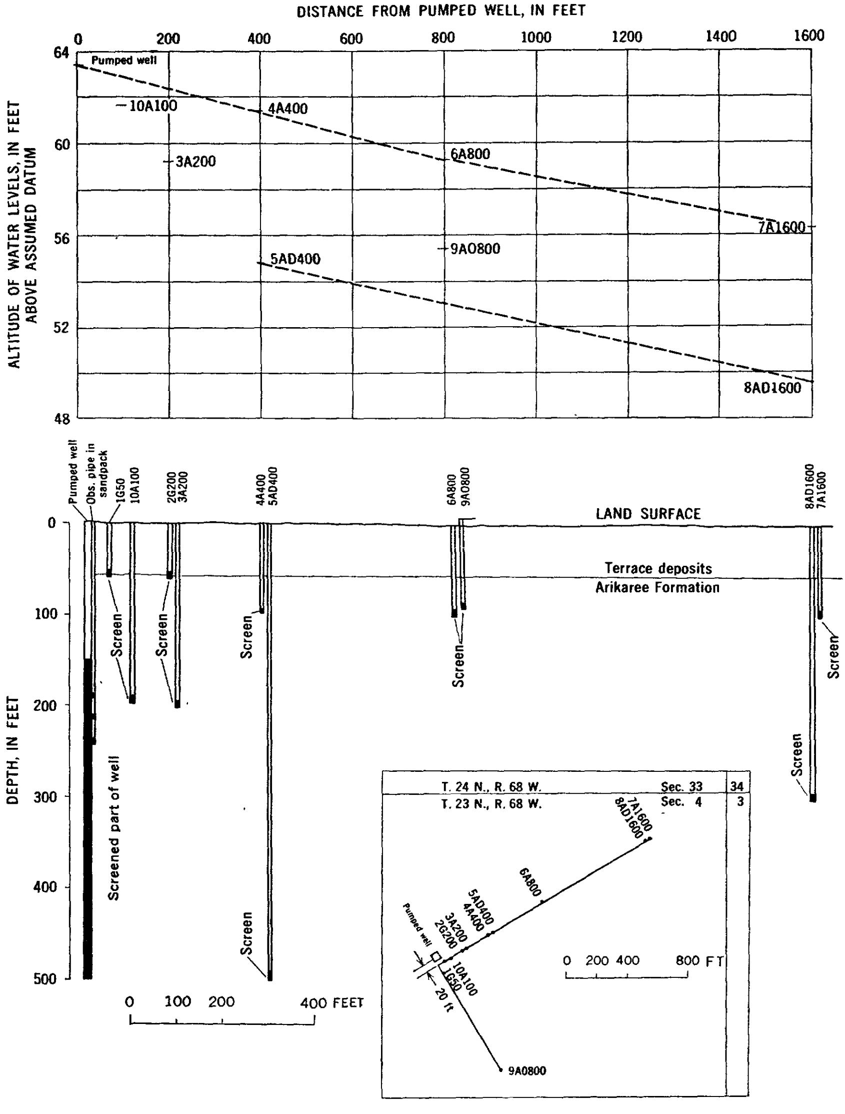

FIGURE 4.—Sketch showing relative locations, depths, and altitudes of static water levels in observation wells used for aquifer tests at site of pumped well 23-68-4abc. Observation-well numbers are those used by the U.S. Bureau of Reclamation.

altitude between Chugwater Creek, the Laramie River, and Sybille Creek; most of the downward movement of water and consequent decline in head with depth occur above this level. Thus the slope of the piezometric surface depicts approximate changes in head due to the horizontal movement of water through the formation. Ground-water flow is from the Arikaree Formation to the major streams, and water in the formation is under some artesian pressure in the areas underlying the stream valleys. Altitudes along the streams were used for control in drawing the piezometric-surface map but, because of the artesian pressure, the contours were rounded at the streams, and the altitudes of the contours at their points of intersection with the streams are higher than the topographic altitudes there.

COMPONENTS OF HEAD

The head at any point in an aquifer may be separated into two components—that due to the location and configuration of the aquifer boundaries and that due to accretion to the aquifer. Accretion is used here to represent the net rate at which water is gained or lost in response to external forces. The piezometric head for the Arikaree Formation in the Wheatland Flats area was broken down into its boundary and accretion components so that estimates could be made of changes in water levels produced by changing the accretion rate by increasing ground-water pumpage in the area.

THE BOUNDARY COMPONENT OF HEAD

The boundary component of head within the Wheatland Flats was determined by use of a conducting-paper analog field plotter, as described by Reed and Bedinger (1961, p. 2425). The aquifer boundaries were simulated on a sheet of semiconducting paper, which was trimmed to represent a model of the aquifer. For this determination, it was assumed that the aquifer is homogeneous and that flow through the aquifer is in a horizontal plane.

The aquifer boundaries on the west, north, and east are represented by Sybille Creek, the Laramie River, and Chugwater Creek, respectively. These are constant-head boundaries and were represented on the analog model by maintaining electric potentials proportional to stream elevations at 24 points along the trace of the streams on the model.

A relatively impermeable boundary occurs on the south side of the area. The boundary is the result of a large increase over a short distance in the clay content of the Arikaree Formation that reduces its permeability. The southern boundary has been idealized as a definite impermeable vertical plane for the purpose of this report. The impermeable boundary is actually somewhat gradational, and certain assumptions were made in determining its trace for the analog model study.

The impermeable boundary was drawn between wells 23–68–20cdd2 and 23–68–18dad. Samples from well 23–68–20cdd2 (samples were examined but not logged by the author) indicated that rocks of the Arikaree Formation contain much clay at this site and that the permeability is extremely low. The well was drilled as an irrigation well, but it yielded only a few gallons of water per minute by bailing. Samples and the electric log (fig. 4) of well 23–68–18dad indicate that the rocks are somewhat more permeable here than at well 23–68–20cdd2. The trace of the boundary was drawn just south of well 23–68–15ddd because the samples and electric log for this well show that rocks of the Arikaree Formation contain much clay and silt at this site, which in turn indicate low permeability. The boundary was arbitrarily extended from its trace, as located by the well data, to intersect the major streams.

The boundary component of head was determined by establishing potentials proportional to altitudes at selected control points along the major streams and drawing contours of potential on the model proportional to altitudes for which piezometric contours were desired. When the contours were determined, they were traced from the model on a base map.

ACCRETION COMPONENT OF HEAD

The accretion component of head is determined by the ratio of the rate of accretion to the transmissibility and by the areal geometric shape of the aquifer and the nature of the hydrologic boundaries. The accretion component of head is equal to the observed head, or piezometric surface, minus the boundary component of head. The map (pl. 6) showing the accretion component of head for the area was prepared by laying the piezometric-surface map (pl. 5) over the map showing the boundary component of head and connecting contour intersections denoting equal differences in elevation between the two surfaces.

The very steep slope of the accretion component of head in the southernmost part of the area probably is caused by the lower transmissibility of the Arikaree Formation in that area.

The contour of the accretion component of head is very steep in the northernmost part of the area near the Laramie River. Some of the best wells in the Wheatland Flats are in this area. The Arikaree Formation is at least as permeable here as anywhere in the Flats, and the steepness of slope may be caused by a higher accretion rate or a higher transmissibility for the aquifer near the Laramie River than elsewhere in the area. Furthermore, water levels in wells near the river may represent piezometric levels for a zone that is stratigraphically higher than the zone hydraulically connected with the river and that would therefore be higher in altitude than the piezometric surface in the formation at river level.

The analog analysis of the components of head assumes that the transmissibility is constant over the entire area. The low transmissibility in the southern part of the area and the high transmissibility in the northern part probably do not cause too great an error in the analog result over most of the Wheatland Flats, however, because the areas of anomalous transmissibility are small and are near aquifer boundaries.

DIFFERENCE IN HEAD

Because of the decline in head with depth, the piezometric surface in the Arikaree Formation lies below the water table in most of the area. The difference in head between these two surfaces was determined (pl. 7) by laying the water-table map over the piezometric-surface map and connecting contour intersections of equal difference in altitude. The difference in head between the two surfaces ranges from 0 to 20 feet in much of the area and from 0 to 40 feet in most of the area. The difference in head between the two surfaces is more than 40 feet near the major streams and probably more than 40 feet in some places of perched water in the terrace deposits. In three areas the water table is below the piezometric surface and flow upward from the Arikaree Formation to the terrace deposits is thus indicated.

WATER-LEVEL FLUCTUATIONS

Water levels do not remain stationary but fluctuate in response to changes in storage in the ground-water reservoir in much the same manner as the water level in a surface reservoir varies with changes in storage. However, the water level in a ground-water reservoir does not rise or decline uniformly with a change in storage, and changes in the water level of one well do not necessarily reflect changes throughout the ground-water reservoir. To determine quantitative changes in ground-water storage, it is therefore necessary to make periodic measurements in a network of observation wells throughout the area.

Periodic water-level measurements have been made in the Wheatland Flats since August 1948, when Littleton (1950, p. 22) started observations in 25 wells tapping the terrace deposits and in 5 wells tapping the Arikaree Formation. In July 1949, the number of wells measured was reduced to 9 in the terrace deposits and 1 in the Arikaree Formation. In May 1958, the network was expanded to 31 wells tapping the terrace deposits and 22 tapping the Arikaree Formation. In 1958–59, the Bureau of Reclamation installed 55 additional wells, each 5 feet deep, in areas where the water table was near the surface. Water levels in these wells were measured periodically from the fall of 1958 to October 1960.

FLUCTUATIONS OF THE WATER TABLE

In the Wheatland Flats area, the water table rises sharply during the irrigation season (May–September) when much more water is being added to the ground-water reservoir from surface-water applications than is being discharged by evapotranspiration and to streams, drains, and wells. After the irrigation season, the water table declines slowly, as water drains from the ground-water reservoir to streams, drains, and springs. The declines in water levels generally slow or halt in April or May, as recharge from precipitation increases owing to snowmelt and increased rainfall. Hydrographs of water levels in two wells tapping the terrace deposits and graphs of the volumes of surface water applied for the period 1949–60 (fig. 5) show the correlation between the rise in the water table and the surface-water applications during the irrigation season. Quantitative determinations of the change in storage, as determined by changes in the water table, are discussed in a separate section.

FLUCTUATIONS OF THE PIEZOMETRIC SURFACE

Water levels have been observed at monthly intervals from July 1958 to August 1961 in 22 deep wells tapping the Arikaree Formation. Hydrographs of eight of these wells are shown in figure 6. The water levels fluctuate seasonally; they generally reach their seasonal highs in November or December, and decline to their seasonal lows in August or September. Part of the fluctuation is caused by changes in the rate of recharge to the Arikaree Formation, which occurs when the water table in the terrace deposits rises or falls. Recharge to the

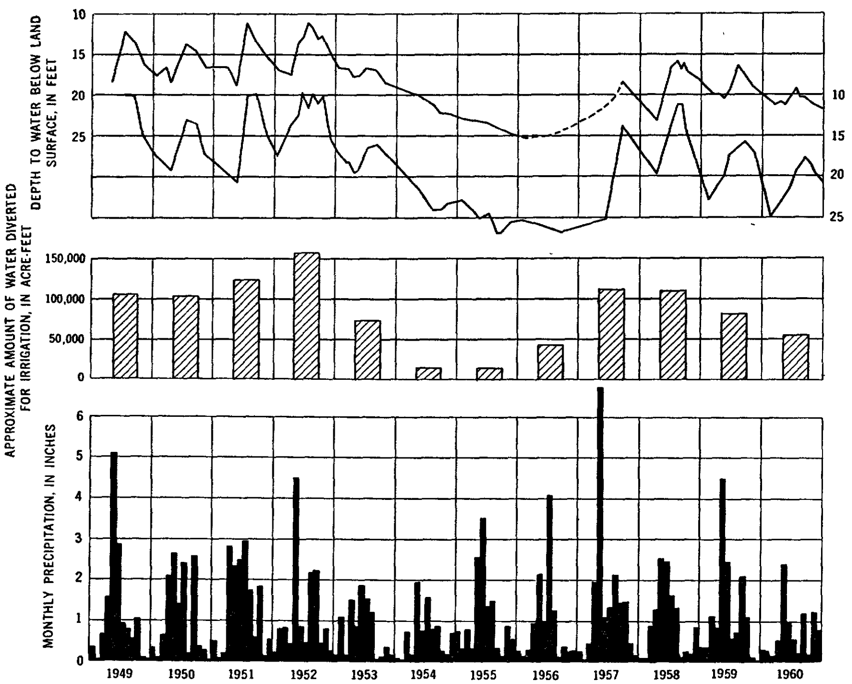

FIGURE 5.—Graphs showing fluctuations of water levels in two wells tapping the terrace deposits in the Wheatland Flats, monthly precipitation at Wheatland, and the amount of surface water applied annually for irrigation.

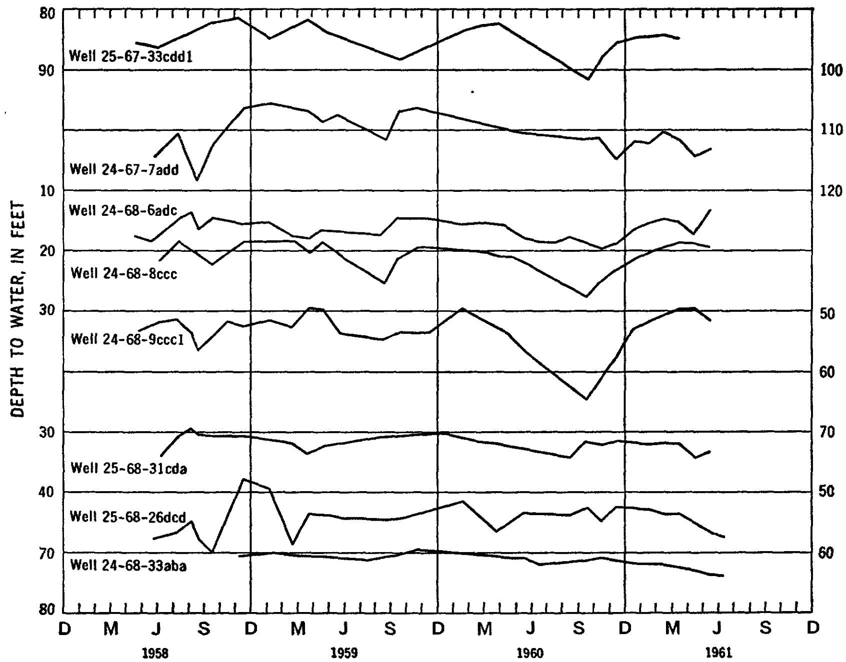

FIGURE 6.—Hydrographs of eight wells tapping the Arikaree Formation at depth in the Wheatland Flats area.

lower strata increases with an increase in the difference in head between the piezometric level of water in those strata and the water table. However, there is a lag of several months between the time the water table reaches its highest level and the time the piezometric surface achieves its peak. The water levels decline sharply in July, August, and September, in response to heavy pumping for irrigation.

The water levels have declined since 1958 in much of the area. The declines reflect the reduced recharge caused by diminishing surface-water supplies for irrigation (fig. 5) each year from 1958 to 1961 and the increased discharge from expanded ground-water pumpage (table 7) from the Arikaree Formation. However, water levels in wells in the northwest corner of the area (secs. 5, 6, 8, and 9 T. 24 N., R. 68 W., and sec. 31, T. 25 N., R. 68 W.) have remained about steady on a yearly basis, although they have shown considerable seasonal fluctuations. Possibly there is less resistance to downward movement of water in this area than elsewhere on the Wheatland Flats, which allows the water level in these wells to recover more quickly after the pumping season than that in wells in other parts of the area.

Water levels have been measured periodically since August 1948 in one well (25–67–27ccc) tapping the Arikaree Formation (fig. 7). The

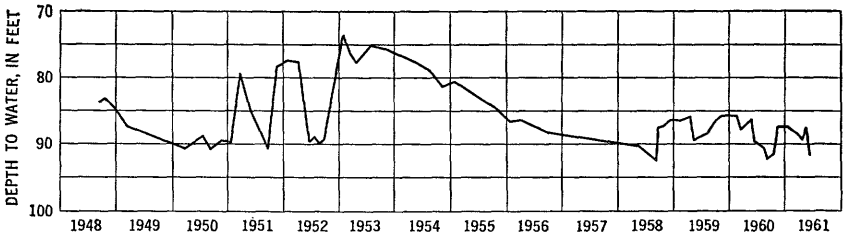

FIGURE 7.—Hydrograph of well 25-67-27ccc showing fluctuations in the water level between August 1948 and June 1961.

hydrograph for this well shows an erratic pattern of fluctuations quite different from those shown by hydrographs of other wells in the area. The water level in the well sometimes has risen or fallen 10 to 12 feet in a period of 3 to 4 months, for no apparent reason. The well is not in an irrigated area, and there are no other wells nearby.

Erratic fluctuations have been observed in two other Arikaree wells in which water levels have been measured since July 1958. The water level in well 25–68–26dcd rose 12.2 feet between October and December 1958. It subsequently declined 11.0 feet between December 1958 and March 1959 and thereafter resumed a pattern similar to that shown by levels in other wells in the area. This well is an irrigation well drilled to a depth of 636 feet and cased to a depth of 140 feet. The level in observation well 6A800 (fig. 4) also showed an erratic rise of 7.3 feet from November 16 to November 19, 1959, the last 3 days of a 56-day drawdown test on well 23–68–4abc, 800 feet away. The level in the well previously had drawn down 3.4 feet in response to the pumping in well 23–68–4abc; therefore, the level rose to a point 3.9 feet above its altitude at the start of the test. The level declined slowly after this, and by February 15 it had declined nearly to the level measured before the start of the aquifer test in September 1959. Since that date and through 1961, it has shown a normal pattern of fluctuation.

CHANGES IN GROUND-WATER STORAGE

Changes in ground-water storage are closely related to recharge and discharge to and from the aquifer; before estimates of recharge and discharge could be made, it was necessary to determine these changes quantitatively. This was done by multiplying the change in saturated volume for each period between observation-well measurements by the specific yield of the aquifer.

Changes in the volume of saturated material within the aquifer were calculated by using the Theissen mean method (Theissen, 1911, p. 1,082). This method involves constructing a polygon around each well in which water levels are observed periodically and assuming that the change in water level in the well is the change in water level throughout the area of the polygon. Change in saturated volume is computed by multiplying the change in water level by the area of each polygon, as determined by a planimeter. Figure 8 shows the polygon network for the observation wells used in this determination.

The specific yield of the ground-water reservoir was computed by dividing the change in saturated volume into 100 times the total discharge, both units being stated in cubic feet. Estimates of ground-water discharge were made from stream measurements of February 1959. Most of the discharge from the ground-water reservoir for this period was to the streams—because evapotranspiration losses are small in the winter and very little ground water was being pumped.

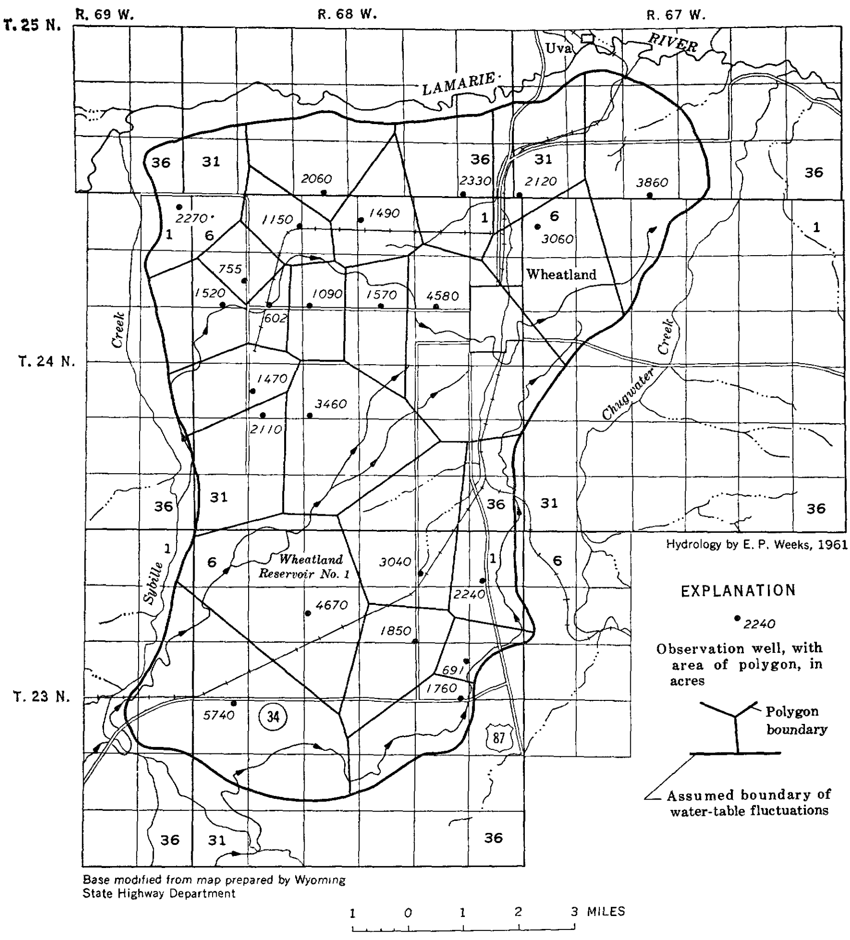

FIGURE 8.—Map of the Wheatland Flats area, Platte County, Wyo., showing polygons used for determining changes in ground-water storage.

Streamflow measurements listed in table 3 were made February 26–27 at seven stations on the streams, and these data were used with streamflow data gathered at permanent Geological Survey gaging stations on Sybille Creek at Muleshoe Ranch (24–69–23ccc), on the North Laramie River 15 miles northwest of Wheatland, and on the Laramie River 7½ miles east of Uva, Wyo., to determine the total gain in streamflow from ground water discharged from the Wheatland Flats. It was assumed for this determination that gains in underflow in the alluvium of the Laramie River due to its thickening and widening in the downstream direction nearly balance the volume of water added to the streams from the aquifer bordering the streams opposite the Wheatland Flats and that no appreciable gains in flow occurred in the reach of the North Laramie River between the gaging station and its confluence with the Laramie River. It also was assumed that gains in streamflow in the reach of Sybille Creek bordering the Wheatland Flats above the gaging station in the NE¼ sec. 23, T. 24 N., R. 69 W., and the reach of Chugwater Creek bordering the Wheatland Flats above the upper flow section in sec. 21, T. 24 N., R. 67 W., nearly equaled gains in streamflow in the reach of the Laramie River between its confluence with Chugwater Creek and the gaging station below Uva.

The last assumption in the preceding paragraph was made because the areas within the Wheatland Flats drained by those reaches of

TABLE 3.—*Streamflow measurements made on February 25–26, 1959, at various sites on Chugwater Creek, Sybille Creek, and Laramie River*

[Measurements made by author, except as otherwise indicated]

Stream	Location	Discharge (cfs)	Remarks
Chugwater	24–67–21abb	24. 3 (inflow)	
	10bbc	37. 4	
	25–67–35bcc	40. 2	
	23ddc	42. 7	Near confluence with Laramie River.
Sybille	24–69–23ccc	[1] 11 (inflow)	Gaging station 6666.
	25–69–35abb	16. 7	Near confluence with Laramie River.
N. Laramie	25–70–2d	[1] 10 (inflow)	Gaging station 6675.
Laramie	25–69–26dcc	12. 8 (inflow)	Near confluence with Sybille Creek.
	25–68–26bbc	25. 8	
	25bba	30. 6	
	25–67–19dcc	31. 8	
	25–66–16bc	[1] 100 (outflow).	Gaging station 6700.
Net gain [2]		41. 9	

[1] Daily mean discharge from records of U.S. Geological Survey.
[2] Net gain equals outflow minus sum of inflows at designated stations. Other stations measure gains along intermediate reaches of the stream system. Location of measuring sites are shown on plate 5.

Sybille and Chugwater Creeks are fairly small, and much of the seepage feeding the Laramie River below its confluence with Chugwater Creek probably is derived from ground water recharged in the Wheatland Flats. Because the lenticularity of the formation restricts vertical movement of water through the formation, some ground water probably moves horizontally through the formation downstream for some distance before being discharged.

The stream measurements indicate that during the latter part of February 1959 the major streams were gaining about 40 cfs (cubic feet per second) or about 80 acre-feet per day released from storage from the ground-water reservoir in the Wheatland Flats area. Gross changes in ground-water storage during this period, as calculated from water-level data by the Theissen mean method, amounted to about 670 acre-feet a day. The average specific yield for the materials lying within that range of water-table fluctuations was computed to be about 12 percent. The specific yield will vary for different intervals of fluctuation because of differences in the water-bearing properties of the materials lying at different depths within the aquifer, but the value of 12 percent probably represents a fairly accurate average for the aquifer as a whole. The value represents an average for all the different materials lying within that zone of fluctuation, including sandstone of the Arikaree Formation and the gravel, silt, and clay of the terrace deposits.

Total storage within the ground-water reservoir above the boundary component of head was computed by determining storage between the piezometric surface and the boundary component of head and between the piezometric surface and the water table, and adding the two values. Storage beneath the level of the piezometric surface (fig. 4) and above the level of the boundary component of head within the aquifer was computed by multiplying the average value for the accretion component of head for the piezometric surface (pl. 6) by the areas of the flats and the specific yield of 12 percent. Storage between the piezometric surface and the water table was computed by multiplying the planimetered areas between contour lines on the head-difference map (pl. 7) by the mid-values between each pair of contours and by the value for specific yield. Total storage above the boundary component of head was computed to be about 880,000 acre-feet for December 1959-January 1960, the interval during which data used in preparing the water-table and piezometirc maps were collected. Storage for each of the other months in which water levels were measured was then computed by algebraically adding changes in storage over the periods between measurements.

Figure 9 shows changes in ground-water storage for the period October 1958 to February 1961.

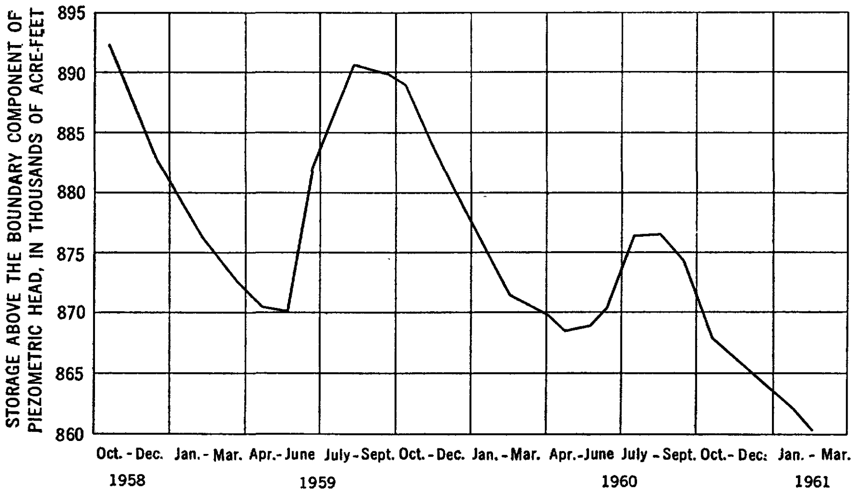

FIGURE 9.—Changes in storage in the ground-water reservoir from October 1958 to February 1961, as determined from water-level fluctuations.

RECHARGE

In the Wheatland Flats area, almost all the recharge to the ground-water reservoir is derived from precipitation, from seepage losses in irrigation canals and ditches, and from water applied for irrigation. Little water is contributed by underflow. The amount and rate of recharge to the ground-water reservoir governs the amount of ground water available for development; therefore quantitative estimates of recharge were made.

Recharge from water applied for irrigation.—Estimates of the recharge rate were made from the sum of the daily change in storage, the daily discharge rate to the major streams, the total pumpage from the terrace deposits, and one-half the pumpage from the Arikaree Formation divided by the sum of surface applications and total well discharge, in acre-feet per day. Discharge to the streams was determined by methods discussed on pages 29 to 34 and the total ground-water pumpage was determined by a pumpage inventory discussed on pages 50 to 60. The pumpage from the Arikaree Formation was adjusted because some of the water pumped is diverted from water that otherwise would reach the major streams, and the pumpage diminishes the streamflow somewhat. Adding all the estimated discharge to streams and all the pumpage probably would cause part of the discharge to be included twice. Table 4 gives the results of the recharge determinations for the summers of 1959 and 1960. Percentage values of recharge from surface water applications were adjusted for rainfall by averaging the recharge values for months in which little rainfall occurred and assigning that value to the rainy

TABLE 4.—*Results of recharge study made in the area for 1959 and 1960*

Time interval	Discharge to streams (acre-ft per day) estimated from graph	Change in storage (acre-ft per day)	Pump discharge (acre-ft per day)	Recharge (acre-ft per day)	Surface water applications (acre-ft per day)	Percentage of surface water appearing as recharge: Unadjusted for rainfall	Percentage of surface water appearing as recharge: Adjusted for rainfall	Recharge from rainfall (estimate)	Remarks
1959									
Apr. 23–May 22	69	−9	2	62	132	47	47	--------	
May 22–June 23	91	+350	8	449	772	58	48	2,500	Heavy rainfall.
June 23–Aug. 10	161	+180	21	362	736	49	49	--------	
Aug. 10–Sept. 17	204	−14	30	220	470	47	47	--------	
Average	--------	--------	--------	273	528	52	48	--------	
1960									
May	65	+18	12	95	110	86	38	1,600	Heavy rainfall.
June	65	+64	23	152	424	36	36	--------	
July	80	+180	50	310	788	39	39	--------	
Aug	95	+9	53	160	413	39	39	--------	
Sept	91	−79	30	43	67	61	38	480	Some rain.
Average	--------	--------	--------	163	360	45	38	--------	

months. Quantities of recharge from rainfall were then computed from the difference between the adjusted and unadjusted figures.

The computed recharge rate was higher for 1959 than for 1960. This difference was due, in part, to differences in the distribution of precipitation in the 2 years. Much rain fell in the summer of 1959, and it was fairly evenly distributed over the irrigation season. Some of the precipitation probably was not included in the estimates of recharge from surface-water applications, except for that in June, which was greater than for the other months. In 1960 there was little precipitation, and much of it occurred as intense storms. Therefore, most of the recharge by precipitation could be adjusted from the figures for the rate of recharge from surface-water applications for the 1960 irrigation season, and these figures probably are more accurate than those for 1959.

The recharge rate from surface-water applications for 1960 also was smaller, in part, because of changes in irrigation practices in the 2 years. In 1959, farmers were apportioned water by a rate of delivery; that is, they could draw water at a certain rate at any time water was available in their canals or laterals. This apportionment system led to heavy irrigation and to some wasteful irrigation practices. In 1960 the delivery system was changed, and water was apportioned on a volume basis. Each farmer was credited with a volume of water at the beginning of the irrigation season, and when this volume was exhausted he could receive no more. This system led to better

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irrigation practices, and much less water was wastefully applied. Consequently, a smaller percentage of the applied water reached the ground-water reservoir during the 1960 irrigation season, and a larger percentage was used by crops. The irrigation efficiencies achieved in 1960 probably will continue as long as the volume-delivery system remains in effect.

Estimates of the recharge rate may be somewhat in error because of inaccuracies in estimating discharge to the streams, as discussed under that section. Discharge to streams, however, is a small part of the total recharge in many months, and a relatively large error in the estimate of discharge to streams will produce only a small error in the estimate of the recharge rate.

Recharge from precipitation.—The major factors governing the volume of water reaching the water table from precipitation are the physical properties of the soil and subsoil, the moisture content and cultivation of the soil, the depth to the water table, and the amount, distribution, and intensity of precipitation. In the Wheatland Flats area, most of the recharge from precipitation is from snowmelt in March and April and from heavy rainfall in May and June. Recharge from precipitation was estimated for March and April 1960 by computing the difference between changes in storage and the discharge rate obtained from the graph on figure 10. This difference was about 2,000 acre-feet for the 2 months.

June 1959 and May and September 1960 were months of intense rainfall, and the recharge rates for these months are much higher than for the other months during the irrigation season, if all the recharge is assumed to occur from surface-water applications. Recharge from precipitation was computed for the 3 months by assuming that the percentage rate of recharge from surface-water applications for these months equaled the average rate determined for the other months and attributing the difference to recharge by precipitation. The computed recharge from precipitation was 2,500 acre-feet in June 1959, 1,600 acre-feet in May 1960, and 480 acre-feet in September 1960.

Morris and Babcock (1960, p. 64–65) assumed from data collected in areas adjoining Platte County that about 5 percent of the precipitation contributed recharge to the ground-water reservoir in Platte County and that about 3,800 acre-feet of water was contributed annually during normal years from precipitation in the Wheatland Flats. This figure is about the same as the results obtained above.

Total recharge.—Total recharge varies from year to year, depending on the amount and distribution of rainfall and on surface-water supplies for irrigation. Total recharge was estimated to be about 55,000 acre-feet in 1959 and 25,000 acre-feet in 1960. These estimates probably are low because they do not include recharge from precipitation during the fall and winter; the quantity of recharge during this time, however, probably is small.

DISCHARGE

Ground water from the Wheatland Flats area is discharged to the major streams by seepage from the Arikaree Formation to the valley alluvium, which in turn feeds water to the stream, and by the flow of the small streams, drains, and springs that tap the terrace deposits. Some ground water probably moves northward out of the area through that part of the Arikaree Formation lying beneath the Laramie River. However, the fact that the piezometric gradient in the Arikaree Formation north of the Laramie River, as shown by Morris and Babcock (1960, pl. 1), is small compared to piezometric gradients observed in the Arikaree Formation in the Wheatland Flats area indicates that underflow in this direction is small. Ground water also is discharged to wells in the area, and some ground water is discharged to the atmosphere by evapotranspiration. Estimates of the quantities of ground-water discharge to streams and to wells were made, as was an estimate of total evapotranspiration including losses both from ground water and from soil moisture.

DISCHARGE TO STREAMS

Seepage from the Arikaree Formation.—Seepage from the Arikaree Formation through the valley alluvium to Chugwater Creek, Sybille Creek, and the Laramie River (pl. 1) contributes much of the gain in flow in these streams where they border the Wheatland Flats. A seepage run was made on February 26–27, 1959 (table 3), to determine the volume of discharge from this source. The run was made in reaches of Sybille Creek, the Laramie River, and Chugwater Creek (pl. 5), but it did not include the entire reach of these streams bordering the Wheatland Flats. Results of the run were expanded to include seepage from the aquifer underlying the entire area of the Wheatland Flats by a flow-net analysis. Flowlines were drawn on the piezometric-surface map (pl. 5) through the measuring stations on the streams. The gain in streamflow across each reach of stream between a pair of flowlines, taken from table 3, was divided by the planimetered area between the flowlines to compute flow contributions to the streams per square mile of aquifer.

Values for the flow contribution per square mile of aquifer for the different reaches of stream differ greatly, from a negative value for the reach on the Laramie River between its confluence with Sybille Creek and station 25–68–26bbc to a very high value for the reach on Chugwater Creek between stations 24–67–21abb and 24–67–10bbc. The wide range in these values is probably caused by changes in the width, depth, and permeability of the alluvium of Sybille Creek, the

Laramie River, and Chugwater Creek. The alluvium in 25–68–26bbc on the Laramie River is about twice as deep and twice as wide as the alluvium on the Laramie River just below its confluence with Sybille Creek. No data were available on changes in thickness of the alluvium along Chugwater Creek, but the large increase in flow along the reach between stations 24–67–21abb and 24–67–10bbc probably is a result of a decrease in the permeability of the alluvium along that reach.

Gains in flow in each reach do not accurately represent discharge by seepage from the Arikaree Formation because of the changes in the ability of the valley alluvium to transmit water between the individual reaches. However, the changes balance out somewhat over the full lengths of streams measured, and the average figure determined for all the reaches probably represents discharge from seepage fairly accurately.

Some seepage comes from the Arikaree Formation in areas outside the Wheatland Flats. Contributions to streamflow from this source are small, however, and they have not been considered in making the computations.

The average flow contribution per square mile of aquifer surface multiplied by the total area of the Wheatland Flats gives a figure of seepage to the streams of about 39 cfs or about 28,000 acre-feet per year. This is almost as large a figure as the 40 cfs determined for the total discharge of the ground-water reservoir during that period. (See p. 22 to 26.) However, the reach of Sybille Creek above the gaging station (24–69–23ccc) and the reach of Chugwater Creek above the uppermost flow section (pl. 5) drain the southernmost part of the area where the rocks of the Arikaree Formation are much less permeable because of their higher clay content. The formation here probably contributes much less water per square mile of aquifer surface than it does farther north. If this part of the area is excluded from the determination, seepage to the streams is about 32 cfs, or about 23,000 acre-feet per year. The difference of about 8 cfs is discharge from minor streams, artificial drains, and springs to the major streams at the time of the seepage run. This figure probably is approximately correct.

Discharge from seepage was determined from data gathered at only one time (February 1959). However, the small fluctuations of the piezometric surface (fig. 6) indicate that this discharge probably does not vary much seasonally and that the daily discharge figure might be projected over the entire year without introducing too much error.

Although several sources of error exist in the above determination, the figures probably are sufficiently accurate to be used in making a quantitative analysis of the ground-water hydrology of the area.

Flow from small streams, springs, seeps, and artificial drains.—A stream-drainage system including Rock Creek, Ayers Draw, and Wheatland Creek has developed on the terrace deposits (fig. 4). These streams derive most of their flow from seepage from the terrace deposits, and, according to residents, the streams have had perennial flow only since irrigation was begun in the area. Festo Lake, which is fed by ground water, also contributes flow to these streams. The flow of Wheatland Creek, which carries the water to the Laramie River, is a few cubic feet per second during most of the year. However, the flow is much less during the irrigation season, when water is diverted from the stream for irrigation.

Springs discharge at the outcrop of the contact of the terrace deposits with the Arikaree Formation along the cliffs above the major streams at a few places. These springs are small, and many of them flow only during periods when the ground-water reservoir is being heavily recharged by greater than normal surface applications. Springs are of minor importance as discharge agents and probably do not discharge more than a few hundred acre-feet a year.

In several places on the Wheatland Flats—topographic lows, slight topographic slopes, and in areas where the terrace deposits are thin or absent—the water table is at or near the land surface and forms seeps or waterlogged soil. The seeps generally are drained into the small streams by natural or artificial open channels. In some areas where the water table is sufficiently close to the surface to hinder cultivation, subsurface tile drains have been constructed. The largest of these drains, constructed about 1931, runs through secs. 8, 17, and 20, T. 24 N., R. 68 W. (fig. 5). These drains remove from 1 to 2 cfs of water from the terrace deposits and carry it in an open drain ditch to a small pond in 24–69–1cdd, where most of the water seeps down to Sybille Creek or is lost by evapotranspiration. Pumps have been installed to tap these tile drains for irrigation water at five sites, and at times during the summer the pumps intercept most of the discharge of the drains. Several smaller subsurface drains have been constructed in Wheatland Flats and are shown on plate 3. Most of these drains are limited to one farm and discharge to the natural drains in the area (Wheatland Creek and its tributaries). Total discharge from the drains probably is small, and most of it appears in the flow of Wheatland Creek.

Total ground-water discharge to the major streams.—Total ground-water discharge was computed from change-in-storage data because streamflow data available for the area were inadequate to measure the ground-water discharge directly. In using the change-in-storage data, it was assumed that during the winter changes in ground-water storage reflect and equal discharge to streams.

The assumption that changes in storage computed from water-level declines in wells some distance from the drains should reflect and represent discharge to the streams was checked by calculation, because some lag might occur between the time recharge ceased and the time the water levels should decline in response to discharge to natural and artificial drains in the area. The check was made by calculating the water-level decline along the center of an infinite strip of an ideal aquifer bounded by parallel drains 6 miles apart, a distance that represents about the widest separation of natural drains in the area. The coefficient of transmissibility for the ideal aquifer was assumed to be 50,000 gpd (gallons per day) per ft, or 7,000 sq ft per day, which is near the average value determined for the terrace deposits. (See p. 36 to 50.) The water-level declines along the center of this strip were computed to be 0.5 foot and 7 feet 30 days and 180 days respectively, after recharge stopped, assuming that discharge was at the uniform rate of 4×10^{-3} feet per day before it instantaneously ceased. The computations were made with the aid of an equation formulated by Jacob (1943, p. 566–67).

Water-level declines during the entire winter, in most of the observation wells used in computing changes in ground-water storage, ranged from about 5 to 10 feet. These declines agree well with those computed for the ideal aquifer and indicate that the assumption that changes in water levels during the winter reflect stream discharge probably is valid. The assumption that changes in ground-water storage equal discharge to the streams during the winter probably is also valid and fairly accurate, because during this period little recharge takes place and discharge by evapotranspiration and to wells is small.

During the summer much water is recharged to the ground-water reservoir from water applied for irrigation, and the discharge cannot be computed directly from change-in-storage data. The discharge during the summer was estimated indirectly from ground-water storage data by assuming that discharge is proportional to the volume of water in storage above the boundary component of head in the aquifer. (See p. 22 to 26.) A graph showing the assumed relationship was prepared by plotting the ground-water discharge calculated from change-in-storage data for the winter on a logarithmic scale against ground-water storage above the boundary component of head on an arithmetic scale and then drawing the straight line that most nearly describes the data (fig. 10). The lower part of the graph is shown as becoming steeper, because the discharge rate probably is much less affected by small changes in storage when the water table

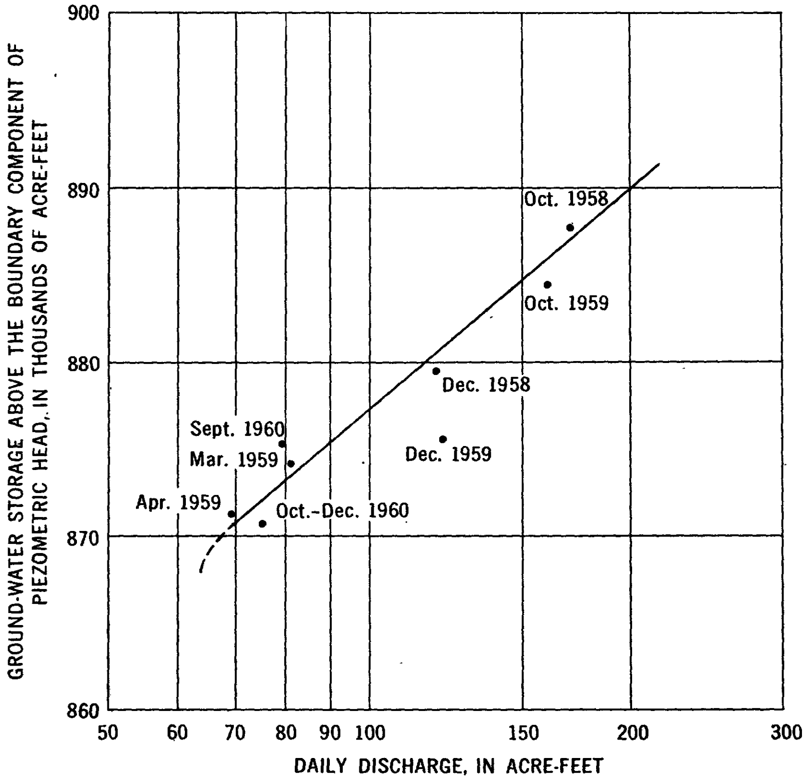


FIGURE 10.—Graph used in estimating discharge to the streams, drains, and springs from computed values of ground-water storage. Circled points represent storage and discharge rates computed from changes in storage for months of little recharge.

declines to a level below which discharge to the minor streams, drains, and springs is small.

Estimates of the discharge rate to streams and drains during the summer were then made by computing the average storage for each period between measurements and selecting the discharge rate corresponding to that volume of storage from the graph (fig. 10). These estimates probably are somewhat low, because hydrologic conditions for the periods when data were gathered to prepare the graph were those of no ground-water recharge and of water-level decline, while during the irrigation season recharge is occurring and water levels are being built up in the area. Because of these different conditions, discharge to streams in the winter is smaller for water levels of a given height than during the irrigation season.

Differences in the rates of discharge for the two sets of conditions were calculated for an ideal aquifer bounded by parallel streams of infinite length located 6 miles apart. The aquifer was assumed to have a coefficient of transmissibility of 50,000 gpd per ft. and a specific yield of 12 percent. The discharge rate for conditions of recharge and water-level buildup was computed to be about 20 percent higher than for conditions of no recharge for any given water level altitude at the center of the area.

Hydrologic conditions during the irrigation season also are altered from those during the winter by changes in the evapotranspiration rate between the two periods. Because of the high evapotranspiration rate during the irrigation season, some of the water that would be discharged to the major streams during the winter is lost to the atmosphere. This causes the discharge rate to be lower during the summer than during the winter and tends to reduce the effects of differences between conditions of recharge and water-level buildup and those of no recharge and water-level decay. No correction has been made for either of these effects in computing ground-water discharge to the streams.

The total discharge to the streams varies from year to year, depending on the amount of surface water applied, the amount of precipitation in the area, and losses to evapotranspiration and changes in storage during the year. Discharge to streams was computed to be about 50,000 acre-feet in 1959 and about 30,000 acre-feet in 1960. Much more surface water was available and rainfall was more plentiful in 1959 than in 1960. Discharge data for individual months during the winter are shown in figure 10, and discharge data for individual months during the summer are shown in table 4.

DISCHARGE TO WELLS

Ground water is discharged to numerous wells drilled to obtain water for irrigation, domestic and stock, and municipal use. The quantity of water pumped from these wells was 3,960 acre-feet in 1959 and about 7,750 acre-feet in 1960. Results of the pumpage inventory are discussed in detail under the section on present ground-water development.

EVAPOTRANSPIRATION

In the Wheatland Flats area, water is discharged to the atmosphere by evaporation from man-made and natural surface-water bodies, from soil moisture and ground water, and by transpiration through plants. The recharge study based on changes in ground-water storage indicates that 60 to 65 percent of the surface water applied and 90 to 95 percent of the precipitation in the area is discharged to the atmosphere by evapotranspiration. The estimate of 60 to 65 percent for the consumptive use of surface water may be too small, because the computed ground-water discharge for the summer used in making estimates of recharge includes some water discharged by evapotranspiration. Discharge by direct runoff from precipitation and surface wastage from irrigation has been included in the estimates of evapotranspiration losses. Only a small error is introduced in this manner, however, because the discharge is small. Significant quantities of water are discharged by evapotranspiration from the ground-water reservoir in areas where the water table lies within about 10 feet of the surface. The amounts discharged vary inversely with the depth to water. Plate 8 is a map showing the depth to the water table, areas of high evapotranspiration from the water table (areas in which the water table is less than 5 feet), and areas of moderate evapotranspiration from the water table (areas in which the water table is from 5 to 10 feet below land surface).

Most of the water discharged to the atmosphere in the Wheatland Flats is transpired by crops and decorative trees and, thus, is beneficially used. The principal nonbeneficial consumptive use is transpiration by hydrophytes growing in the seepage areas and along the natural and manmade drains. These hydrophytes—cattails, watercress, reeds, and certain grasses—grow profusely in water-logged areas. These plants are of little economic importance, but they consume large quantities of water. Mower and Nace (1957, p. 21) quote figures determined in tank and lysimeter experiments at Fort Collins, Colo., by Young and Blaney (1942) for the consumptive use by rushes of 4.4 feet of water annually. They also quote figures from tank and lysimeter experiments by Criddle and Marr (1945) on cattail at Bonner's Ferry, Idaho and on a thick growth of rushes and cattail at Grays Lake, Idaho. In each of these experiments, 5.1 feet of water was consumed annually by the plants. Less significant is the discharge by nondesirable phreatophytes, of which cottonwood is the most important. Water is lost directly to the atmosphere by evaporation from seeps, open drains, and ponds, and from areas where the water table lies near the surface.

The Bureau of Reclamation made estimates of the nonbeneficial consumptive use in the area by using the results of a detailed land classification made in 1958–60 and figures for consumptive use by hydrophytes determined in other areas. Their figures indicate that nonbeneficial consumptive use amounts to about 2,500 acre-feet annually (Robert Cross, oral communication, 1961).

Much of this water could be salvaged by lowering the water table in the terrace deposits, because the hydrophytes grow only in seepage areas or along natural and artificial drains. Some evaporation losses from the water table could be diminished by lowering the water table in areas where it lies within 10 feet of the surface. However, lowering the water table in these areas might decrease the irrigation efficiency, because the crops use some ground water where the water table is near the surface, and larger surface-water applications would be required.

HYDRAULIC PROPERTIES OF FORMATIONS COMPOSING THE GROUND-WATER RESERVOIR

The ability of an aquifer to yield water to a well or to transmit water under a pressure gradient depends on certain hydraulic properties of its constituent materials. The principal hydraulic properties of aquifers are expressed mathematically as the specific yield, the coefficient of storage, and the coefficients of permeability and transmissibility.

The specific yield of an aquifer is defined as the volume percentage of water that will drain by gravity from saturated sediments. In unconfined aquifers it is nearly equal to the coefficient of storage. The coefficient of storage (*S*) of an aquifer is the volume of water released from or taken into storage per unit surface area of the aquifer per unit of change in the component of head normal to that surface.

The coefficient of permeability (*P*) is defined as the number of gallons of water a day that can be transmitted by a strip of aquifer 1 foot high and 1 foot wide, under a hydraulic gradient of 1 foot per foot, and is expressed as gallons per day per square foot. The coefficient of permeability is dependent on the size and shape of the pore spaces, their interconnection, and the nature of the material making up the boundaries of the pore spaces.

The coefficient of transmissibility (*T*) is the number of gallons a day at a prevailing water temperature that would be transmitted across a strip 1 foot wide and extending the height of the saturated thickness of the aquifer under a hydraulic gradient of 1 foot per foot. The coefficient of transmissibility is equal to the average coefficient of permeability times the saturated thickness of the aquifer and is expressed in gallons per day per foot.

Several methods, including analysis of data collected during aquifer tests, were used in estimating or computing the hydraulic properties of the aquifers in the area. The aquifer tests were made by observing declines in water levels in pumping wells and in wells in their vicinity (drawdown tests), or by observing the rise in water levels after a well has been shut down (recovery tests). The methods used in analyzing the data collected depended on the geologic and hydrologic setting at the well site. The specific methods used in analysis of aquifer tests are discussed under the sections on the hydraulic properties of the individual aquifers, as are other methods used to obtain the aquifer coefficients.

HYDRAULIC PROPERTIES OF THE TERRACE DEPOSITS

AQUIFER TESTS

Aquifer tests on the terrace deposits were analyzed by the Theis nonequilibrium method, or the Theis recovery method (Theis, 1935, p. 519–524), by using the procedure described by Wenzel (1942, p. 87–91 and p. 95–96).

Aquifer tests at wells 24–68–16add, 24–68–18acc, and 25–67–31ccc2 were made by Morris and Babcock (1960, p. 46 and 54) in 1953–55. Data gathered at the three sites were analyzed to yield coefficients of transmissibility of 67,000, 87,000, and 120,000 gpd per ft. and coefficients of permeability of 2,700, 2,600, and 5,100 gpd per sq. ft., respectively. The data could not be analyzed to yield a reliable figure for the coefficient of storage.

SPECIFIC CAPACITIES OF WELLS

The specific capacity of a well is defined as the yield in gallons per minute per foot of drawdown. The specific capacity decreases as the time of pumping increases, but after a time it decreases slowly. Other factors affecting the specific capacity of a well are the permeability, thickness, and storage coefficient of the aquifer at the well site, the presence of hydrologic boundaries such as streams or ponds, large changes in saturated thickness over short distances in the vicinity of the well, and the construction and development of the well.

Specific-capacity figures are useful for comparing the efficiency of construction of different wells and the transmissibility of the aquifer at the different sites. Care should be used in making such comparisons because specific capacity is affected by many variables.

Theis and others (1954, p. 11) prepared a chart for estimating the coefficient of transmissibility from specific-capacity data. This chart was used to determine the coefficients of transmissibility and permeability for the terrace deposits at 12 well sites. Values for these determinations are given in table 5. The estimates of the figures for the coefficient of permeability made from the specific capacities are not very reliable, but they do indicate the magnitude and range of the permeabilities in the terrace deposits. The wide ranges in permeability are due principally to large differences in clay and silt content over short distances.

HYDRAULIC PROPERTIES OF THE ARIKAREE FORMATION

AQUIFER TESTS

The geologic and hydrologic setting for Arikaree wells in which the uppermost part of the formation has been cased off is such that the wells behave as though they tapped a leaky aquifer, and data collected from them were analyzed by the leaky-aquifer method developed by Hantush (1956, p. 702–714) or by the modified leaky-aquifer method developed by Hantush (1960, p. 3713–3725).

TABLE 5.—*Estimates of the coefficient of permeability from specific-capacity data for 12 wells tapping the terrace deposits*

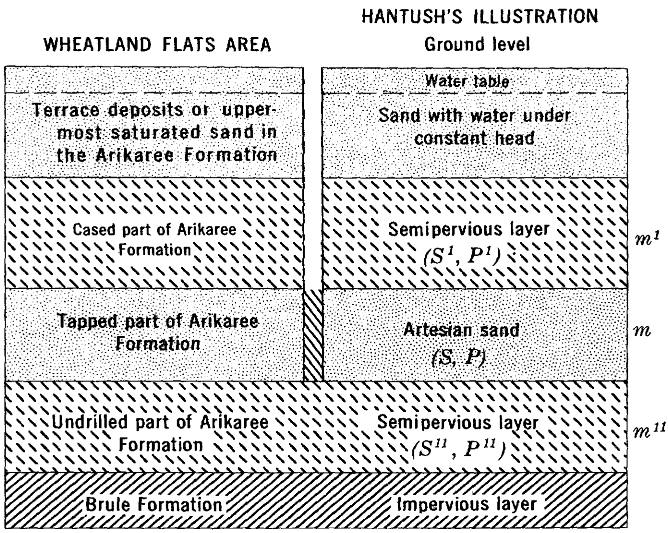
Well	Specific capacity (gpm per ft of drawdown) after number of hours shown in parentheses	Transmissibility (gpd per ft)	Saturated thickness at well site (feet)	Coefficient of permeability (gpd per sq ft)
23-68-1ccd	44 (3)	80,000	20	4,000
24-67-6bcd1	17 (170)	22,000	23	1,000
24-68-2dcc	34 (354)	45,000	19	2,400
3bcb	7 (10)	9,000	18	500
4cbc	13 (50)	20,000	14	1,400
7dcc	8 (5)	13,000	11	1,200
9ccc2	15 (24)	22,000	8	2,500
11cbc	10 (8)	17,000	22	700
11ccc	39 (7)	70,000	27	2,600
15acb	28 (several)	45,000	11	4,000
20ccd1	40 (8)	72,000	13	5,600
33cdd2	22 (5)	36,000	10	3,600

The geohydrologic setting is analogous to that assumed for a leaky aquifer. The lenticularity of the formation causes the vertical permeability to be much less than the horizontal permeability, and the cased-off and undrilled parts of the formation, therefore, act as semiconfining beds to vertical flow. In most of the wells, the zone of saturation just below the water table acts as a sand containing water under constant head, and the underlying Brule Formation acts as an impermeable bed. Figure 11 illustrates the analogy between the stratigraphic setting for wells tapping the Arikaree Formation in the area and two of the leaky-flow systems for which Hantush (1960, p. 3713–3725) derived his modified equations of flow.

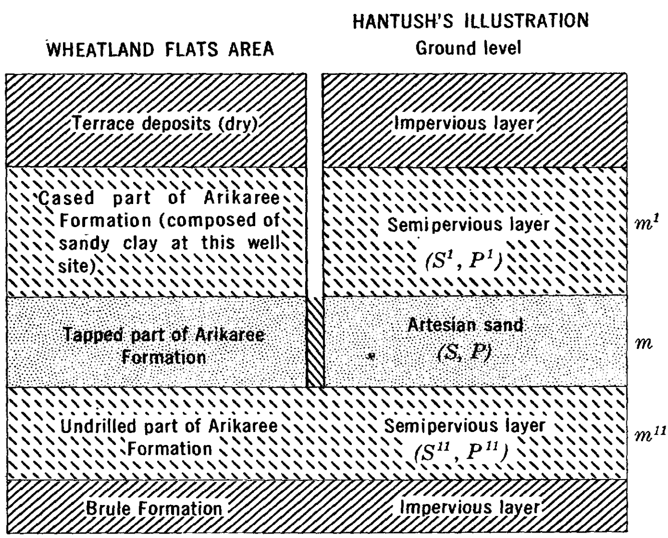
Because of the distribution of impermeable lenses in the Arikaree Formation, observation wells used in the tests yielded data showing variation in characteristics of vertical flow. Data from some wells indicated that part of the water pumped was derived from storage within the semiconfining beds; data from other wells, however, indicated that little or no water was being derived from that source.

Data indicating that water was being derived from storage within the semiconfining beds were analyzed by a method that utilizes the modified theory of leaky aquifers (Hantush, 1960, p. 3713–3725), which was explained to the author by Hantush (written communication, 1961). Data indicating that little or no water was derived from storage were analyzed by a type-curve solution developed by H. H. Cooper (written communication, 1959) from the data for leaky-aquifer equations computed by Hantush (1956, p. 702–714).

Nine aquifer tests were made at the sites of wells tapping the Arikaree Formation. Conditions at seven of the nine well sites were analogous to case 1 of figure 11 and to case 2 of figure 11 for one test site (24–68–34bbc1). Well 24–68–27acc1 was cased with perforated



Case 1. Conditions at most of the wells tested (analogous to case 3, Hantush, 1960, p. 3717).



Case 2. Conditions at well 24-68-34bbc1 (analogous to case 2, Hantush, 960, p. 3717).

FIGURE 11.—Semischematic sketches showing the analogy between the stratigraphic setting for wells tapping the Arikaree Formation in the Wheatland Flats area and two of the flow systems for which Hantush (1960, p. 3713-3725) derived equations of flow.

casing to a point above the level of the water table in the quicksand zone; data from this well were analyzed by the Theis method.

The results of the test are tabulated in table 6, and a brief discussion of each test follows.

The first test was made at well 24–68–12dbc, which was pumped 46 hours at 600 gpm. Discharge was regulated with a gate valve. Drawdown and recovery data were obtained at the pumped well and at observation well 24–68–12dbb2 located 1,050 feet from the pumped well. The observation well did not tap the same part of the formation as the pumped well and the aquifer coefficients derived by analysis of data from the observation well are, therefore, not reliable. Few

TABLE 6.—*Aquifer coefficients for the Arikaree Formation as determined from aquifer tests.*

Test number: Number of test as discussed in the text. Tests number chronologically.
Location of pumped well: See section on well-numbering system.
Location of observation well from pumped well: Location of observation well for which data were obtained, in feet and direction from pumped well (N, north; S, south; E, east; W, west).
Leakance factor (λ): Leakance factor for leaky systems in which some leakage is derived from storage within semiconfining beds.
Leakage factor $\left(\frac{p'}{m'}\right)$: Vertical permeability of the semiconfining bed divided by its thickness.
Assumed thickness of semiconfining bed (m'): Thickness of semiconfining bed assumed to be distance between the contact of the Arikaree Formation and terrace deposits, and open or screened part of well. For observation wells in which the upper part of the Arikaree Formation has been cemented off, m' is assumed to be the distance from cement plug to contact. For wells drilled in areas where terrace deposits are not saturated, m' is assumed to be distance between the approximate level of water table and open hole or screened part of well.
Method of analysis: A, leaky-aquifer method; B, modified leaky-aquifer method; C, Theis nonequilibrium formula method.

Test	Location of pumped well	Location of observation well from pumped well	Coefficient of transmissibility (gpd per ft)	Coefficient of storage ($\times10^{-4}$)	Leakance factor (λ) ($ft^{-1}\times10^{-3}$)	Leakage factor $\left(\frac{p'}{m'}\right)$ (gpd per cu ft $\times10^{-3}$)	Assumed thickness of semiconfining bed m' (feet)	Vertical permeability p' (gpd per sq ft)	Method of analysis
1	24–68–12dbc	Pumped well	5,400						A
		1,050 S [1]	7,100	50		2.2			A
2	24–68– 9ccc1	Pumped well	5,200						B
		2,510 S [2]	18,000	24	0.3				B
3	24–67– 6bcd2	Pumped well	4,000	6	2				B
		597 E	3,700	3	.7	2.3	120	0.28	B
4	23–68– 4abc	100 E [1]	9,800	30	6				B
		200 E [1]	6,200	6	1				B
		400 E	4,000	5		6	80	.48	A
		1,600 E [1]	9,800	5	2				B
5	25–68–31cbd	Pumped well	8,000						A
		500 E	8,200	3		21	22	.44	A
		800 N	8,400	10	1	6.4	105	.67	B
6	24–67– 5acc	Pumped well	3,200						A
		400 E	3,200	5		3.2	160	.58	A
		800 E	2,600	5		1.6	160	.27	A
7	24–67– 7add	660 W	10,000	16	4.5				B
8	24–68–34bbc1	800 N [3]	43,000	25	1				B
		400 E [3]	50,000	23	1.5				B
9	24–68–27acc1	Pumped well [3]	38,000						C
		Average [1 2 3]	5,700	5.4	2.0	3.6		0.48	

[1] Observation well does not penetrate same part of aquifer, and results are unreliable. Included in table for comparison. Results not used in computing averages.
[2] Observation well measured between two casings, rather than down well, and results are unreliable. Not used in computing averages.
[3] These wells were not drilled in the same type of material as the others, and results from these tests are not considered to be typical for the Arikaree Formation in the area. The results were not used in computing the averages.

drawdown measurements were made at the pumped well, and only the recovery data from this well were analyzed.

The second test was made at well 24–68–9ccc1, which was pumped 125 hours at 525 to 440 gpm. Water-levels were observed in well 24–68–17add1, tapping the Arikaree Formation, and in wells 24–68–9ccc2 and 24–68–9ccc3 tapping the terrace deposits. Data from observation well 24–68–17add1, which is 2,510 feet south-southwest of the pumped well, indicated a coefficient of transmissibility of 18,000 gpd per ft; the figure may be erroneous, however, because the drawdown was measured in the annular space between the two casings in this well and may not reflect conditions in the same part of the aquifer as the pumped well. Water levels in wells 24–68–9ccc2 and –9ccc3 tapping the terrace deposits did not show declines that could be attributed to drawdown; however, slight drawdown might have been masked by fluctuations due to other causes.

In the third test, well 24–67–6bcd2 was pumped 120 hours at 380 to 350 gpm. Drawdown was observed in well 24–67–6bdc, which is similar in construction to the pumped well and taps the same zone of the Arikaree Formation. Water levels also were observed in well 24–67–6bcd1, which taps the terrace deposits 17 feet from the pumped well. Results of analysis of data for the two wells in the Arikaree Formation were quite consistent. The water level in the well tapping the terrace deposits was not visibly affected by pumping the deep well.

The fourth test was made at the site of well 23–68–4abc. Drawdowns were measured inside the pumped well and in a 1¼-inch pipe installed in the sand pack outside the casing. Two observation wells were constructed in the terrace deposits 50 and 200 feet from the pumped well (U.S. Bureau of Reclamation wells 1G50 and 2G200) and eight were constructed in the Arikaree Formation at intervals of 100, 200, 400, 800, and 1,600 feet from the pumped well and to different depths (U.S. Bureau of Reclamation wells 10A100, 3A200, 4A400, 5AD400, 6A800, 9A0800, 10AD1600, and 7A1600). The wells were drilled 4 inches in diameter and cased with 1¼-inch pipe. The wells in the Arikaree Formation were packed with gravel to a depth near the contact of the Arikaree and terrace deposits, at which depth a bentonite plug was placed to prevent movement of water down the wellbore from the terrace deposits to the Arikaree Formation. Figure 4 shows the depths, locations, and static water levels for the wells used in this test. The two wells in the terrace deposits have remained dry since they were drilled.

During this test the well was pumped at 525 to 540 gpm for the first 13 days; the discharge was regulated with a gate valve. At the end of

13 days, the discharge was reduced to 475 to 485 gpm, and the test was continued for an additional 45 days. Well 5AD400 is the only observation well that penetrates the same thickness of the aquifer as the pumped well and is the only one that yielded reasonable results. Data gathered from wells 10A100, 3A200, and 8AD1600 were analyzed to obtain aquifer coefficients. The results do not accurately represent the formation at that test site, but they provide some insight on the hydrology of the aquifer. The data plot from well 3A200 showed a departure from the type curve, after about 30 minutes of pumping, similar to that caused by an impermeable boundary. This departure probably represents a change in the characteristics of leakage flow in the vicinity of the well. Data gathered at the other wells observed during this test did not show a similar departure.

Water levels in the four wells drilled to a depth of 100 feet (4A400, 6A800, 7A1600, and 9A0800) were not immediately affected by the pumping; however, 5.2 and 3.4 feet of drawdown had been induced in wells 4A400 and 6A800, respectively, by the end of the 58-day test. Water levels in wells 7A1600 and 9A0800 did not show decline attributable to pumping.

The last five tests were made at the sites of private irrigation wells. Before the tests were made, one or two observation wells were drilled in the vicinity of each pumped well by a contractor for the Geological Survey. The observation wells were drilled 4 inches in diameter and cased with 1¼-inch pipe. The wells were drilled to depths about 10 feet below the measured depths of the pumped wells, and grout seals were placed at depths about equal to that at which the casings in the pumped wells were seated.

In the first test of the series, well 25–68–31cbd was pumped 216 hours at 550 to 500 gpm. Two observation wells, one 500 feet east and one 800 feet north of the pumped well, were installed for the test.

The coefficient of transmissibility obtained from the pumped well and the two observation wells check closely. The value for the pumped well is less reliable, however, than that for the others because drawdown data were not collected at the well during the first 10 minutes of the test, and the data gathered after that time yielded a plot which could be matched with equal facility to several type curves.

The data plot from observation well 1 departed from the type curve after about 100 minutes of pumping; probably the departure was due to changes in the pattern of leakage flow in the vicinity of the well.

Well 24–67–5acc was pumped 144 hours at 540 to 480 gpm. Two observation wells were used, one 400 and one 800 feet east of the pumped well. Data obtained from the three wells give results that are consistent.

Well 24–67–7add was pumped 48 hours at 670 to 650 gpm. One observation well was used. Drawdown data could not be obtained at the pumped well during pumping, but the drawdown data from the observation well were analyzed by the modified leaky-aquifer method. Recovery data for the pumped well were analyzed by the Theis nonequilibrium formula to obtain an approximate coefficient of transmissibility, but recovery data for the observation well could not be analyzed because the well was not pumped long enough to establish near-equilibrium conditions.

The last two tests were made in an area in which the Arikaree Formation is composed of much coarser material than elsewhere. This coarser material probably was deposited in a main stream channel within the flood-plain environment in which the sediments composing the Arikaree Formation were laid down. The two tests were made at the sites of wells about 0.9 mile apart, one at 24–68–34bbc1 and the other at 24–68–27acc1.

Well 24–68–34bbc1 was pumped for about 48 hours at 870 to 830 gpm, and drawdowns were observed in two observation wells. Plots of drawdown data for the observation wells differed somewhat from plots of data for the other tests because the semiconfining beds in the vicinity of well 24–68–34bbc1 are composed of thick beds of sandy clay, rather than of relatively impermeable lenses of well-cemented sandstone distributed in permeable sandstone. Because the upper zone of saturation lies within the clay beds, the hydrologic environment at this test site is analogous to case 2, as illustrated by figure 11. Drawdown data could not be obtained for the pumped well because a burr around the casing prevented measurement.

Well 24–68–27acc1 was completed at a depth of 300 feet and was cased with perforated casing from a depth above the water table in the unconsolidated part of the upper unit of the Arikaree Formation to the total depth of the well. The observation well also was drilled to a total depth of 300 feet and was screened at intervals throughout the saturated part of the aquifer. The construction of the wells used in this test is such that results expected in a water-table aquifer were obtained. The well was pumped for 97 hours at 1,000 to 950 gpm. The data from the pumped well met the requirements for a successful aquifer test. Analysis of drawdown data from the observation well, however, did not yield a reasonable value for the coefficient of transmissibility, possibly because the aquifer is nonhomogeneous in the vicinity of this test site. The drilled materials from the observation well are somewhat finer grained and contain much more limestone than those from the pumped well.

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COEFFICIENT OF TRANSMISSIBILITY

DETERMINED BY AQUIFER TESTS

Analysis of aquifer tests indicate that the average coefficient of transmissibility for the Arikaree Formation is about 5,700 gpd per ft and that it ranges from about 2,600 to about 10,000 gpd per ft, or 350 to 1,300 sq ft per day. The wide range probably is due partly to changes in grain size and cementation of the aquifer from place to place and partly to differences in depth of penetration of wells used in the various tests. Because the wells only partially penetrate the aquifer, the determined coefficients of transmissibility probably are low for the aquifer as a whole. These coefficients probably are the best available, however, for predicting local drawdowns obtained by pumping partially penetrating wells.

DETERMINED BY IDEAL GEOMETRIC CONFIGURATIONS

The coefficient of transmissibility was estimated also from the head distribution along the piezometric surface and the accretion rate to the aquifer by fitting the area to two ideal geometric figures.

The circle configuration—The first configuration used was that of a half circle, approximated by Sybille Creek, the Laramie River, and Chugwater Creek. An impermeable boundary parallel to the Laramie River and 3 miles south of the township line separating townships 24 and 25 and extending across the area is assumed to complete the configuration.

For an aquifer of this configuration, having a constant ground-water level maintained about the semicircular arc, the equation for the ground-water head due to accretion is expressed thus:

$$h'=\frac{w}{4T}(b^2-r^2)$$

where h'=head due to accretion (ft),
w=the accretion rate (ft per day),
T=the coefficient of transmissibility (sq ft per day),
b=the radius of the area (ft),
and r=the distance from the center of the circle (ft).

This equation may be rewritten:

$$T=\frac{w}{4h'}(b^2-r^2)$$

to determine the coefficient of transmissibility when the accretion rate and the head due to accretion are known (Robert E. Glover, written communication, 1961).

The rate of accretion in this area was assumed to be equal to the average accretion rate computed for the area, which was obtained by dividing the seepage loss from the Arikaree Formation to the major streams by the area of the Wheatland Flats. This computation gave an average accretion rate of 0.46 foot per year or 1.2×10^{-3} foot per day. The head due to accretion was estimated from the accretion-head map (pl. 6) for a point at the center of the south side of sec. 15, T. 24 N., R. 68 W., to be about 140 feet.

The coefficient of transmissibility is obtained for this idealized figure by substituting $w=1.2\times10^{-3}$ foot per day and $h'=140$ feet in the equation

$$T=\frac{wb^2}{4h'}$$

to give

$$T=1500 \text{ sq ft per day, or } 11{,}000 \text{ gpd per ft.}$$

The rectangle configuration.—The second idealized figure used was that of a rectangle having each of three sides represented by one of the incised streams and having a center line cutting across the rectangle represented by the impermeable boundary.

If the rectangle has a length $2b$ and a width $2a$, an origin at the center, and coordinates x and y measured in the directions of a and b, respectively, the boundary conditions will be $h'=0$ at $x=a$ and $h'=0$ at $y=b$. A solution of the equation of continuity meeting the boundary conditions for this rectangle system is:

$$h'=\frac{16wa^2}{\pi^3T}\sum_{n=1,3,5}^{n=\infty}\frac{1}{n^3}\cdots(-1)^{\frac{n-1}{2}}\left\{1-\frac{\cosh\frac{n\pi y}{2a}}{\cosh\frac{n\pi b}{2a}}\right\}\cos\frac{n\pi x}{2a},$$

with symbols as previously described (Robert E. Glover, written communication, 1961).

For this determination, the rectangle dimensions were assumed to be $a=4.0$ miles and $b=8.0$ miles, and the center of the rectangle was assumed to lie in the NW¼SW¼ sec. 3, T. 23 N., R. 68 W. The equation for head due to accretion at this point becomes:

$$h'=\frac{16wa^2}{\pi^3T}(0.883) \text{ or } T=\frac{16wa^2}{\pi^3h'}(0.883).$$

The average accretion rate of 1.2×10^{-3} feet per day determined from streamflow gains and the value for the head due to accretion of

180 feet determined from the accretion-head map (pl. 6) for that point were substituted in the equation to yield:

$$T=\frac{16\times 1.2\times 10^{-3}\text{ ft per day }(4.0\text{ mi}\times 5280\text{ ft per mi})^2}{(3.14)^3\ 180\text{ ft}}$$

$$=1400\text{ ft}^2\text{ per day}$$

$$=10{,}000\text{ gpd per ft.}$$

Values also were computed for the points

$$x=0,\ y=2,$$

$$x=0,\ y=4,$$

and

$$x=0,\ y=6.$$

The four values were averaged to give a value of T of about 10,000 gpd per ft.

Results obtained from the two geometric figures agree fairly closely, and probably represent reasonable values for the coefficient of transmissibility for the entire aquifer. The rectangle more nearly represents the configuration of the Wheatland Flats than the circle and probably gives more reliable results.

VERTICAL COEFFICIENT OF PERMEABILITY

The average vertical permeability of the Arikaree Formation limits the amount of water that can move down through the formation from the more permeable overlying terrace deposits and has an important bearing on the feasibility of the proposed pumping project. Estimates of the vertical permeability were made from aquifer tests and also from the relation of the average head difference between the water table and the piezometric surface to the accretion rate to the lower part of the Arikaree Formation.

Vertical permeability from aquifer tests.—The vertical permeability (p') of the Arikaree Formation was estimated from the six values of $\frac{p'}{m'}$ determined for data gathered during aquifer tests 3, 4, 5, and 6 (table 6). Values of the assumed thickness of the semiconfining bed (m') for values of $\frac{p'}{m'}$ determined from aquifer tests made at wells in areas where the water table lies within the terrace deposits were assumed to be equal to the thickness of the interval between the base of the terrace deposits and the open-hole or screened part of the observation well. For values of $\frac{p'}{m'}$ determined from aquifer tests made in areas where the water table lies within the Arikaree Formation, m' was assumed to be approximately the distance between the water table and the beginning of the open hole or screened part of the observation well. For observation wells in which water in the upper part of the hole was cemented off from the screened part of the well, m' was assumed to be the thickness of the interval between the top of the Arikaree Formation and the bottom of the cement plug. The values of m' thus obtained are shown in table 6.

The vertical permeabilities were calculated by multiplying the values of $\frac{p'}{m'}$, as determined from the aquifer tests, by the values of m' at the sites of the observation wells for which the $\frac{p'}{m'}$ values were determined. The average value of p' determined by this method was about 0.5 gpd per square foot.

Vertical permeability by head difference and accretion rate.—A value for $\frac{p'}{m'}$ also may be found from the relation of the average difference in head between the piezometric surface and the water table to the accretion rate by using Darcy's equation for flow through porous media:

$$Q=PIA,$$

when

Q=discharge, or flow $\left(\frac{L^3}{T}\right)$,

P=coefficient of permeability $\left(\frac{L}{T}\right)$,

I=hydraulic gradient,

and A=area through which flow occurs (L^2).

The equation may be rewritten for vertical flow through a semiconfining bed:

$$\frac{Q}{A}=\frac{p'}{m'}\Delta h$$

$\frac{Q}{A}$=the accretion rate $\left(\frac{L}{T}\right)=w$,

Δh=difference in head across the semiconfining bed,

and

$\frac{\Delta h}{m'}$=hydraulic gradient for vertical-flow components.

Solving the equation for $\frac{p'}{m'}$ yields: $\frac{p'}{m'}=\frac{w}{\Delta h}$.

The average difference in head between the piezometric surface and the water table equals (1) the sum of the head differences times the area divided by (2) the total area enclosed by contours on plate 7. Areas between selected contours found by planimeter from plate 7 are shown in column 2 of the following table. The areas listed were multiplied by the average value of the enclosing contours to find the volume of head difference for each interval, as listed in the third column. Areas for which the head difference was greater than 60 feet were not used in the computations, because saturated interconnection between the two formations may not exist in those areas.

Contour interval	*Area within contour interval (sq mi)*	*Volume of head difference (cu ft ×10⁹)*
0–10 above	2.6	−0.36
0–20 below	21.2	+5.92
20–40	31.9	26.7
40–60	3.7	5.1
Total	59.4	37.3

The average head difference between the water table and piezometric surface for all the contoured area of plate 7 is found to be 23 feet by dividing the total of all volumes in column 3 by the total of all areas in column 2. The head difference may be somewhat in error, because the limits of saturated interconnection are not known and because the average value of head difference for the interval 0–20 feet, which covers a large area, may not be correct.

The accretion rate was found to be about 0.46 foot per year, or 1.2×10^{-3} feet per day, from a flow-net analysis and study of streamflow gains.

Inserting the values for the accretion rate and average head difference in Darcy's equation:

$$\frac{p'}{m'}=\frac{w}{\Delta h}=\frac{1.2\times10^{-3}}{23}=5.4\times10^{-5}\text{ day}^{-1}$$

or 4.1×10^{-4} gpd per cu ft.

A value for m' was found from the casing records (table 8) and drillers logs (table 11) for wells used in drawing the piezometric contour map. The thickness for m' was assumed to be the distance between the contact of the Arikaree Formation and the terrace deposits and the open-hole part or screened part of the well. The average m' in the wells studied was about 140 feet. Multiplying this value by the value of $\frac{p'}{m'}$ of 4.1×10^{-4} gpd per cu ft yields a value for the vertical permeability of about 0.06 gpd per sq ft.

The latter value of p' is about one-eighth that determined from the aquifer tests. Vertical permeability determined from the aquifer tests may be too high, because the apparent confining bed reflected by the aquifer-test data may not extend to the base of the terrace deposits, but only to an upper porous zone within the Arikaree Formation. Although vertical permeabilities determined by the two methods differ widely, they probably define the range of vertical permeability.

The maximum capacity of pumping wells in the Arikaree Formation is limited to the maximum vertical flow downward through the formation from the overlying terrace deposits and soil zones. This maximum flow may be determined by assuming a gravity gradient between the terrace deposits and the tapped zone of the Arikaree Formation over the area of the Wheatland Flats by using Darcy's equation:

$$Q=PIA.$$

The hydraulic gradient under gravity-flow conditions is equal to unity, the area equals about 50,000 acres, and it may be assumed that the vertical permeability is equal to about 0.06 gpd per sq ft. The maximum recharge to the formation under these conditions would be equal to 0.06 gpd per sq ft×50,000 acres×43,560 sq ft per acre=130,000,000 gpd=400 acre-feet per day. The discharge from the Arikaree Formation, as computed from an analysis of streamflow measurements, presently is about 23,000 acre-feet per year, or about 63 acre-feet per day. Thus, the aquifer under maximum development could accept six or seven times more recharge than it does at present (1961), if the vertical permeability of the formation equals the minimum value determined. If two-thirds of the water to be pumped for the proposed project were to come from increased recharge and if the pumping were to be evenly distributed over a 120-day pumping season, recharge would be increased by about 100 acre-feet per day, or by about 1½ times the present rate of recharge. This is well within the capability of the upper part of the Arikaree Formation to transmit water from the water table downward to the pumping wells without causing ponding at the surface.

THE STORAGE COEFFICIENT AND SPECIFIC YIELD

The storage coefficient for the Arikaree Formation was computed from data obtained from eight of the nine aquifer tests. The average storage coefficient, as determined from data from observation wells most accurately reflecting the hydrologic environment at their sites, was about 5×10^{-4}. This storage coefficient is very small, and little water would be released from storage by declines in the piezometric surface. For example, a decline in the piezometric surface of 30 feet over the area of the Wheatland Flats would release only about 750 acre-feet of water. Thus, the storage characteristics of the pumped zone of the Arikaree Formation are not important in determining water-level changes, because changes in storage are negligible compared with the quantity of water pumped each season. The storage coefficient should be useful, however, for predicting local drawdowns in the vicinity of wells tapping the Arikaree Formation at depth.

An average specific yield of about 0.12 for the materials lying within the range of water-table fluctuations was determined from observed changes in storage and discharge estimates made for February 1959. The water table undoubtedly would decline during the first years the the Bureau of Reclamation's proposed pumping project is in effect, before new equilibrium conditions are established. The volumes of water released from storage within the terrace deposits and the uppermost part of the Arikaree Formation can be computed from the average specific yield and from forecasts of the amount of decline of the water table caused by project pumping.

GROUND-WATER DEVELOPMENT

PRESENT DEVELOPMENT

TERRACE DEPOSITS

Water is obtained for irrigation in the area from about 50 wells in the terrace deposits. The wells yield from 100 to 800 gpm, but the yield of most wells ranges from 200 to 500 gpm. The irrigation wells were drilled with cable tool, rotary, or reverse-rotary rigs or were dug. Most of the wells were drilled a few feet into the Arikaree Formation and fully cased; they generally are from 10 to 48 inches in diameter. All the irrigation wells are equipped with turbine pumps and electric motors except two, which are equipped with centrifugal pumps. The motors range in horsepower from 1.5 to 15, and most are in the 5 to 10 horsepower range. Data on the individual irrigation wells are given in table 8.

Pebble or cobble gravel was used to fill the annular space between the casing and the outside of the hole in many of the wells. None of the wells have a gravel pack designed to prevent sand pumpage; however, most of the wells seem to develop a natural gravel pack and do not pump much sand after the first few weeks of pumping.

About 170 small-discharge wells obtain water for stock and domestic use from the terrace deposits. These wells were drilled by cable-tool or reverse-rotary methods or were dug. Drilled wells generally range in diameter from 4 to 8 inches, but the diameter of the dug wells may be as much as 4 feet. Most of the wells were drilled to depths of a few feet below the base of the terrace deposits and were cased to their total depth. The wells are equipped with jet or cylinder pumps, and most are powered with electric motors. Many abandoned domestic wells have hand-operated pitcher pumps.

ARIKAREE FORMATION

Thirty-three large-discharge wells, records of which appear in table 8, tap the Arikaree Formation in the Wheatland Flats area. These include 5 municipal wells and 28 irrigation wells. In addition, 2 municipal wells and 1 well drilled as an industrial supply for the Great Western Sugar Co. have been abandoned, 3 irrigation wells have failed structurally, and 2 wells drilled for irrigation yielded only small quantities of water and were not completed. One large-diameter well, drilled for irrigation, was plugged without being tested by pumping. Of the above, 22 wells were drilled by cable-tool methods, 4 probably were drilled by cable-tool methods, 7 were drilled by rotary methods, and 9 were drilled by reverse-rotary methods.

Wells drilled by cable-tool rigs were constructed by lowering blank casing down the hole as drilling progressed, to prevent caving, to a depth at which the formation would stand as open hole. The casing was seated at that depth, generally on a hard limy lens, and the well was completed with about 200 to 350 feet of open hole. The depths of seven wells completed in this manner were measured in 1959-60. The wells had caved and partly filled with 150 to 350 feet of material. Three wells (23–68–10cdc, 24–68–13cdd1, and 24–68–34bbc1) were cased with perforated casing below the quicksand zone, rather than being completed as open hole. No depth measurements were obtained on these wells. Wells drilled by rotary methods were completed in much the same manner as those drilled by the cable-tool method.

Most of the irrigation wells drilled by the reverse-rotary method were drilled to depths of 300 to 320 feet; however, well 23–68–4abc is 500 feet deep. The wells were drilled to a diameter of 30 inches and cased with 12-inch to 16-inch casing to their total depth. In most of the wells the casing is perforated from about the water table to the bottom of the well. Pea-sized gravel was installed in the annular space around the casing in all the wells except 23–68–4abc, in which a graded sand pack was installed. Several of the wells packed with pea-sized gravel pump moderate to large quantities of sand. Well 24–68–22acc2 pumped so much sand that, after about five days of pumping, the ground caved around the well and formed a cavern that required 60 cubic yards of material to fill. The owner installed a smaller pump on the well and continued to operate it. After about two months it caved again, and this time about 30 to 40 cubic yards of material were required to fill the cavity.

All the irrigation wells tapping the Arikaree Formation are equipped with turbine pumps except 24–68–27acc2, which has a submersible turbine pump. The wells are powered with 15- to 40-horsepower electric motors, with the exception of 24–67–7add, which is equipped with a 56-horsepower natural gas engine. Most of the wells yield from 450 to 650 gpm.

About 70 domestic and stock wells tap the Arikaree Formation in the area. These wells were drilled by hydraulic-rotary or cable-tool methods. They generally were drilled to depths of 150 to 300 feet and are 6 to 8 inches in diameter. Most of the wells are cased with blank casing to within a few feet of their total depth. The wells are equipped with jet or cylinder pumps and are powered with electric motors.

HISTORY OF DEVELOPMENT OF GROUND WATER FOR IRRIGATION IN THE AREA

The first irrigation well for which data are available, 24–68–8cdc, was drilled in 1931; the well taps both the terrace deposits and the Arikaree Formation. In 1934, well 23–68–10dcc was drilled to a depth of 920 feet in the Arikaree Formation, but the pump column and suction pipe extended only 55 feet below the static water level; after only a short period of pumping, the water level dropped below the end of the suction pipe. This discouraged farmers for some time from constructing deep wells in the Arikaree Formation. Only five irrigation wells were constructed between 1934 and 1953, all in the terrace deposits.

In 1953, as a result of a general drought that greatly reduced the amount of surface water for irrigation, 23 wells were constructed in the terrace deposits. Thirteen wells were constructed in the terrace deposits in 1954, 6 in 1955, and 3 in 1956. By 1956 the water table had declined greatly because of the drought (fig. 5), and the yields of many wells in the terrace deposits had declined to a fraction of what they had been in 1953 and 1954. This led to renewed interest in deep wells tapping the Arikaree Formation as a more dependable ground-water supply and, in the fall of 1956, three deep wells were constructed. Yields of these wells ranged from 500 to 670 gpm. Fifteen deep wells tapping the Arikaree Formation were constructed in 1957, and well drilling probably would have continued at a rapid pace had the drought not ended in that year. Only one well was drilled in 1958. Four deep wells were constructed during the summer and fall 1959, as supplies of surface water became short near the end of the irrigation season. No irrigation wells tapping the terrace deposits were constructed during the period 1957–59.

In 1960, water was again in short supply and 16 new wells were drilled, including 9 in the Arikaree Formation and 7 in the terrace deposits. Of the 9 wells drilled in the Arikaree Formation in 1960, 3 were drilled to replace wells that had failed, and 1 (23–68–9cca) was abandoned by the owner without being tested by pumping; therefore, only 5 new irrigation wells tapping the Arikaree Formation were added during 1960.

GROUND-WATER USAGE

Morris and Babcock (1960, p. 75) determined the following ground-water pumpage for irrigation and municipal use for the years 1953–55. As a part of this investigation, ground-water pumpage for irrigation, municipal, domestic, and stock use was determined for the years 1959–60. (See table 7.) Records of electric-power consumption for each well were

Year	*Water pumped (acre-feet)*
1953	1,900
1954	2,300
1955	700

obtained from the power company. The amount of water pumped by electrically powered irrigation wells was then computed by measuring the power input and the discharge of each well to derive a figure for acre-feet of water pumped per kilowatt-hour of electricity used. This figure was multiplied by the electric power used to obtain the total discharge for each well. Discharges of wells not pumped by electricity were measured, and the owners were asked to keep a record of the days the wells were pumped. The daily discharge of the wells was multiplied by the number of days pumped to obtain the total discharge.

TABLE 7.—*Ground-water pumpage in the Wheatland Flats area for 1959–60, in acre-feet*

Use	Arikaree Formation		Terrace deposits	
	1959	1960	1959	1960
Irrigation:				
April	-----------	70	-----------	90
May	30	280	60	210
June	150	560	190	400
July	190	970	230	1,030
August	590	980	780	1,160
September	520	550	550	640
October	130	180	60	110
Municipal	400	420	0	0
Domestic and stock	30	30	50	50
Total	2,040	4,040	1,920	3,710

Figures for pumpage from the Arikaree Formation are more accurate than those from the terrace deposits because the discharges of wells tapping the Arikaree Formation do not vary much seasonally, whereas the discharges of wells tapping the terrace deposits vary considerably as the water table fluctuates during the irrigation season.

Municipal pumpage was obtained from meter readings for three of the wells used by the town of Wheatland and from an estimate of discharge for one well (24–68–13cdd1).

Domestic and stock pumpage was estimated from interviews with about 20 farm owners. The average pumpage for domestic and stock use for each farm was determined to be about 0.3 acre-foot annually. Although the estimates are only approximate, they probably are of about the right order of magnitude.

PROPOSED FUTURE DEVELOPMENT

The Bureau of Reclamation proposes to pump about 15,600 acre-feet more water per year from the Arikaree Formation. The project plan also requires an additional 12,000 acre-feet of surface water to be made available by increasing storage facilities and by lining canals outside the area (Robert Cross, oral communication, 1962). This measure would add about 27,600 acre-feet annually to the irrigation-water supply.

The Bureau of Reclamation previously had estimated that an additional 18,000 acre-feet of ground water might be required for the project. That amount of ground water, plus the 12,000 acre-feet of additional surface water annually, would have added about 30,000 acre-feet of water annually to the total irrigation-water supply. For the purposes of this report, a figure of 30,000 acre-feet was used as a basis for calculations regarding the effect of the proposed project upon water levels in the report area.

EFFECTS OF PROPOSED PUMPING PROJECT ON WATER LEVELS

Ground water for the proposed project would be obtained from four sources: (1) storage in ground-water reservoirs, (2) diversions from seepage to the major streams, (3) decreases in evapotranspiration losses, (4) and increases in recharge resulting from increases in applications of water for irrigation from surface supplies. Most of the water pumped initially would be derived from storage in the Arikaree Formation; however, as the head on the water in the Arikaree Formation is lowered by this withdrawal, water that otherwise would drain from the formation to the major streams would be diverted to the wells, and more leakage would be induced from the terrace deposits. The water supplying the induced leakage would come from increased recharge because of increased applications of irrigation water on the terraces, from storage within the terrace deposits and the uppermost part of the Arikaree Formation, and, as the water table declines, from decreases in evapotranspiration losses. After the pumping project has been in effect for several years, essential equilibrium will be reestablished and, for average conditions, significant quantities of water no longer will be derived from storage.

Both the piezometric surface of the Arikaree Formation and the water table will decline considerably if the proposed pumping project is begun. Inasmuch as the feasibility of the project depends on the extent of these declines, estimates have been made of their magnitude.

These estimates are for the new equilibrium levels to be established by pumping over several years and do not include releases of ground water from storage. The effects of the proposed pumping project on the water levels will depend on the quantities of water to be derived from the different sources.

Increased recharge to the ground-water reservoir was computed, by multiplying the figure of 30,000 acre-feet of additional water to be applied for irrigation annually by the estimated recharge rate of 35 to 40 percent, to be 10,500 to 12,000 acre-feet a year. Most of this additional recharge would be recaptured by the proposed well field when the water levels are lowered over the area, although some would escape by evapotranspiration and loss to streamflow. It is assumed for this computation that about 9,000 acre-feet would be recaptured by the well field. The additional 9,000 acre-feet would be derived from reduced flow from the Arikaree Formation to the streams and from reduced discharge from the terrace deposits.

The part of the 9,000 acre-feet of water to be diverted to the well field by reduction of present discharge to streams from the Arikaree Formation and the terrace deposits is dependent on the declines in ground-water levels. Therefore, empirical equations were derived to indicate declines in water levels resulting from salvage rates from the two sources of discharge. Values then were assumed for the salvage from each source and tried in the equations until reasonable figures for the declines in head were found.

The first equation derived is used to determine the magnitude of the decline in the piezometric surface necessary to produce a decrease of a certain magnitude in ground-water seepage to the major streams. This equation assumes that the pumping is evenly distributed over the entire area and acts to decrease the accretion rate uniformly. The piezometric head at any point in the flow system due to accretion is proportional to the accretion rate, and the change in head, $\Delta h'$, is found by the equation:

$$\Delta h' = h' \frac{\Delta w}{w}, \qquad \text{(Eq. 1)}$$

when

$\Delta h'$ = change in accretion head due to change in rate of accretion, in feet,

h' = accretion head before the change in the accretion rate, in feet,

Δw = change in accretion rate in any units,

and

w = accretion rate before change occurred, in same units.

The value for the average accretion component of head was determined by finding the area between each pair of contours on the accretion-head map (pl. 6) by use of a polar planimeter, multiplying each area by the mid-value of the enclosing contours, totaling the values for each interval, and dividing by the total area to get an average head value. The value was determined to be about 105 feet. The accretion to the Arikaree Formation at depth is about 23,000 acre-feet a year, as determined from streamflow data, and, for the change in accretion rate in acre-feet a year, equation 1 becomes

$$\Delta h'_a = 105 \frac{\Delta w}{23{,}000},$$

when

$\Delta h'_a$=average accretion component of head.

The latter equation is an approximation because the head values from areal segments were not weighted to account for nonlinearity in the equation relating head, accretion, and space; however, estimates based on this approximation are believed to be of adequate accuracy for this study.

Under proposed project conditions, much more water than presently does so will move down from the terrace deposits and the uppermost part of the Arikaree Formation to the deeper water-bearing zones in the Arikaree Formation; therefore, the difference in head between the water table and the piezometric surface will increase. The increase in downward flow will be equal to the ground-water pumpage minus the amount salvaged from direct flow to the streams (Δw, in equation 1). Downward flow is proportional to the difference in head between the two formations; therefore, the change in head difference between the water table and piezometric surface may be expressed by equation 2:

$$\Delta D = D \times \frac{P - \Delta w}{w},$$

when

D=average head difference between the water table and piezometric surface over area,

ΔD=change in head difference caused by change in accretion,

w=accretion rate,

P=pumping rate,

and

Δw=change in accretion rate due to pumping.

The average head difference (D) was determined to be about 23 feet (p. 48), the accretion rate w, is equal to about 23,000 acre-feet a year, and the pumping rate is about 18,000 acre-feet a year. Thus, equation 2 becomes:

$$\Delta D = 23 \times \frac{41{,}000 - \Delta w}{23{,}000}.$$

Saturated interconnection between the terrace deposits and the lower part of the Arikaree Formation probably does not exist in some areas near the streams bounding the Wheatland Flats. The increased depth to the piezometric surface caused by pumping the proposed well field would cause the size of the unsaturated area to increase, and the area where saturated interconnection between the two formations now exists would become smaller. Consequently, the amount of head difference between the two formations would need to increase more than proportionally in order to cause a proportional increase in the accretion rate. The increased difference in head between the water table and the piezometric surface would increase the vertical component of downward movement relative to the horizontal component, and, as a consequence, the quantities of water moving downward would increase more than proportionally with an increase in the difference in head.

The influences of these two factors on equation 2 are not known, but it is assumed that they are compensating.

Finally, the decline in the water table may be expressed by equation 3:

$$\Delta h_{wt} = \Delta h'_a - \Delta D,$$

when

Δh_{wt}=change in the level of the water table.

By assigning various assumed values for the volume of present accretion to be intercepted by the proposed well field, expressed as Δw, various combinations of declines in head of the two surfaces—the water table and the piezometric surface—may be computed, and the most reasonable combination may be determined. Sample calculations are given below.

If it is assumed that about 4,000 acre-feet of water is to be diverted from present seepage to the major streams and that 9,000 acre-feet is to be salvaged from increased recharge, then 5,000 acre-feet will be derived by decreasing present discharge from the terrace deposits. Using these figures in the three equations:

$$\Delta h'_a = 105 \frac{\Delta w}{23{,}000},$$

$$\Delta D = 23 \times \frac{18{,}000 - \Delta w}{23{,}000},$$

and

$$\Delta h_{wt} = \Delta h'_a - \Delta D,$$

the following is obtained:

$\Delta h'_a$=18 feet,

ΔD=18 feet,

and

$\Delta h_{wt}=0$ foot.

Because no water could be salvaged from the discharge from the terrace deposits and uppermost part of the Arikaree Formation without a decline in the water table, the assumed value of Δw must be too low.

If a value of Δw of 5,000 acre-feet a year is assumed, values of

$\Delta h'_a=23$ feet,

$\Delta D=17$ feet,

and

$\Delta h_{wt}=6$ feet

are obtained.

An average decline of 6 feet in the water table might be expected to yield 4,000 acre-feet of salvaged discharge annually, and these figures may represent good assumptions for the declines in head.

Moreover, if a value of Δw of 6,000 acre-feet is assumed,

$\Delta h'_a=27$ feet,

$\Delta D=13$ feet,

and

$\Delta h_{wt}=14$ feet.

A decline in the water table of that magnitude should yield more than 3,000 acre-feet a year in salvaged recharge from the terrace deposits and uppermost part of the Arikaree Formation; therefore, the estimate of Δw must be too high.

The sample computations indicate that under the new equilibrium conditions imposed by the proposed pumping project, the piezometric surface probably would decline, on an average, 20 to 25 feet from present levels, and the water table probably would decline, on an average, 3 to 10 feet below its present average level. These declines in head would not be evenly distributed over the area, and for the piezometric surface they would range from 0 to about 50 feet; for the water table, they would range from 0 to 20 feet.

PUMPING LIFTS UNDER PROJECT CONDITIONS

Average pumping levels may be computed for the wells tapping the Arikaree Formation at depth by totaling the local drawdown for the well determined from data from the aquifer tests, the depth to the piezometric surface at present, and the average decline in the piezometric surface under the proposed project conditions. The average local drawdown in the vicinity of a pumping well may be computed from the aquifer coefficients determined from the analysis of aquifer tests. This was done for a well assumed to be drilled at a location for which the aquifer has the average aquifer coefficients as determined by the aquifer tests. These aquifer coefficients are:

T=5,700 gpd per ft,

$S=5\times10^{-4}$,

and

$\frac{p'}{m'}=4\times10^{-3}$ gpd per cu ft.

It also was assumed that

t (length of pumping)=120 days,

Q (discharge of well)=500 gpm,

and

r (radius of well)=3 feet.

A radius of 3 feet was used because analysis of data gathered during the aquifer tests indicated that each pumped well behaved as though its radius were at least 3 feet. A local drawdown of 120 feet at the pumped well at the end of 120 days was determined from the above values.

It was next assumed that wells in the proposed field would be spaced on a rectangular grid 3,000 feet apart. The combined drawdown at the well produced by pumping the four wells 3,000 feet away was computed, using the same values, to be about 5 feet. Drawdown caused by the more distant wells was assumed to be negligible. After adding 35 feet for the average depth to the piezometric surface and 20 to 25 feet for the average decline in the piezometric surface, the average pumping lift for a well pumping 500 gpm under equilibrium conditions was computed to be 180 to 185 feet.

These pumping lifts would be reduced somewhat by locating as many of the wells as feasible in areas where the coefficient of transmissibility is very high, such as the apparent channel of coarser material in the western part of sec. 34, the center part of sec. 27, and the center part of sec. 22, T. 24 N., R. 68 W. (See logs of observation wells 24–68–27bdd, –34bbb, and –34bbc1 and for irrigation well 24–68–27acc1, tables 10 and 11.) Pumping lifts might also be reduced by constructing the wells to tap a greater part of the total thickness of the Arikaree Formation and by deriving part of the water from wells tapping the terrace deposits in areas where its saturated thickness is greatest.

SOURCE OF WATER PUMPED

Projected head declines also indicate that quantities of water pumped from the different sources can be broken down thus: about 9,000 acre-feet from salvaged increased recharge, from 5,000 to 6,000 acre-feet from discharge salvaged from direct accretion to the major

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streams, and from 3,000 to 4,000 acre-feet from discharge salvaged from evapotranspiration and from seeps, drains, and small streams tapping the terrace deposits and the uppermost part of the Arikaree Formation.

Because part of the water now discharged from the terrace deposits and uppermost part of the Arikaree Formation finds its way to the major streams, total flow in the Laramie River below its confluence with Chugwater Creek eventually may be diminished 6,000 to 7,000 acre-feet a year by the decline in head caused by installation of the project. Present evapotranspiration losses from the ground-water reservoir would be reduced by 2,000 to 3,000 acre-feet a year, although total evapotranspiration from the project area would be increased by about 16,000 to 17,000 acre-feet a year because of the additional applications of water for irrigation. Some of the water salvaged by decreasing evapotranspiration losses would otherwise be used by nondesirable hydrophytes and phreatophytes or would be lost directly to the atmosphere, but some would be used by crops.

From 1,500 to 3,000 acre-feet of the 10,500 to 12,000 acre-feet of additional recharge which would occur under proposed project conditions probably would be in areas where perched ground water exists, and most of this water probably would not be salvaged by the project wells. Much of the water probably would be discharged from the area by evapotranspiration, although some would reach the streams.

SUMMARY

The Wheatland Flats area may be considered to be a hydrologic unit, because little water enters or leaves the area by underflow. Ground-water movement toward the area from the south is restricted by the low permeability of the rocks in that part of the area. Some ground water probably moves northward out of the area through that part of the Arikaree Formation lying beneath the Laramie River. However, the piezometric gradient in the Arikaree Formation north of the Laramie River, as shown by Morris and Babcock (1960, pl. 1), is small compared to piezometric gradients observed in the Arikaree Formation in the Wheatland Flats area, and indicates that underflow in this direction is small. Ground-water recharge is derived almost entirely from surface water applied for irrigation and from precipitation in the area. From 35 to 40 percent of the applied irrigation water and from 5 to 10 percent of the precipitation reaches the ground-water reservoir. Ground water is discharged from the area to streams and by wells and evapotranspiration.

Two formations constitute the ground-water reservoir—the Arikaree Formation of Tertiary age and the terrace deposits of Quaternary age. The hydraulic properties of the Arikaree Formation were determined from nine aquifer tests performed at the sites of partially-penetrating wells and from a regional analysis of water-level data. Data obtained from the aquifer tests indicate that the Arikaree Formation has a coefficient of transmissibility of 5,700 gpd per ft, a storage coefficient of 5×10^{-4}, and a vertical permeability of 0.5 gpd per sq ft. The regional water-level analysis indicates that the Arikaree Formation has a coefficient of transmissibility of 10,000 gpd per ft, a storage coefficient of 0.1, and a vertical permeability greater than 0.06 gpd per sq ft. The coefficient of permeability of the terrace deposits, as determined from aquifer tests, ranges from 500 to 4,000 gpd per sq ft. The aquifer coefficients determined from the regional water-level analysis were used to predict overall declines in water levels and in streamflow caused by increased pumping, and the data from the aquifer tests were used to predict local drawdown in the vicinity of individual wells. The data show that an additional 18,000 acre-feet of water per year can be pumped annually from the Arikaree Formation in the Wheatland Flats area. Under the new equilibrium that results from pumpage of that magnitude, regional water levels in the Arikaree Formation would decline 20 to 25 feet, and water levels in the terrace deposits would decline 5 to 10 feet. Pumping lifts probably would average 180 to 185 feet under project conditions. Streamflow of the Laramie River eventually might be reduced by 6,000 to 7,000 acre-feet per year because of the additional draft on the ground water.

TABLE 8.—*Record of large-discharge wells in the Wheatland Flats area, Platte County, Wyo.*

Well: See text for description of well-numbering system.
Method used in drilling well: D, drilled; D–C, cable tool; D–R, rotary; D–RR, reverse rotary; Dug, Dug well.
Depth of well: No symbol, measured; R, reported.
Well-completion data: GP, gravelpacked; P, factory perforated; Tp, torch perforated.
Use of water: I, irrigation; N, none; P, public supply.
Depth to water below land surface: No symbol, measured; R, reported.
Discharge: No symbol, measured; R, reported.
Drawdown: No symbol, measured; R, reported.
Remarks: L, log; AT, aquifer test.

Well	Owner	Date drilled	Altitude of land surface at well site (feet)	Method used in drilling well	Depth of well (feet)	Well-completion data	Use of water	Depth to water below land surface (feet)	Date of measurement	Discharge (gallons per minute)	Drawdown (feet)	Hours of pumping	Date of measurement	Remarks
Arikaree Formation														
23-68-4abc	Wheatland Irrigation Dist.	1959	4,948	D-RR	500R	Sand packed. P 150-500 ft.	I	67	6-3-60	480	178	1,000	Oct. 1959	AT, 10 observation wells drilled in vicinity.
4acc	William Burzlaff	1960	4,950	D-RR	300R	GP, pea gravel. P 50-300 ft.	I	57	8-20-60	575	128	130	Aug. 1960	
9cca	Gus Graefy	1960	5,002	D-RR	320R	Not completed								Filled in without being tested.
10cdc	Ayers Trust	1934	5,001	D-C	920R		I	13	6-26-58	250R	55R	1		Not used.
20cdc1	Roy Wallesen	1957	5,148	D-C	313R 159	Open hole below 83 ft.	N	16	6-26-58	125R				Tested at 125 gpm when 100 feet deep.
20cdc2	do	1959	5,148	D-C	430R	Open hole below 410 ft.	N	49	12-8-59					Bailed dry in few minutes.
27baa	Byrd	1960	5,145	D-R	125R	P 45-105 ft. Open hole below 105 ft.	N	37	9-28-60	60R	35R	½	Aug. 1960	Bail tested 4.
24-67-5acc	Ben Lockman	1959	4,678	D-C	605R					475	130	140	Jan. 1960	L, AT, observation wells drilled.
					341	Open hole 250-341 ft.	I	78	1-20-60	515	126	150	July 1960	
5cdd	Karl Kreiger	1957	4,711	D-C	630R	Open hole below 265 ft.	I	98	5-20-58	665		12	Aug. 1958	
6bcc	Eldon Johnston	1960	4,656	D-C	470R	Open hole below 250 ft.	I	30R	6-4-60	285		740	Aug. 1960	Discharge measured while well 600 ft. away was pumping.
6bcd2	do	1957	4,648	D-C	450R					350	98	120	Oct. 1958	L, AT.
					218	Open hole 164-218 ft.	I	32	7-8-58	300	107	740	Aug. 1960	

6bdc	do	1957	4,649	D-C	470R	Open hole below 160 ft.	I	31	10-13-58	437	88	170	Aug. 1958	
										430	100	740	Aug. 1960	
7add	L. A. Shepard	1957	4,740	D-C	555R					650		1	June 1958	L, AT, observation well drilled.
					352	Open hole below 285 ft.	I	115	6-24-58	620	105	30	Jan. 1960	
8dbb	State Bank of Wheatland.	1957	4,718	D-C	518R	Open hole below 300 ft.	I	105R	1957	665		1	Aug. 1958	
										605		170	Aug. 1959	
24-68- 5dcd	Lipsac	1957	4,764	D-C	500R	Open hole below 85 ft.	I	42	7- 3-58	587		1	Aug. 1958	
										575		5	Aug. 1960	
6acd	Woodrow May	1957	4,724	D-C	508R					630	86	30	July 1958	
					231	Open hole below 145 ft.	I	18	5-14-58	635	93	72	July 1960	
8bdd	Ward Goodrich	1931	4,754	D-R	225R	P 0-100 ft								
					180	Open hole below 100 ft.	I	6	6-26-58	165			June 1954	
8ccc	Doval Johnston	1957	4,774	D-C	500R	Open hole below 130 ft.	I	19	12- 8-59	630	105	140	July 1960	L.
9ccc1	do	1957	4,791	D-C	655R					450	98	125	Aug. 1958	
					258	Open hole 220-258 ft.	I	52	7- 2-58	440	103	1,100	Aug. 1960	L, AT.
12dbb1	Great Western Sugar Co.	1933	4,700		281	Open hole 268-281 ft.	N	14	1954	220R	100R			
12dbb2	Town of Wheatland	1933	4,702		453R	Tp 174-274, 344-453 ft.	P	12	9-25-58	563R	100R		1934	
12dbc	Town of Wheatland	1933	4,700	D-R	507R	Tp 200-486 ft	P	20R	9- -33	600	82	46	Aug. 1956	AT, pumped at 500 gpm.
12dcc	do	1936	4,708	D-R	508R	TP 0-191, 201-508 ft.	P	12R	9- -36	1,028R	180R		1936	Pumped at 500 gpm.
13cdc	do	1946	4,798	D-R	355R	P	P	89	6-18-54	500R				
13cdd1	do	1934	4,760	D-C	560R	Tp 308-560 ft	P			600R				
13cdd2	do	1910			400R		N	30R	1910					
13cdd3	do	1910			450R		N	30R	1910					
17adc1	Herman Hellbaum	1957	4,804	D-C	550R									Well caved to 197 ft (bottom of casing) and failed.
					197	Open hole below 200 ft.	N	52	7- 9-58					
17adc2	do	1960	4,804	D-RR	300R	GP, pea gravel								
						P 30-300 ft	I	40R	2- -60	460	120	700	July 1960	
22acc1	Ed Lietz	1960	4,865	D-RR	300R	GP, pea gravel								Casing ruptured after 5 days of pumping, and well failed. Well pumped large quantities sand.
						P 50-300 ft	N	78	7- 6-60	500	31	4	June 1960	
22acc2	do	1960	4,867	D-RR	300R	GP, pea gravel				550	80	30	July 1960	Pumped large quantities sand.
						Tp 50-300 ft	I	80R	8- -60	330	31	25	Aug. 1960	

TABLE 8.—*Record of large-discharge wells in the Wheatland Flats area, Platte County, Wyo.*—Continued

Well	Owner	Date drilled	Altitude of land surface at well site (feet)	Method used in drilling well	Depth of well (feet)	Well-completion data	Use of water	Depth to water below land surface (feet)	Date of measurement	Discharge (gallons per minute)	Drawdown (feet)	Hours of pumping	Date of measurement	Remarks
Arikaree Formation—Continued														
24-68-27acc1	Joe Bowen	1959	4,894	D-RR	300R	GP, pea gravel								L, samples, AT. Pumped much sand. Well failed because of casing rupture.
27acc2	do	1960	4,894	D-RR	300R	P 50-300 ft GP, P 50-300 ft	N I	72 79	1-13-60 10- 8-60	900 650	44 61	73 55	Jan. 1960 Aug. 1960	
28cbc	Van Pelt	1960	4,668	D-RR	320R	GP, pea gravel								
34bbc1	John Rutz	1957	4,920	D-C	300R	TP 30-300 ft Tp 200-300 ft	I I	31 70R	8- 7-60 1957	480 850	90 	30 48	Aug. 1960 Feb. 1960	AT, observation wells drilled.
25-67-31cdc2	Ed Preuitt	1957	4,652	D-C	512R	Open hole below 155 ft.	I	37	7- 3-58	415	98	210	Aug. 1958	L.
33cdd	John Geringer	1957	4,629	D-C	500R	Open hole below 128 ft.	I	87	6-18-58	465 468R	102 	70 	Aug. 1960 1957	
25-68-26dcd	Joe Howard	1956	4,643	D-R	636R	Open hole below casing.	I	58	6-25-58	452 645	102 	9 	Aug. 1958 June 1958	
31cbd	Steve Black	1956	4,675	D-C	425R 265	 Open hole 141-265 ft.	 I	 34	 7- 9-58	595 505 505	78 87 105	360 22 144	Aug. 1960 Aug. 1958 Dec. 1959	AT, 2 observation wells drilled.
35dbc	John Foos	1957	4,651	D-C	512R	Open hole below 210 ft.	I	12	6-25-58	600	101	5	Aug. 1958	L.
36bcb	LeRoy Rutz	1956	4,636	D-R	628R	Open hole below 170 ft.	I	20	8-12-58	670	106	8	July 1957	
36ccc	Henry Geringer	1958	4,655	D-C	505R	Open hole below 172 ft.	I	4	6-25-58	550	124	5	June 1959	

Terrace deposits

23-68-1ccc	R. S. Willson	1953	4,922	D	43R	No GP, P	I	4	6-4-54	420	10		June 1954	
1ccd	do	1955	4,920	D-C	32R	GP, pebbles, P	I	2	7-1-58	525	12	3	June 1959	
2ccb1	Wallace Baker	1954	4,916	D-C	22R	GP, pebbles, P	N	6	8-18-58	150R			1954	Not used.
2ccb2	do	1960	4,915	D-C	54R									
					51	GP, cobbles, P	N	2	7-21-60	300R	35R	3	Aug. 1960	Tested by pumping.
14ada	J. R. and J.L. Turner	1953	5,026	D	75R	Open hole below 52ft.	I	48	7-18-60	170	18	24	June 1954	
18acc1	Joe Bowen	1953	5,058	Dug	24	P	I	10	12-18-59	820	12	30	Aug. 1958	Fed by radiating tile lines.
18acc2	do	1959	5,058	D-C	70R	P 20-70 ft. No GP	N	10	12-18-59	450R			July 1959	Tested by pumping.
22bcc1	Dr. Corman	1956	5,098	D-RR	40R	GP, cobbles, P	I	5	8-10-60	630		½	Sept. 1958	
										565	11	17	Aug. 1960	Derives water from Ayers Draw.
22bcc2	do	1954	5,098	D-C	28R	P	I	7R	1954	405		½	Sept. 1958	Do.
24-67-4acc	Tom Bennett	1953	4,645	D-C	72R	P	N	58	6-25-58	87R	22	Several	July 1953	Abandoned.
6bcd1	Eldon Johnston	1953	4,670	D-R	43R	P	I	17	7-8-58	220			1954	
										225	13	170	Aug. 1958	
										175	17	240	Aug. 1960	
24-68-2dcc	Whalen	1954	4,715	D	15R	P	I	7R	1954	800R			1954	Not used.
3abc	Robert Harman	1960	4,723	D-C	27R									
					24	GP, cobbles, P	I	5	7-21-60	540	16	287	Aug. 1960	
3bcb	J.W. Lawyer	1953	4,733	D	40R	GP, cobbles, P	I	15	4-6-54	130	18	10	June 1954	
										180	22	360	Aug. 1960	
3bcc	do	1954	4,736	D	33	P	I	17	6-4-54	195	11	10	June 1954	
										215	15	360	Aug. 1960	
4bdc	Leo Norris	1953	4,743	D	38R	P	I	16	6-7-54	210		24	June 1954	
4cbc	Arvid Johnson	1953	4,753	D	42R	P	I	19	6-22-54	227	18	50	June 1954	
5add	Fred Martinez	1953	4,745	D	40R	P	I	15	6-7-54	215	20	130	July 1959	
										125	28	100	Aug. 1960	
5ddd	R. W. Lipsac	1941	4,764	Dug		P	I	23	6-8-54	330		24	July 1959	
7caa	Emerson Utter	1955	4,753	D-C	44R	P	I	10R	1954	100	8		June 1954	
										420	22	5	June 1960	Near subsurface drain.
7dcc	do	1954	4,771	D-RR	33	GP, pebbles, P	I	7	6-23-60	100	25	10	June 1960	
										230	28	5	Aug. 1960	Small rise in water table greatly increases yield.
8adc	Floyd Andrews	1953	4,776	D	42R	P	I	23	6-8-54					
8ccd	Doval Johnston	1955	4,771	D-C	25R	P	I	6	12-8-59	330		25	Aug. 1960	Three wells. Discharge for all three.
8cdc	do	1954	4,775	D-C	25R	GP, P	I	5	9-13-60	110	5	30	Aug. 1959	
8ddc	Floyd Andrews	1953	4,786	D-R	40R	P	I	23	12-8-59					Not used.
9ccc2	Doval Johnston	1953	4,789	D	60R	P	I	15	9-14-60	190	13	24	June 1954	
										165	20	700	Aug. 1960	
9ccc3	do	1953	4,789	D	50R	P	N	21	6-8-54					Not used for irrigation.
9dab	John Brecht	1956	4,773	D-RR	40R	GP, cobbles, P	I	7	12-8-60	430	18	170	July 1959	
										410	25	220	Aug. 1960	
10cdc	Fred Hanes	1953	4,777	D	37R	P	I	7	9-5-58	380	6	1	Sept. 1958	
10cdd	do	1953	4,775	D	38R	P	I	7	9-5-58	220	7	1	Sept. 1958	

TABLE 8.—*Record of large-discharge wells in the Wheatland Flats area, Platte County, Wyo.*—Continued

Well	Owner	Date drilled	Altitude of land surface at well site (feet)	Method used in drilling well	Depth of well (feet)	Well-completion data	Use of water	Depth to water below land surface (feet)	Date of measurement	Discharge (gallons per minute)	Drawdown (feet)	Hours of pumping	Date of measurement	Remarks
						Terrace deposits—Continued								
24-68-10dcc1	Marvin Shoop	1960	4,775	D-C	35R	No GP, P	I	13	6-15-60	130	12	4	Aug. 1960	
10dcc2	do	1960	4,774	D-C	36R	No GP, P	I	16	6-15-60	125	13	45	Aug. 1960	
11cbc	Chaplin	1960	4,760	D-C	46R	GP, pebbles, P	I	15R	7- -60	190	20	8	July 1960	
11ccc	Marker	1960	4,761	D-C	42R	GP, pebbles, P	I	12	7-21-60	425	22	7	July 1960	
11cad	Arlo Bowen	1953	4,742	D-C	40R	P	I	10	8- 8-58	120	8	1	Aug. 1958	
11cdc	do	1954	4,741	D-RR	37R	GP, pebbles, P	I	1	8- 8-58	645	17	1	Aug. 1958	
11cdd	do	1953	4,738	Dug	25R	P	I	7	8- 8-58					Not used.
15acb	Leonard Reese	1953	4,782	Dug	25R	P	I	14	6- 8-54	315	11	Several	June 1954	
15bbd	do	1953	4,785	D	43R	P	I	16	12-11-59					Not used.
16adc	U. V. Combs	1940	4,797	D	37R	P	I	23R	3- -51	300			June 1954	
16cdd	Leonard Reese	1950	4,818	D	52R	P	I	19	3-11-54	465	14	24	Mar. 1954	AT.
17bba	Herman Hellbaum	1955	4,771	D-C	27R	P 12-27 ft	I	7	7- 9-58	385			June 1955	Two wells connected by tile line. Discharge is for both wells.
17dcd	O.S. Preuitt		4,801	Dug	25R	P	I	4	12- 9-59	485	7	9	Sept. 1958	
18acc	R. M. Straw	1938	4,788	D	36R	P	I	10	6-25-53	270	9		June 1953	
18acd	do	1954	4,786	D-C	32R	P	I	10	6-17-54	380		4	June 1954	
18add1	do	1954	4,785	D-C	28R	P	I	12	7-15-54	290		Several	July 1954	
18add2	do	1960	4,784	D-C	25R	P	I	8	8-12-60	230	15	½	Aug. 1960	
20acc	Pearl Sears	1955	4,818	Dug	25R	P	I							
20bcc	R. A. Brown		4,822	D	60R	P	I	17	6- 8-54	260			June 1954	Not used.
20bcd	do	1939	4,822	D	75R	P	N	15	6- 8-54					Do.
20ccd1	Louis Lauck	1934	4,836	Dug	27R	P	I	15	6- 8-54	425			June 1954	
										690	9	8	Sept. 1958	
20ccd2	do	1956	4,837	D	30R	P	I	7	9-24-58	200	5	8	Sept. 1958	
21abc	E. A. and F. R. Miller.	1953	4,822	D	41R	P	I	13R	7- -53	275			June 1954	
21bdb	Leonard Reese	1951	4,830	D	70R	P	I	24	6- 8-54	435	20	Several	June 1954	
21ccc	Chris Franzon	1953	4,849	D	53R	P	I	21	9-13-60	135			June 1954	
										170	20	5	Aug. 1959	

25-67-31ccc2	Robert Hall	1953	4,648	D		40R	P	I	21	5- 6-54	250	5	3	July 1955	AT.
31cdc1	Ed Preuitt	1955	4,650	D		43R	P	I	18	9-15-60	135			July 1955	
											150	18	235	Aug. 1960	
33cdd2	John Geringer	1957	4,630	D		25R	P	I	8	8- 7-58	130	6	5	Aug. 1960	Well connected to tile gathering line.
25-68-31bcd1	Eldon Johnston	1954	4,664	D		68R	P	N	22	6- 9-54					Not used. Pumped 100 gpm, reported.
31bcd2	do	1954	4,663	D		36R	P	N							Not used.
31bda	do	1954		D		58R	P	N	17	9-15-54					Do.
31cba	do	1954		D		52R	P	N	20R	1954					Not used. Pumped 125 gpm, reported.
35dbb	John Foos	1953	4,656	D		85R	P	I	8	6- 9-54					Not used.

TABLE 9.—*Sample logs of test holes and observation wells drilled in the Wheatland Flats area, Wyo.*

Well 23-68-15ddd

[Test hole drilled by Bureau of Reclamation. Log prepared from sample descriptions by R. W. King, Bureau of Reclamation]

Description	*Thickness (feet)*	*Depth (feet)*
Soil	2	2
Terrace deposits:		
Sand and gravel, containing some cobbles	26	28
Sand and gravel, interbedded with brown clayey silt	14	42
Arikaree Formation:		
Sand, brown, fine-grained, silty	11	53
Silt, light-gray	11	64
Sandstone, grayish-brown, fine-grained; interbedded with thin beds of white hard sandy limestone	16	80
Sand, light-gray, fine-grained, silty	5	85
Silt, light-gray, sandy, interbedded with white hard sandy limestone	8	93
Sand, gray, fine-grained, silty	9	102
Limestone, white, hard, sandy	4	106
Sand and sandstone, grayish-brown, fine-grained, silty; interbedded with thin beds of white hard sandy limestone and thin beds of dark-gray shaly clay	15	121
Limestone, white, hard, sandy	7	128
Sandstone, gray, fine-grained, silty, interbedded with white hard sandy limestone	6	134
Sand and sandstone, grayish-brown, fine-grained	4	138
Silt, light-gray, clayey	12	150
Silt, light-gray, clayey, slightly sandy	25	175
Silt, light-gray, sandy	17	192
Sand, light-gray, fine-grained, silty, interbedded with a few thin beds of white hard sandy limestone	48	240
Silt, light-gray to white, clayey, limy	11	251
Sand, light-gray, fine-grained, silty; interbedded with thin beds of white hard limestone	11	262
Sand, light-gray, fine-grained, silty	31	293
Sand, light-gray, fine-grained, silty; thinly interbedded with white hard sandy limestone	7	300
Sand and sandstone, light-gray to light grayish-brown, fine-grained, silty; interbedded with several thin beds of white hard sandy limestone	102	402
Limestone, white, hard, sandy; thinly interbedded with light-gray, fine- to very fine-grained limy sandstone	16	418
Sand and sandstone, light grayish-brown, fine-grained, and a few beds of medium to coarse sand	23	441
Sand and sandstone, grayish-brown, very fine to fine-grained; interbedded with a few white hard sandy limestone beds	11	452
Silt, brown, clayey, sandy; interbedded with thin beds of white hard sandy limestone	23	475
Sand and sandstone, grayish-brown, very fine to fine-grained, silty; interbedded with thin beds of white hard sandy limestone	72	547
Limestone, white, hard, sandy	5	552
Sandstone, light grayish-brown, very fine to fine-grained	13	565
Limestone, white, hard, sandy	3	568
Sandstone, grayish-brown, fine-grained, silty, thinly interbedded with white hard sandy limestone	29	597
Silt, brown, clayey	5	602

Well 24-67-5acd

[Observation well drilled 800 ft east of irrigation well 24-67-5acc]

Soil	3	3
Terrace deposits:		
Gravel, medium to coarse, subrounded, with medium to coarse sand matrix	15	18

TABLE 9.—*Sample logs of test holes and observation wells drilled in the Wheatland Flats area, Wyo.*—Continued

Description	*Thickness (feet)*	*Depth (feet)*
Well 24-67-5acd—Continued		
Arikaree Formation:		
Quicksand, light-brown, fine to medium, well-rounded	80	98
Sand, fine to medium, well-rounded; thinly interbedded with hard limy lenses	14	112
Sand, fine to medium, well-rounded	8	120
Sand, fine, clayey	5	125
Sand, fine to medium, firm; poorly to moderately cemented with lime and clay; hard lens at 140 feet	71	196
Sandstone, hard, limy	2	198
Sand, fine, firm, and a little clay; thinly interbedded with sandy clay	18	216
Sandstone, hard, limy	2	218
Sand, fine to very fine, very clayey, firm, with thin hard limy lenses at 227, 236, and 241 feet	26	244
Sand, coarse, well-rounded (lost circulation)	6	250
Sandstone, hard, limy	4	254
Sand, light-brown, fine, clayey	6	260
Limestone, white, hard	1	261
Sand, light-brown, fine to very fine, containing some clay	28	289
Sandstone, hard, limy	4	293
Sand, very fine, clayey	5	298
Sandstone, hard, limy	1	299
Sand, fine, and some clay	5	304
Sandstone, hard, limy	2	306
Sand, light-brown, fine to medium; thinly interbedded with fine to very fine clayey sand	12	318
Sand, fine, and some clay; thinly interbedded with hard limy sandstone beds	6	324
Sand, fine, very clayey	4	328
Sand, fine, and a little clay	6	334
Sand, fine, clayey; thinly interbedded with hard limy beds, 6 to 12 in. thick	16	350
Well 24-67-7acd		
[Observation well drilled 660 ft west of irrigation well 24-67-7add]		
Soil	6	6
Terrace deposits:		
Clay, white, calcareous	1	7
Gravel, medium, subrounded; has coarse-sand matrix	1	8
Clay, brown, sticky	10	18
Gravel, medium, subrounded	1	19
Clay, brown, sticky	9	28
Gravel, medium to coarse, subrounded; has coarse-sand matrix	26	54
Clay, brown, sticky	2	56
Gravel, medium to coarse, subrounded; has coarse-sand matrix	22	78
Arikaree Formation:		
Quicksand, light-brown, fine to very fine	17	95
Sand, fine to very fine, firm; cemented with various amounts of clay	46	141
Sand, greenish-brown, fine to medium, well-rounded, quartzitic	67	208
Clay, brown, sandy	5	213
Sand, fine to medium; interbedded with fine-grained clayey sand and hard limy sandstone at 235, 239 ft	43	256
Limestone, white, hard, sandy	2	258
Sand, light-brown, fine, clayey	14	272
Sand, fine, clayey; interbedded with medium to coarse well-rounded quartzitic sand	39	311
Limestone, white, hard, sandy	1	312
Sand, medium to coarse, well-rounded, quartzitic	8	320

TABLE 9.—*Sample logs of test holes and observation wells drilled in the Wheatland Flats area, Wyo.*—Continued

Description	*Thickness (feet)*	*Depth (feet)*
Well 24-67-7acd—Continued		
Arikaree Formation—Continued		
Sandstone, hard, limy	1	321
Sandstone, light-brown, very fine grained, silty, well-cemented	11	332
Sand, medium to coarse, well-rounded, quartzitic	7	339
Limestone, white, hard	1	340
Sandstone, light-brown, fine-grained, firm	20	360
Bottom of hole		360
Well 24-68-27bdd		
[Observation well drilled 400 ft west of irrigation well 24-68-27accl]		
Soil, sandy loam	2	2
Terrace deposits:		
Gravel, medium to coarse, subrounded; medium to coarse-sand matrix. Pebbles, predominantly quartz and some andesine feldspar	10	12
Clay, brown, sticky	6	18
Gravel, medium to coarse, subrounded; has medium- to coarse-sand matrix. Pebbles, predominantly quartz, and some andesine feldspar	8	26
Clay, brown, sticky	12	38
Gravel, medium to coarse, subrounded; has medium- to coarse-sand matrix. Pebbles, predominantly quartz, and some andesine feldspar	3	41
Clay, brown, sticky	9	50
Gravel, medium to coarse, subrounded; has medium- to coarse-sand matrix. Pebbles, predominantly quartz, and some andesine feldspar	4	54
Clay, brown, sticky	5	59
Gravel, medium to coarse, subrounded; has medium- to coarse-sand matrix. Pebbles, predominantly quartz, and some andesine feldspar	7	66
Arikaree Formation:		
Sand, light-brown, very fine to coarse, predominantly fine, well-rounded, quartzitic	29	95
Sand, light-brown, fine to coarse, predominantly medium, some cementing	30	125
Limestone, white, hard	1	126
Sand, light-brown, medium to coarse, well-rounded	20	146
Sandstone, light-brown, medium to coarse, well-rounded	8	154
Sand, light-brown, fine to medium; contains lenses cemented with clay at intervals throughout	44	198
Limestone, white, hard	5	203
Sand, light-brown, fine to medium; contains lenses cemented with clay	43	246
Limestone, white hard	2	248
Sand, light-brown, fine to medium	7	255
Limestone, white, hard	2	257
Sand, light-brown, fine, clayey	1	258
Sandstone, light-brown, fine to medium; moderately to firmly cemented with lime or clay	18	276
No sample caught	4	280
Sand, light-brown and greenish, medium to coarse, moderately cemented, well-rounded	20	300
Well 24-68-34bbb		
[Observation well drilled 800 ft north of irrigation well 24-68-34bbc]		
Soil	4	4
Terrace deposits:		
Clay, brown, sticky	3	7
Gravel, coarse to fine, subrounded; has medium to coarse quartz sand matrix	17	24

TABLE 9.—*Sample logs of test holes and observation wells drilled in the Wheatland Flats area, Wyo.*—Continued

Description	*Thickness (feet)*	*Depth (feet)*
Well 24-68-34bbb—Continued		
Arikaree Formation:		
Clay, light- to chocolate-brown, sandy, containing lumps of very fine grained clayey sand	87	111
Sand, white to pink and some gray, very coarse to fine, subangular. Grains composed of quartz and orthoclase and andesine(?) plagioclase; contains lumps of pink fine to medium sand, clay binder from 140 to 160 ft.	94	205
Clay, light-brown, sticky, containing some silt	5	210
Sand, coarse-grained, well-rounded; firmly cemented with lime and clay; predominantly quartz	6	216
Limestone, white, hard, sandy	1	217
Sand, coarse-grained, well-rounded; firmly to poorly cemented with lime and clay; predominantly quartz	36	253
Clay, light-brown, sandy	3	256
Sandstone, coarse-grained, well-rounded, hard; cemented with lime	1	257
Sand, white to pink, coarse, rounded; predominantly quartz	5	262
Limestone, white, hard, containing little sand	4	266
Sandstone, light-brown, fine to very fine grained; firmly cemented with clay binder	24	290
Sand, light-brown to pink, coarse to medium, rounded	6	296
Sand, light-brown, fine to very fine, clayey	4	300
Bottom of hole		300
Well 24-68-34bbc2		
[Observation well drilled 400 ft east of irrigation well 24-68-34bbc1]		
Soil	3	3
Terrace deposits:		
Clay, white, calcareous	3	6
Gravel, coarse to medium, subrounded, containing quartz, orthoclase, and metamorphic minerals; medium to coarse sand matrix	12	18
Arikaree Formation:		
Clay, light-brown, sandy	4	22
Sandstone, light- brown, fine-grained, hard, limy	1	23
Clay, light-brown, sandy	25	48
Clay, yellow, flakey, calcareous	2	50
Clay, light-brown, sandy	6	56
Limestone, white, hard, sandy	1	57
Clay, light-brown, sandy	3	60
Limestone, white, hard	1	61
Clay, light-brown, sandy	13	74
Sand, very coarse to medium, subangular; of quartz and orthoclase and andesine plagioclase composition	16	90
Sand, fine to coarse, subrounded to subangular, poorly to well-cemented with lime and clay; predominantly quartz and containing some orthoclase and andesine	52	142
Limestone, white, hard, silty	4	146
Clay, light-brown, sandy	6	152
Sand, very coarse to medium, subrounded, quartzitic, containing some andesine; slightly to moderately cemented with clay and lime	52	204
Limestone, white, hard	3	207
Sandstone, coarse to medium, rounded; slightly cemented with lime; quartzitic	9	216
Sand, light-brown, fine to very fine, clayey	6	222
Limestone, white, hard, silty	2	224
Sandstone, medium-grained, quartzitic, well-rounded; firmly cemented with lime	26	250
Sandstone, same as above, but not so well cemented	16	266
Clay, light-brown, sandy	5	271

TABLE 9.—*Sample logs of test holes and observation wells drilled in the Wheatland Flats area, Wyo.*—Continued

Description	*Thickness (feet)*	*Depth (feet)*
Well 24-68-34bbc2—Continued		
Arikaree Formation—Continued		
Limestone, white, hard, clayey	1	272
Sand, light-brown, fine to medium, well-rounded, quartzitic	5	277
Clay, light-brown, sandy	4	281
Sandstone, medium to coarse, well-rounded, quartzitic; well cemented with lime	15	296
Clay, light-brown, sandy, to clayey very fine sand	10	306
Limestone, white, hard, silty	3	309
Sandstone, medium-grained, well-rounded, quartzitic, moderately indurated	26	335
Clay, light-brown, sandy	7	342
Clay, white, limy, containing some sand	6	348
Clay, light-brown, sandy, sticky	6	354
Limestone, white, hard	1	355
Clay, brown, sandy, sticky	5	360
Limestone, white, hard	1	361
Clay, white, limy, sandy	1	362
Limestone, white, hard	2	364
Clay, brown, sandy, sticky	5	369
Sand, very coarse to medium, subrounded, quartzitic with some andesine. Some lime cement	11	380
Limestone, white, hard; interbedded with white limy sandy clay at 381–384 and 387–389 ft	11	391
Clay, brown, sandy	3	394
Sand, coarse, well-rounded, quartzitic, moderately cemented; interbedded with light-brown sandy clay	6	400
Limestone, white, hard	2	402
Sandstone, coarse-grained, well-rounded; well cemented with lime	8	410
Sand, light-brown, very fine, clayey	8	418
Sandstone, light-green, fine- to medium-grained, well-indurated, firm; brown sandy clay at 426–428 ft	22	440
Bottom of hole		440
Well 25-68-31 caa		
[Observation well drilled 800 ft north of irrigation well 25-68-31cbd]		
Soil	4	4
Terrace deposits:		
Gravel, medium to coarse, subrounded, composed of quartz, orthoclase, and metamorphic rocks, has a matrix of rounded medium to coarse quartz sand	29	33
Arikaree Formation:		
Quicksand, light-brown, very fine to fine	11	44
Quicksand, light-brown, very fine to fine; interbedded with lenses of very light brown fine-grained hard limy sandstone. Sandstone beds 3 to 6 in. thick, 1 to 2 ft. apart	14	58
Sandstone, hard, limy	2	60
Quicksand, light-brown, fine	5	65
Sandstone, hard, limy	1	66
Quicksand, light-brown, fine; interbedded with lenses of sandstone, moderately cemented with clay and lime	12	78
Sand, light-brown, very fine to fine; moderately cemented with clay and lime	11	89
Sandstone, hard, limy	1	90
Quicksand, light-brown, fine; interbedded with several 3- to 4-in. lenses of hard limy sandstone	5	95
Sandstone, light-brown, fine-grained; firmly cemented with lime and clay; interbedded with 3- to 4-in. lenses of hard limy sandstone	20	115
Sandstone, hard, limy	1	116

TABLE 9.—*Sample logs of test holes and observation wells drilled in the Wheatland Flats area, Wyo.*—Continued

Description	*Thickness (feet)*	*Depth (feet)*
Well 25-6B-31caa—Continued		
Arikaree Formation—Continued		
Sandstone, light-brown, fine-grained; firmly cemented with lime and clay	4	120
Sandstone, hard, limy	2	122
Sandstone, light-brown, fine-grained; firmly cemented with lime and clay; contains 6- to 12-in. lenses of hard very limy sandstone at 133, 138, 143, 150, 157, 159, 161, 163, 169, 174, 179, 184, 204 ft.	115	237
Limestone, white, hard, sandy	2	239
Sandstone, light-brown, fine-grained; firmly cemented with lime and clay containing 6- to 12-in. lenses of hard very limy sandstone	35	274
Limestone, white, hard, sandy	1	275
Sandstone, light-brown, fine-grained; firmly cemented with lime and clay containing 6- to 12-in. lenses of hard very limy sandstone	3	278
Bottom of hole		278
Well 25-68-31cda		
[Observation well drilled 500 ft east of irrigation well 25-68-31 cbd]		
Soil	3	3
Terrace deposits:		
Gravel, medium, subrounded; has coarse sand to silt matrix; pebbles consist of quartz, orthoclase, and metamorphic rocks.	10	13
Clay, light-brown, containing much fine sand	4	17
Gravel, medium to coarse; has coarse sand matrix interbedded with reddish-brown sticky clay	16	33
Arikaree Formation:		
Sandstone, light-brown, fine to very fine grained; firmly cemented with lime	1	34
Quicksand, light-brown, very fine, uncemented	11	45
Sandstone, fine-grained, firm; cemented with lime	1	46
Sand, loose, very fine to fine; interbedded with numerous beds of hard well-cemented sandstone; sandstone beds about 3 in. thick, 1 to 2 ft apart	9	55
Quicksand, light-brown, fine	10	65
Sand, light-brown, fine; firmly cemented with lime, and clay	13	78
Sandstone, very light brown, fine-grained, hard; well-cemented with lime	1	79
Sand, light-brown, fine, firm	13	92
Sandstone, very light brown, fine-grained, hard; cemented with lime	1	93
Sand, light-brown, very fine to fine, firm; interbedded with occasional thin lenses of limy white clay	28	121
Sandstone, very light brown, hard; cemented with lime	1	122
Sand and sandstone, light-brown, fine-grained; firmly cemented with clay and lime	42	164
Sandstone, limy, hard	1	165
Sand, light-brown, fine, firm	4	169
Sand, light-brown, fine, firm; thinly interbedded with beds of hard limy sandstone 4 to 5 in. thick	7	176
Sand, light-brown, fine, firm	7	183
Sandstone, very light brown, hard, limy	2	185
Sand, light-brown, fine, firm	34	219
Sandstone, hard, limy	1	220
Sand, light-brown, fine, firm	7	227
Limestone, white, hard, sandy	3	230
Sand, light-brown, fine, firm, contains limy layer at 238 ft	47	277
Limestone, white, hard, sandy	2	279
Bottom of hole		279

TABLE 10.—*Drillers' logs or sample logs of selected irrigation wells tapping the Arikaree Formation in the Wheatland Flats area, Wyo.*

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Well 23-68-27baa [Drilled for Byrd by Elbert Howe]					
Soil	6	6	Arikaree Formation—Continued		
Terrace deposits:			Gumbo-quartz rock and sand	15	80
Sand, coarse	9	15	Sand and gravel	17	97
Caliche and sand	7	22	Sand, pack	28	125
Sand and gravel	5	27	Reddish-pink silt observed on top of the cuttings pile. Probably Brule siltstone at bottom of hole		
Shale, light-gray	16	43			
Sand and gravel	5	48			
Arikaree Formation:					
Shale, gray, and sand	17	65			
Well 24-67-5acc [Drilled for Ben Lockman by C. J. Galusha]					
Surface loam	6	6	Arikaree Formation—Continued		
Terrace deposits:			Sandstone, brown, soft	20	250
Sand, gray, fine	26	32	Sandstone, brown	30	280
Boulders(?)	8	40	Shell, hard	5	285
Arikaree Formation:			Sandstone, brown	55	340
Shell, hard	2	42	Sandstone, brown, and hard shells	45	385
Sandstone, brown, fine	14	56	Sandstone, brown	55	440
Shale brown	6	62	Sandstone, brown, hard, and shells	25	465
Shale, brown, sandy	8	70	Sandstone, brown, and thin shale streaks	81	546
Sandstone, light-brown	5	75	Shale, brown	12	558
Shale, brown, sandy, and shells	65	140	Sand, light-gray	27	585
Shale, brown, and shells	40	180	Sand, brown, and shells	20	605
Sandstone, brown	12	192			
Shale, brown	23	215			
Shale, brown, sandy	15	230			
Well 24-67-6bcd2 [Drilled for Eldon Johnston by C. J. Galusha]					
Soil	12	12	Arikaree Formation—Continued		
Terrace deposits:			Sand, fine, loose	10	320
Shale and gravel stringers	58	70	Lime, coarse	10	330
Arikaree Formation:			Sand, brown, fine, caving	50	380
Sand, fine caving	51	121	Lime shell, hard	4	384
Shale, brown	28	149	Shale, sandy	6	390
Sand, fine, caving	71	220	Shale, brown	10	400
Lime, coarse, sandy	10	230	Sand, fine, brown	10	410
Sand, brown, fine, caving	10	240	Shale, brown	5	415
Lime, coarse, sandy	40	280	Shell, hard	5	420
Sand, brown, fine, loose	15	295	Sand, brown	10	430
Clay, white, sticky	1	296	Sand, brown, and shale	10	440
Lime, fine, sandy	4	300	Sand, brown	10	450
Lime, coarse, sandy	10	310			
Well 24-67-7add [Drilled for L. A. Shepard by C. J. Galusha]					
Surface	4	4	Arikaree Formation—Continued		
Terrace deposits:			Shale, brown	15	275
Sandrock, gray	2	6	Sandstone, brown	50	325
Shale, gray	24	30	Sand, brown, and shale streaks	60	385
Sand and gravel	55	85	Sand, brown, and hard shells	15	400
Arikaree Formation:			Sand, brown	50	450
Sandrock, gray	30	115	Sand,light-brown	30	480
Shale, gray	50	165	Shale, brown	2	482
Sandstone, gray	20	185	Sand, brown, and shells	18	500
Shale, gray	45	230	Sand, brown, caving	10	510
Sandstone, gray	20	250	Sandstone, brown	25	535
Sandstone, brown	10	260	Sandstone, brown, and shells	21	556

TABLE 10.—*Drillers' logs or sample logs of selected irrigation wells tapping the Arikaree Formation in the Wheatland Flats area, Wyo.*—Continued

Well 24-67-8caa
[Drilled for John Rutz by C. J. Galusha]

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Terrace deposits:			Arikaree Formation—Continued		
Gravel and boulders	38	38	Sandrock	19	191
Sand	18	56	Sand	23	214
Boulders	12	68	Sandrock	5	219
Arikaree Formation:			Sand	28	247
Sand, clay-streaked	57	125	Gravel	4	251
Boulders (?)	3	128	Rock	5	256
Clay, sandy	23	151	Sand	36	292
Sandstone	13	164	Sand and sandstone	226	518
Clay	8	172			

Well 24-68-5ddc
[Drilled for Daniel Jensen by C. J. Galusha]

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Surface	3	3	Arikaree Formation—Continued		
Terrace deposits:			Sandstone, brown	60	285
Boulders	40	43	Sand, brown, with shale streaks	15	300
Arikaree Formation:			Sandstone, brown, fine	50	350
Sand, fine	22	65	Sandstone, varicolored (?)	30	380
Sandstone, brown	75	140	Sand, brown	20	400
Sandrock shell, hard	5	145	Shale, gray	2	402
Sandstone, brown	35	180	Sand shell, hard	8	410
Shell, hard	3	183	Sand, varicolored	10	420
Shale, gray	1	184	Sand, brown, hard	20	440
Sandstone, brown	16	200	Sand, varicolored, hard	10	450
Sand, brown, and shale streaks	20	220	Shell, hard	15	465
Shell, hard	5	225	Sand, brown, shale streaked	35	500

Well 24-68-8ccc
[Drilled for Doval Johnston by C. J. Galusha]

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Terrace deposits:			Arikaree Formation—Continued		
Gravel	25	25	Sand, brown, and shells	85	250
Arikaree Formation:			Sandstone, brown, and brown sand	70	320
Sand, brown, fine	35	60	Shells, hard, and shale streaks	45	365
Shells, hard, and brown sand	75	135	Sand, varicolored, and shale	60	425
Sandstone, brown, containing shale streaks	15	150	Sand, brown, and shale	65	490
Shale, gray	15	165	Shale, gray, sandy	10	500

Well 24-68-9ccc
[Drilled for Doval Johnston by C. J. Galusha]

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Surface	2	2	Arikaree Formation—Continued		
Terrace deposits:			Sand, brown, soft	15	330
Gravel	23	25	Sand, light-brown	30	360
Boulders	9	34	Shell, hard	4	364
Arikaree Formaion:			Shale, gray	4	368
Sandrock, gray, hard	26	60	Sand, light-brown	17	385
Shale, gray	15	75	Sand, brown; shale-streaked	15	400
Sand, light-brown	15	90	Sand, brown	15	415
Shell, hard	4	94	Shale, gray	3	418
Shale, gray	16	110	Sand, light-brown	12	430
Shell, hard	4	114	Sand, varicolored	6	436
Shell, gray	6	120	Sand, gray, hard	14	450
Sand, gray, hard	5	125	Sand, varicolored	6	456
Shale, gray	20	145	Shale, gray	4	460
Shell, hard	5	150	Sand, gray, hard	30	490
Sandstone, gray, hard	25	175	Shale, gray	16	506
Sand, brown	25	200	Sand, gray	14	520
Sand, brown; shale-streaked	30	230	Shale, brown	10	530
Shale, gray	5	235	Sand, light-brown	18	548
Sand, brown	15	250	Sand, varicolored	12	560
Shale, gray	4	254	Sand, varicolored, containing shale streaks	40	600
Sandstone, brown	16	270	Shell, hard, and gray shale	30	630
Sand, light-brown	40	310	Sand, brown, hard	25	655
Shale, gray	5	315			

723-431—64——6

TABLE 10.—*Drillers' logs or sample logs of selected irrigation wells tapping the Arikaree Formation in the Wheatland Flats area, Wyo.*—Continued

Well 24-68-17adc1

[Drilled for Herman Hellbaum by C. J. Galusha]

Material	Thickness (feet)	Depth (feet)
Terrace deposits:		
Gravel	25	25
Arikaree Formation:		
Sand, gray, fine	20	45
Sand, gray, fine, and shale streaks	25	70
Sand, light-brown, fine, caving	25	95
Shell, hard	3	98
Sand, brown, fine, caving	10	108
Shell, hard	4	112
Sandstone, brown	28	140
Arikaree Formation—Continued		
Sand, brown, fine, caving	55	195
Sandstone, brown	5	200
Sand, brown, and shells	120	320
Sand, brown, and shale streaks	80	400
Sand, varicolored	30	430
Shale, gray	12	442
Sand, brown and varicolored	58	500
Shale, gray	15	515
Sand, light-brown, and shale streaks	35	550

Well 24-68-27acc1

[Log of samples from irrigation well drilled for Joe Bowen]

Material	Thickness (feet)	Depth (feet)
No sample	52	52
Arikaree Formation:		
Sand, medium, rounded, well-sorted; grains predominantly quartz; some orthoclase and mafic minerals	3	55
No sample	65	120
Gravel, medium to fine, rounded to subangular; very coarse sand matrix; particles consist of quartz, orthoclase, and metamorphic minerals; pebbles coated with thin lime concretion	5	125
No sample. Driller reports this interval to be the same as 120–125 ft	20	145
Sand, light-brown, fine to very fine, clayey	10	155
No sample	10	165
Sand, very light brown medium, rounded, quartzitic	29	194
Clay, brown, sandy	1	195
Limestone, very light brown, hard, fissile, silty	5	200
Gravel, medium, subangular; pebbles composed of quartz, orthoclase, and andesine; sample also contains pinkish fine- to medium-grained sandstone cemented with lime	3	203
Arikaree Formation—Continued		
No sample	13	216
Sand, medium rounded, quartzitic	10	226
No sample	9	235
Sand, brown to gray, medium to very coarse, rounded to subrounded; predominantly quartz and some andesine	10	245
Clay, light-brown, silty	10	255
Sand, light-brown, fine to very fine, containing much clay and silt	12	267
Gravel, fine, subangular; medium to very coarse sand matrix; predominantly andesine and some quartz	3	270
No sample	5	275
Sand, medium, rounded, quartzitic	10	285
No sample	10	295
Sand, coarse, rounded; predominantly quartz and some andesine; sample also contains light-brown fine to very fine sand and very little medium sand	5	300

Well 25-67-31cdc2

[Drilled for Ed Preuitt by C. J. Galusha]

Material	Thickness (feet)	Depth (feet)
Terrace deposits:		
Sand, coarse, and gravel	35	35
Boulders	20	55
Arikaree Formation:		
Shell, hard	3	58
Gravel and fine sand	17	75
Sand, gray, fine	35	110
Shale, gray	10	120
Sandstone, brown, soft	35	155
Gravel embedded in sandstone	25	180
Sandstone, brown	30	210
Shell, hard	5	215
Sand, brown, and shale streaks	45	260
Sandstone, brown	40	300
Arikaree Formation—Continued		
Sand, varicolored	10	310
Sandstone, light-brown	10	320
Sand, brown, and gravel	30	350
Sand, brown, caving	10	360
Sand, brown, and shells	40	400
Shale, gray	6	406
Sandstone, brown	24	430
Shale, gray	6	436
Shell, hard	4	440
Sandstone, brown	40	480
Shale, gray	5	485
Sandstone, gray	27	512

TABLE 10.—*Drillers' logs or sample logs of selected irrigation wells tapping the Arikaree Formation in the Wheatland Flats area, Wyo.*—Continued

Well 25-68-35dbc

[Drilled for John Foos by C. J. Galusha]

Material	Thickness (feet)	Depth (feet)	Material	Thickness (feet)	Depth (feet)
Soil	3	3	Arikaree Formation—Continued		
Terrace deposits:			Shell, hard	6	224
Gravel, sand, and shale (clay?)	17	20	Sand, brown, and shale streaks	36	260
Arikaree Formation:			Sand, light-brown	25	285
Sand, brown, fine	20	40	Sand, varicolored	30	315
Shell, hard	10	50	Shale, gray	6	321
Sand, brown, soft	15	65	Sand, varicolored	14	335
Shell, hard	7	72	Shale, gray	7	342
Sand, brown, hard, and shale streaks	68	140	Shell, hard	3	345
Sandrock, gray, hard	10	150	Shale, gray	15	360
Sand, brown, soft	55	205	Sand, brown, and shale streaks	40	400
Sand, hard	7	212	Sand, brown, and shale	50	450
Sand, brown, soft	6	218	Sand, varicolored, and shale streaks	62	512

SELECTED REFERENCES

Criddle, W. D., and Marr, J. C., 1945, Consumptive use of water in Idaho: U.S. Soil Conserv. Service, Div. Irrigation, 46 p. Duplicated report.

Darton, N. H., 1903, Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian: U.S. Geol. Survey Prof. Paper 17, 69 p., 23 figs.

Edwards, A. R., 1941, Underground water resources of Chugwater Creek, Laramie River, and North Laramie River valleys, Wyoming: Wyoming Geol. Survey Bull. 32, 32 p., 3 figs.

Hantush, M. S., 1955, Preliminary quantitative study of the Roswell ground-water reservoir, New Mexico: New Mexico Inst. of Mining and Technology, 113 p.

——— 1956, Analysis of data from pumping tests in leaky aquifers: Am. Geophys. Union Trans., v. 37, p. 702–714.

——— 1960, Modification of the theory of leaky aquifers: Jour. Geophys. Research, v. 65, no. 11, p. 3713–3725.

Hantush, M. S., and Jacob, C. E., 1954, Plane potential flow of ground water with linear leakage: Am. Geophys. Union Trans., v. 35, p. 917–936.

——— 1955, Non-steady radial flow in an infinite leaky aquifer: Am. Geophys. Union Trans., v. 36, p. 95–100.

Hubbert, M. K., 1953, The theory of ground-water motion: Jour. Geology, v. 48, pt. 1, no. 8, 944 p., 48 figs.

Jacob, C. E., 1940, On the flow of water in an elastic artesian aquifer: Am. Geophys. Union Trans., v. 21, p. 574–586.

——— 1943, Correlation of ground-water levels and precipitation on Long Island, N.Y.; pt. 1, Theory: Am. Geophys. Union Trans., p. 564–573 [1944].

Littleton, R. T., 1950, Reconnaissance of the ground-water resources of the Wheatland Flats area, Wyoming: U.S. Geol. Survey Circ. 70, 31 p.

Lugn, A. L., 1939, Classification of the Tertiary System in Nebraska: Geol. Soc. America Bull., v. 50, no. 8, p. 1245–1276.

Meinzer, O. E., 1923a, The occurrence of ground water in the United States, with a discussion of principles: U.S. Geol. Survey Water-Supply Paper 489, 321 p., 31 pls., 110 figs.

Meinzer, O. E., 1923b, Outline of ground-water hydrology with definitions: U.S. Geol. Survey Water-Supply Paper 494, 71 p., 35 figs.

Morris, D. A., and Babcock, H. M., 1960, Geology and ground-water resources of Platte County, Wyo., *with a section on* Chemical quality of the water, by R. H. Langford: U.S. Geol. Survey Water-Supply Paper 1490, 195 p., 4 pls., 20 figs. [1961].

Mower, R. W., and Nace, R. L., 1957, Water consumption by water-loving plants in the Malad Valley, Oneida County, Idaho: U.S. Geol. Survey Water-Supply Paper 1412, 31 p., 2 pls., 8 figs.

Rapp, J. R., Visher, F. N., and Littleton, R. T., 1957, Geology and ground-water resources of Goshen County, Wyo., *with a section on* Chemical quality of the ground water, by W. H. Durum: U.S. Geol. Survey Water-Supply Paper 1377, 145 p., 6 pls., 12 figs.

Reed, J. E., and Bedinger, M. S., 1961, Projecting the effect of changed stream stages on the water table: Jour. Geophys. Research, v. 66, no. 8, p. 2423–2428.

Theis, C. V., 1935, The relationship between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., pt. 2, v. 16, p. 889–902.

Theis, C. V., and others, 1954, Estimating transmissibility from specific capacity: U.S. Geol. Survey open-file report, 11 p.

Theissen, A. H., 1911, Precipitation averages for large areas: Monthly Weather Rev., July, p. 1082.

U.S. Bureau of Reclamation, 1958, Supplemental water supply, Wheatland area, Wyoming: U.S. Bureau of Reclamation open-file reconnaissance report, Denver, Colo., 33 p.

Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials with special reference to discharging-well methods: U.S. Geol. Survey Water-Supply Paper 887, 192 p., 6 pls., 17 figs.

Wenzel, L. K., Cady, R. C., and Waite, H. A., 1946, Geology and ground-water resources of Scotts Bluff County, Nebr.: U.S. Geol. Survey Water-Supply Paper 943, 150 p., 12 pls., 14 figs.

Wood, H. E., and others, 1941, Nomenclature and correlation of the North American continental Tertiary: Geol. Soc. of America Bull., v. 52, p. 1–48.

Young, A. A., and Blaney, H. F., 1942, Use of water by native vegetation: Calif. State Div. Water Res., Bull. 50.

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[Major references are in italic]

The U.S. Geological Survey Library has cataloged this publication as follows:

Weeks, Edwin P 1936–

Hydrologic conditions in the Wheatland Flats area, Platte County, Wyoming. Washington, U.S. Govt. Print. Off., 1964.

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Bibliography: p. 77–78.

(Continued on next card)

Weeks, Edwin P 1936– Hydrologic conditions in the Wheatland and Flats area, Platte County, Wyoming. 1964. (Card 2)

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