Ground-Water Resources and Geology of Northern and Central Johnson County Wyoming

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1806

Prepared in cooperation with the Wyoming State Engineer

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By HAROLD A. WHITCOMB, T. RAY CUMMINGS, *and* RICHARD A. McCULLOUGH

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CONTENTS

ILLUSTRATIONS

TABLES

GROUND-WATER RESOURCES AND GEOLOGY OF NORTHERN AND CENTRAL JOHNSON COUNTY, WYOMING

By Harold A. Whitcomb, T. Ray Cummings, and Richard A. McCullough

ABSTRACT

Northern and central Johnson County, Wyo., is an area of about 2,600 square miles that lies principally in the western part of the Powder River structural basin but also includes the east flank of the Bighorn Mountains. Sedimentary rocks exposed range in age from Cambrian to Recent and have an average total thickness of about 16,000 feet. Igneous and metamorphic rocks of Precambrian age crop out in the Bighorn Mountains. Rocks of pre-Tertiary age, exposed on the flanks and in the foothills of the Bighorns, dip steeply eastward and lie at great depth in the Powder River basin. The rest of the project area is underlain by a thick sequence of interbedded sandstone, siltstone, and shale of Paleocene and Eocene age. Owing to the regional structure, most aquifers in Johnson County contain water under artesian pressure.

The Madison Limestone had not been tapped for water in Johnson County at the time of the present investigation (1963), but several wells in eastern Big Horn and Washakie Counties, on the west flank of the Bighorn Mountains, reportedly have flows ranging from 1,100 to 2,800 gallons per minute. Comparable yields can probably be obtained from the Madison in Johnson County in those areas where the limestone is fractured or cavernous. The Tensleep Sandstone reportedly yields 600 gallons per minute to a pumped irrigation well near its outcrop in the southwestern part of the project area. Several flowing wells tap the formation on the west flank of the Bighorn Mountains. The Madison Limestone and the Tensleep Sandstone have limited potential as sources of water because they can be developed economically only in a narrow band paralleling the Bighorn Mountain front in the southwestern part of the project area.

Overlying the Tensleep Sandstone is about 6,000 feet of shale, siltstone, and fine-grained sandstone that, with a few exceptions, normally yields only small quantities of water to wells. The Cloverly Formation and the Newcastle Sandstone may yield moderate quantities of water to wells; but, in some areas, properly constructed wells tapping both formations might yield large quantities of water. The Shannon Sandstone Member of the Cody Shale will probably yield only small quantities of water to wells, but it is the best potential source of ground water in the stratigraphic interval between the Newcastle and Parkman Sandstones.

The Parkman Sandstone and the Lance Formation yield water to relatively shallow wells principally in the southwestern part of the project area. The

Fort Union Formation yields adequate supplies of water for stock and domestic use from relatively shallow wells near its outcrop almost everywhere in the county. A few deep wells tap the Fort Union along the Powder River valley in the northeastern part of Johnson County. Some of these wells flow, but their flows rarely exceed 10 gallons per minute; larger yields could be undoubtedly be obtained by pumping.

The Wasatch Formation is the principal source of ground water in Johnson County. It yields adequate supplies to many relatively shallow stock and domestic wells, some of which flow, but much larger yields probably would require pumping lifts that are prohibitive for most purposes. The Kingsbury Conglomerate and Moncrief Members of the Wasatch Formation, though, may yield moderate quantities of water in some places.

Alluvial deposits underlying the valleys of the Powder River and Crazy Woman, Clear, and Piney Creeks are potential sources of moderate to large supplies of water in the Powder River drainage basin. The permeability of these deposits decreases with distance from the Bighorn Mountain front, so that largest yields can probably be obtained along the upper reaches of these streams.

Most ground water utilized in the project area is for domestic and stock supplies and is obtained from drilled wells and from springs. Water for irrigation is obtained almost entirely by diverting flows of perennial streams. The discharge of wells and springs is small compared to the amount of ground water available, and pumpage generally could be increased considerably without noticeably affecting the quantity of ground water in storage. Overdevelopment of water in the alluvium of the upper reaches of Crazy Woman, Clear, and Piney Creeks, however, might seriously reduce the amount of surface water that currently is available for irrigation.

Water from Precambrian rocks, the Tensleep Sandstone, glacial deposits, and alluvial deposits in the western part of the project area is generally of good quality for domestic, irrigation, and stock use. Water from the Frontier Formation, the Lance Formation, and alluvial deposits in the eastern part of the project area is of poor quality for domestic use and of fair to poor quality for stock use. The water is unsuitable for irrigation under ordinary conditions because of its very high salinity hazard. Water from the Parkman Sandstone is usable as a domestic supply but has limited suitability for irrigation because of its high salinity and high sodium hazards. As a source for stock supplies, the Parkman Sandstone yields water of fair quality. Water from the Cody Shale is unsuitable for most uses.

Water from the Fort Union and Wasatch Formations is usable for domestic purposes, although at many locations the water does not meet suggested domestic standards with respect to dissolved solids, iron, manganese, and sulfate. Hydrogen sulfide is an objectionable constituent of water from some wells. The water generally is unsuitable for irrigation, either because of its high sodium and high bicarbonate content or because of its high salinity hazard. It ranges from good to poor quality for stock use.

INTRODUCTION

LOCATION AND EXTENT OF AREA

The project area constitutes about 2,600 square miles and includes approximately the northern two-thirds of Johnson County (fig. 1).

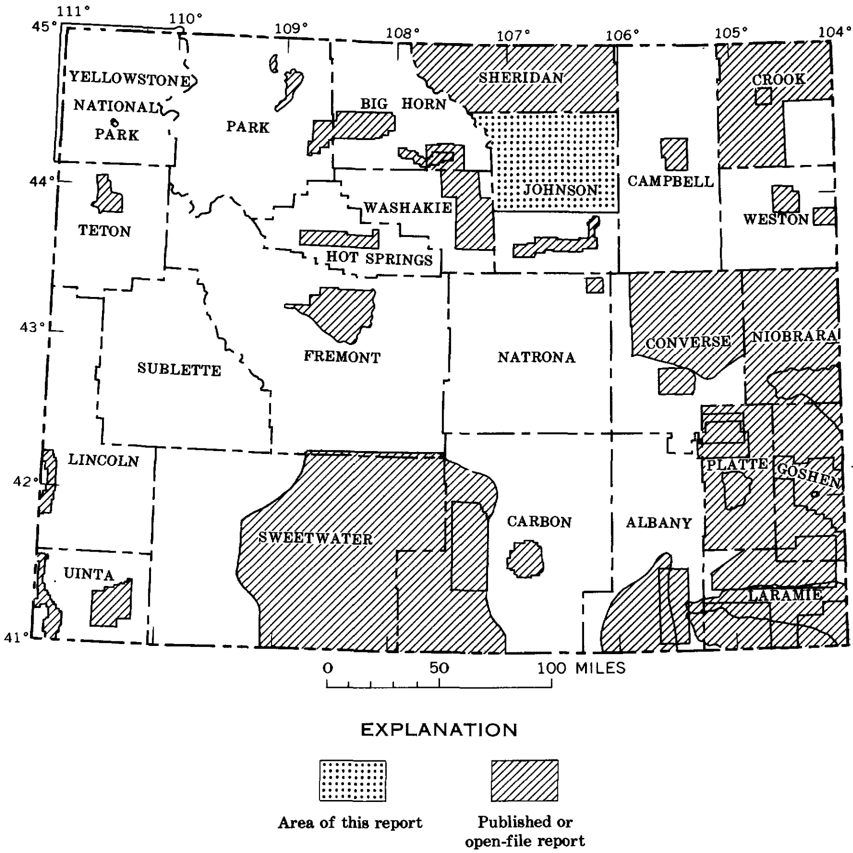

FIGURE 1.—The project area.

The west boundary of the county conforms, for the most part, to the drainage divide along the crest of the Bighorn Mountains. Sheridan County adjoins Johnson County on the north. The east boundary of Johnson County lies 5–8 miles east of the Powder River. The south boundary of the report area is the south line of T. 46 N.

PURPOSE AND SCOPE OF THE INVESTIGATION

The investigation of the ground-water resources of northern and central Johnson County is a part of the continuing program of ground-water studies that was begun in Wyoming in 1940 by the U.S. Geological Survey in cooperation with the Wyoming State Engineer. The purpose of the investigation was to evaluate the ground-water resources and to determine the possibility of developing additional supplies of ground water where present (1963) supplies are unsuitable or inadequate. The work involved a study of the character, thickness, and extent of the principal water-bearing formations and the occurrence, movement, quantity, and quality of the ground water.

The work was begun in October 1959 by R. A. McCullough, who collected much of the hydrologic data. The responsibility for the completion of the investigation was assumed by H. A. Whitcomb upon the transfer of Mr. McCullough in June 1961. T. R. Cummings collected most of the water samples and wrote the chemical-quality section of this report.

PREVIOUS INVESTIGATIONS

Several previous geologic studies included parts of Johnson County. Among the earliest studies were those by Darton (1906 a, b, c), whose geologic descriptions of the Bighorn Mountains and the Bald Mountain-Dayton and Cloud Peak-Fort McKinney quadrangles include the western part of the project area. Gale and Wegemann (1910) made a reconnaissance study of the Tertiary coal deposits in the vicinity of Buffalo, and Wegemann (1912) studied the Sussex coal field, which extends into the southern part of the project area. Demorest (1941) mapped Paleozoic and Triassic units and described faults and folds along the east flank of the Bighorn Mountains. Sharp (1948) studied and mapped the Tertiary conglomeratic rocks along the east flank of the Bighorns. Hose (1955) and Mapel (1959) described and mapped the geology and discussed the mineral deposits in the contiguous Crazy Woman Creek and Buffalo-Lake De Smet areas, respectively.

METHODS OF INVESTIGATION

The study of the geology of northern and central Johnson County, preparatory to the writing of this report, consisted of a brief examination of outcrops and a study of drillers' records and logs. The exposed formations had previously been mapped and described by other geologists, and much of this information has been utilized in preparing this report.

Records were obtained of 278 wells that probably are representative of most of those in the county. The depths of wells and depths to water were measured where possible; otherwise, the data were obtained from the well owner or driller. Information regarding the construction and discharge of wells and the character and thickness of water-bearing materials was usually obtained from drillers' records or from well owners. The discharge of flowing wells was measured where possible.

Water samples for chemical analysis were collected from 31 wells tapping various aquifers and from 3 springs. Test holes were augered at three sites in the valley of the Powder River to determine the thickness and physical character of alluvial deposits.

Geologic and hydrologic field data were recorded directly on a base map adapted from the Wyoming State Highway planning map for Johnson County. Aerial photographs were used in the field to insure maximum accuracy where map detail was lacking.

WELL-NUMBERING SYSTEM

Water wells and oil-test holes shown on the accompanying geologic map (pl. 1) are numbered according to the Federal system of land subdivision. The number shows the location of the well or test hole by township, range, section, and position within the section, as illustrated in figure 2.

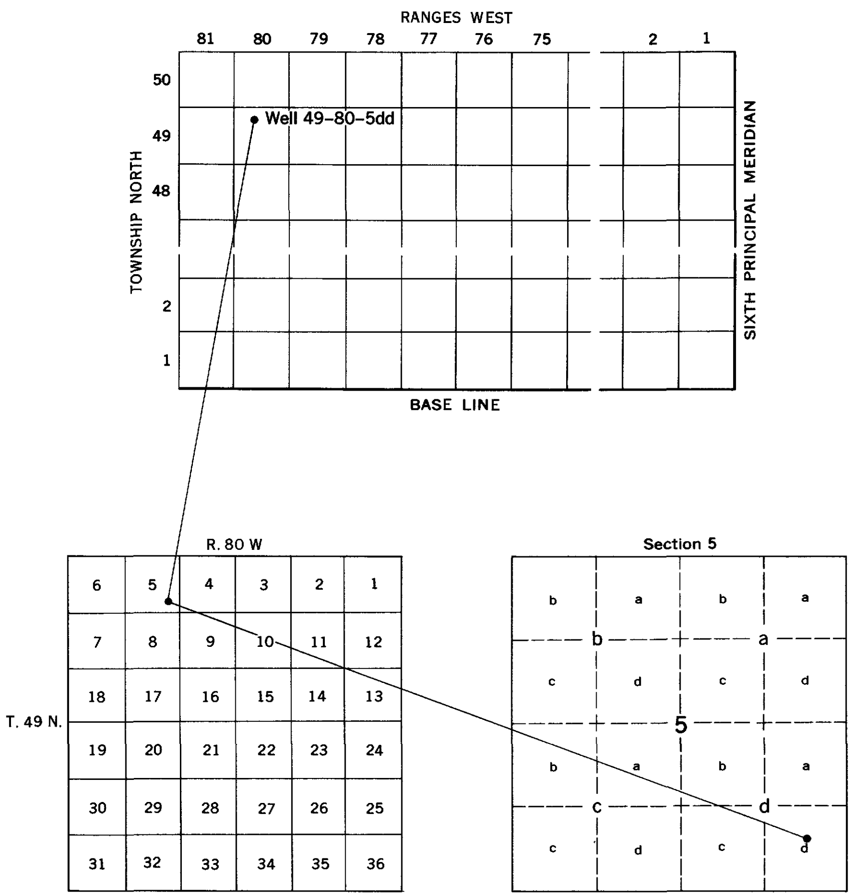

FIGURE 2.—Well-numbering system used in this report.

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 and the second letter the quarter-quarter section (40-acre tract). The subdivision of the sections and quarter sections are lettered a, b, c, and d in a counterclockwise direction beginning in the northeast quarter. Where more than one well is in a 40-acre tract, consecutive numbers beginning with 1 are added to the well number.

ACKNOWLEDGMENTS

The authors appreciate the cooperation of the several well drillers who furnished many well data that could not have been obtained otherwise. Mr. C. T. Reid of Sheridan, Wyo., was especially helpful and provided records of many wells drilled in Johnson County. Ranch owners and tenants permitted and often assisted in collecting hydrologic data and water samples. The Johnson County Agricultural Stabilization and Conservation Office at Buffalo made available records of wells drilled under the conservation program. Mr. Luke H. Baumgardner, geologist for the Reynolds Mining Corp., supplied data on wells drilled in the vicinity of Lake De Smet and records of periodic measurements of water levels in the wells. The Planning Division of the Wyoming Highway Department provided a base map of Johnson County.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

Nearly all the project area lies within the Powder River drainage basin. A small sector along the central part of the west county line however, drains westward into the Bighorn River drainage basin, and about 70 square miles in the northwest corner of the county lies within the Tongue River drainage. The Bighorn Mountains occupy a large part of western Johnson County, whereas central and eastern Johnson County is largely a dissected plain. Altitudes range from about 3,700 feet in the valley of the Powder River at the Sheridan County line to 13,165 feet at the summit of Cloud Peak, the highest point in the Bighorn Mountain range. The maximum relief is about 2,000 feet in the plains east of the mountains, where altitudes range from 3,700 feet to an average of about 5,700 feet in the foothills at the base of the Bighorn Mountain front.

In this report, the term "Powder River structural basin" refers to the broad elongate synclinal region of dipping sedimentary rocks between the Bighorn Mountains on the west and the Black Hills uplift on the east. The Powder River drainage basin, the drainage reach of the Powder River, extends westward to the crest of the Bighorn Mountains.

BIGHORN MOUNTAINS

The Bighorn Mountains, which extend from north-central Wyoming into south-central Montana, are a part of the Rocky Mountain system. They rise abruptly along the west margin of the Powder River Basin to form a high, nearly impassable barrier between the Powder River Basin and the Bighorn Basin to the west (fig. 3). Altitudes along the crest of the mountains generally range from 8,000 to 9,000 feet, although higher summits rise 3,000–4,000 feet above the general level.

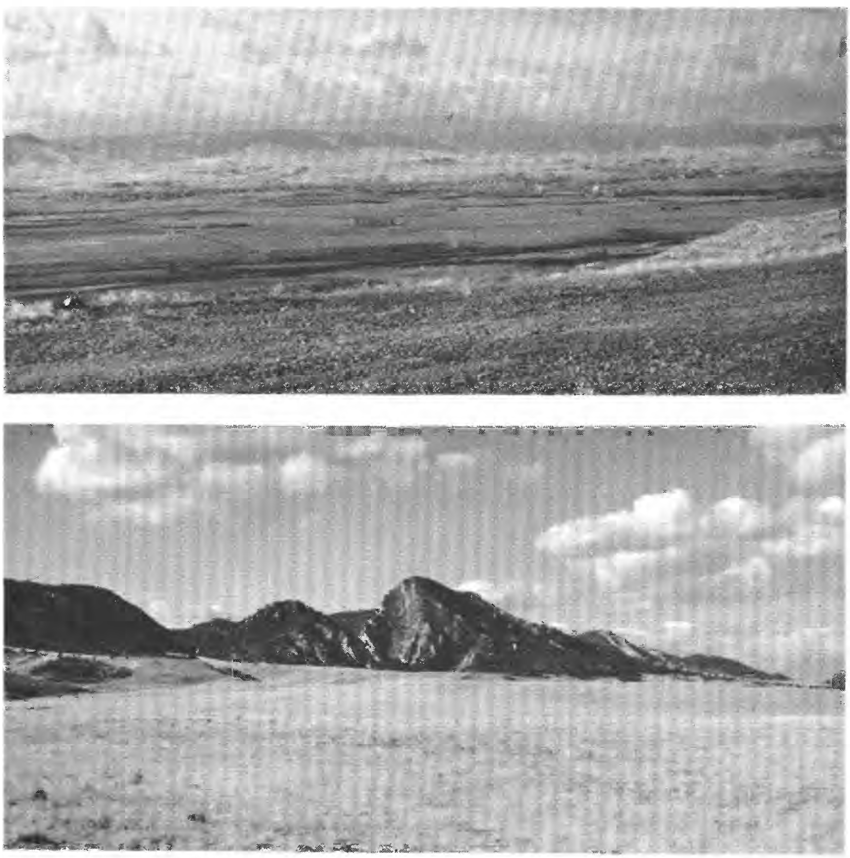

FIGURE 3.—Foothills and Bighorn Mountains northwest across the valley of Clear Creek (upper photo.), and steeply dipping strata along east flank of Bighorn Mountains and gentle basinward slope of pediment (lower photo.).

The higher peaks are underlain principally by granite and have been extensively glaciated. High ridges, deep valleys, and steep-sided cirques, many of which contain small lakes, are characteristic. Remnants of the glaciers that carved this rugged terrain still can be seen in some places. Most of this part of the project area lies above timberline and consists of bare bedrock or of masses of talus at the foot of precipitous slopes. The crest of the mountains, which has a relatively uniform altitude (8,000–9,000 ft.) except where higher peaks rise above the general level, was called the "central plateau" by Darton (1906c, p. 1). Surrounding the central plateau are scarps formed by the upturned edges of strata that dip into the adjacent structural basins. In places the scarps display cliff faces several hundred feet high.

Drainage in the Bighorn Mountains is mainly peripheral away from the summit peaks. Rivulets originating as melt water from deep snow banks converge to form glacial lakes, whence rise the streams that constitute the principal drainage systems in the project area. Piney and Clear Creeks and the forks of Crazy Woman Creek have cut deep narrow canyons in the east flank of the Bighorn Mountains in their descent to the plains. Flows normally are perennial in these upper reaches, but discharges range widely—from spring floods to late summer low flows.

FOOTHILLS

The relatively narrow band of foothills adjacent to the mountain front is characterized by a gently sloping pediment surface that has been carved into rounded ridges and flat-topped benches and terraces by basinward-flowing streams (fig. 3). A few higher ridges, underlain by cobbles and boulders, stand several hundred feet above the surrounding terrain. The ridges and terraces decrease in prominence eastward and gradually coalesce with the broad surface of the Powder River drainage basin.

Dendritic patterns of northeastward-flowing drainage systems have intricately incised the foothills. Most of the streams are intermittent, flowing only during the spring when fed by melting snow on the flanks of the Bighorns or during the summer after heavy or prolonged rains. Clear Creek and its major tributaries, Piney and Rock Creeks, in the northern part of the area, and the forks of Crazy Woman Creek and the North Fork Powder River, in the southern part, generally are perennial and flow during most years. The natural basin occupied by Lake De Smet serves as a storage reservoir for water diverted from Piney Creek during periods of heavy surface runoff. Water thus stored is released into Piney Creek as needed for irrigation downstream during late summer, when streamflow is normally lowest.

POWDER RIVER DRAINAGE BASIN

That part of the Powder River drainage basin in Johnson County east of the foothills is characterized by rounded knobs and steep-flanked ridges and by narrow valleys that become more deeply incised toward the Powder River. The many small streams that are tributary to the Powder River and Crazy Woman Creek have carved the soft shale and sandstone of the basin into local badlands.

The Powder River is the principal stream in the region. It has a drainage area of about 6,000 square miles in Johnson County. Its major tributaries, Crazy Woman and Clear Creeks, head in the Bighorn Mountains and are perennial in their upper reaches, but extensive diversion of water for irrigation may cause flows to be intermittent in the lower reaches during the summer. Drainage is generally to the northeast into the Powder River, thence northward into the Yellowstone River, and ultimately into the Missouri. The Powder, throughout most of its reach in the project area, occupies a rather deeply incised north-trending valley, about ½–1 mile wide. The stream has cut a meandering channel several feet below the general flood-plain level. Flow in the Powder River is extremely variable, ranging from none to several thousand cubic feet per second during sporadic floods after heavy or prolonged precipitation on the drainage area or during the spring period of runoff from snowmelt in the Bighorn Mountains.

CLIMATE AND VEGETATION

The climate of eastern Johnson County is principally that of the northern High Plains—a region of low precipitation, high rate of evaporation, and wide ranges in temperature. In the western part of the county, however, the Bighorn Mountains have a climate of low mean temperatures and relatively high precipitation. The average annual precipitation at Buffalo is 12.11 inches (table 1); this figure is applicable to most of Johnson County except for the foothills, where the average annual precipitation is about 15 inches. Nearly 50 percent of the total annual precipitation normally occurs during April–June. Summer rains are generally brief but heavy, and they are often accompanied by thunder and lightning and occasionally by strong winds and hail Snowfall during the winter is generally light but is frequently driven by strong winds; occasionally, blizzards have caused heavy loss of stock.

Mean monthly and annual temperatures recorded at four weather stations in northern Johnson County are given in table 1. The highest temperature recorded during the period of record (1957–60) at Buffalo is 104°, and the lowest is −28°. Temperatures on the plains to the east

TABLE 1.—*Average monthly and annual precipitation and mean monthly and annual temperatures in northern and central Johnson County, Wyo.*

Station	Period of record (years)	Altitude (feet)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Precipitation [Inches of water; based on published records of U.S. Weather Bur.]															
Buffalo	21	4,645	0.46	0.39	0.96	1.61	1.97	1.92	1.23	0.66	1.10	0.86	0.54	0.42	12.11
Buffalo 5W, 5 miles W. of Buffalo	19	5,240	.45	.52	.93	1.89	2.64	2.73	1.42	.91	1.21	1.03	.72	.45	14.90
Lower Crazy Woman Creek, 25 miles E. of Buffalo	13	3,900±	.54	.42	.80	1.07	1.96	2.86	1.06	.95	.97	.66	.52	.42	12.23
Metz Ranch, 10 miles S. of Buffalo	21	5,280	.32	.32	.71	1.59	2.20	2.19	1.25	.94	1.12	.72	.59	.35	12.31
Temperatures [Degrees Fahrenheit; based on published records of U.S. Weather Bur.]															
Buffalo	4	4,645	22.5	25.5	33.3	42.1	54.2	61.9	68.9	68.6	57.8	46.6	32.3	29.3	45.2
Buffalo 5W, 5 miles W. of Buffalo	18	5,240	25.1	26.6	30.2	42.2	51.0	58.2	67.8	67.0	56.9	47.9	34.2	29.7	44.8
Lower Crazy Woman Creek, 25 miles E. of Buffalo	13	3,900±	18.0	23.1	30.7	43.7	53.0	61.3	70.4	69.1	57.8	46.4	32.1	22.0	44.0
Metz Ranch, 10 miles S. of Buffalo	21	5,280	24.3	27.1	31.0	42.2	52.1	59.9	69.0	68.0	58.6	48.9	34.1	29.5	45.4

are generally somewhat higher in the summer and lower in the winter than are those at Buffalo. Both the highest and the lowest temperatures (107° and −47°) in the project area were recorded at the weather station on lower Crazy Woman Creek, about 25 miles east of Buffalo. The growing season at Buffalo averages 121 days; the shortest period on record between killing frosts is 72 days, and the longest is 167 days. The growing season is somewhat longer in the eastern part of the project area; in the valley of Powder River, it ranges from 100 to 195 days.

Vegetation in the Powder River Basin is principally sagebrush, native grasses, and prickly pear, although dense growths of willows, ash, and cottonwoods flourish locally along the Crazy Woman Creek and Powder River valleys. The slopes and uplands in the Bighorn Mountains support large stands of pine, spruce, and cedar. Aspen thrive in the mountain meadows. Above timberline, vegetation is largely restricted to moss, lichens, dwarf willows, and a sparse cover of hardy native grasses in protected areas.

ECONOMIC DEVELOPMENT

The first white settlers in Johnson County were cattlemen attracted by the abundance of natural resources in the western part of the Powder River drainage basin The vast grazing lands watered by numerous perennial streams were ideal for stock raising. Nearby mountain meadows provided pasturage during the summer, when the climate of the grass lands at lower altitudes becomes hot and dry. Timber growing on the mountain slopes supplied building material, and coal deposits in the vicinity of Buffalo were a convenient source of fuel. The abundance of water also promised adequate supplies for irrigation and industrial development.

Sheep and cattle raising and the cultivation of crops to support the stock industry are the bases of the county's economy; mineral and recreational resources also have contributed to the economy. Hay is the principal crop, but feed grains such as corn, oats, and barley are also grown. Wheat, sugar beets, and potatoes—the major cash crops—are cultivated on a relatively small scale. Wheat is grown by dry-farming methods, and alfalfa and feed grains are grown on both dry and irrigated land, whereas sugar beets and potatoes require irrigation throughout most of the growing season. Coal has been mined intermittently in the Buffalo area for many years, but most of the production has been used by local ranchers. With the advent of natural and manufactured gas fuels, mining was drastically curtailed; and at the present time (1963), production is limited almost entirely to that for domestic use by the mine owners. Coal beds thick enough to be of commercial importance, however, occur in the southern part of the project area, but little effort has been made to develop them. The Billy Creek gas field, about 13 miles south of Buffalo, produced an appreciable quantity of gas before 1947, when its reserves were depleted. Several attempts in recent years to develop other commercial quantities of oil and gas have met with little or no success. Recreational facilities, principally for hunting and fishing, are available in the Bighorn Mountains and at nearby Lake De Smet and are playing an increasingly important role in the economy of Buffalo.

The population of Johnson County was 5,475 in 1960. At that time, more than half the population (2,907) was centered in Buffalo, the county seat and the only incorporated community in the project area.

The region is served by the Chicago, Burlington & Quincy Railroad, which has shipping points at Clearmont and Sheridan, both in Sheridan County. U.S. Highway 87 connects Buffalo with Casper to the south and with Sheridan to the north. U.S. Highway 16 crosses the Bighorn Mountains from the west and joins U.S. Interstate Highway 90, which connects Buffalo with Gillette and the northeastern part of Wyoming. Several gravel-topped or dirt roads provide access to some of the more remote parts of the project area.

GEOLOGY: SUMMARY OF STRATIGRAPHY

Igneous and metamorphic rocks of Precambrian age are exposed in the Bighorn Mountains in the western part of the project area. Sedimentary rocks underlie the rest of the area; they range in age from Cambrian to Quaternary and average about 16,000 feet in thickness. (See fig. 4.) Only rocks of Silurian and Devonian age are absent from the stratigraphic sequence. Clastic rocks ranging from claystone to boulder conglomerate are the predominant lithologic types, but massive limestone and dolomite occur near the base of the sedimentary series. The physical character and thickness of all these formations are shown graphically on plate 2, and the areas of outcrop and the structural relations of the formations are shown on plate 1 and in figure 4.

The age, physical character, and water-bearing properties of all the formations are summarized in table 2, but only those formations that currently yield water to wells in the project area or that may be potential sources of water in the future are discussed in detail in this report. For more complete descriptions of the geologic formations not discussed in this report, the reader is referred to the publications cited in the list of references.

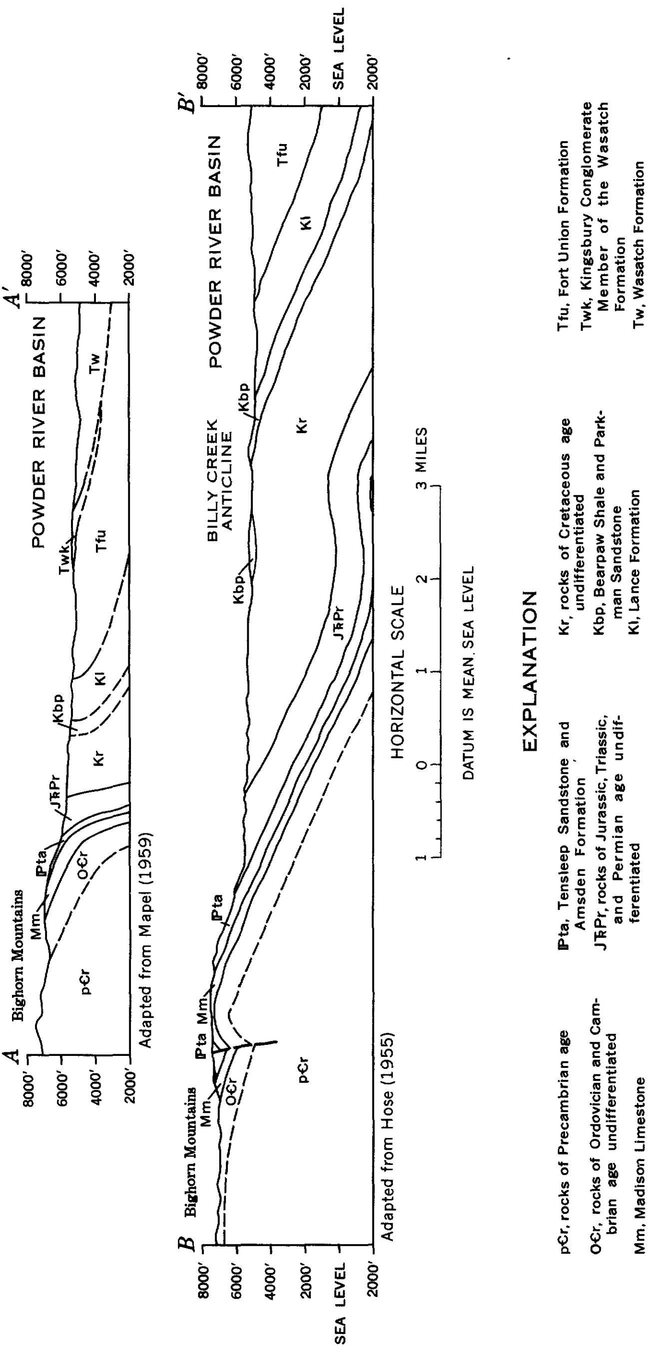

FIGURE 4.—Geologic sections across the east flank of the Bighorn Mountains and the western part of the Powder River structural basin, Johnson County, Wyo. (Location of sections shown on pl. 1.)

TABLE 2.—*Generalized section of the geologic formations in northern and central Johnson County, Wyo.*

System	Series	Stratigraphic unit	Thickness (feet)	Physical character	Water-bearing character
Quaternary	Recent and Pleistocene	Alluvium	0–100±	Unconsolidated flood-plain and terrace deposits of clay, silt, and fine sand containing lenses of coarser sand and gravel that differ locally in thickness and extent.	Yields small quantities of water to a few stock and domestic wells and moderate quantities to several large-diameter wells in the valley of the Powder River.
Tertiary	Eocene	Wasatch Formation: Moncrief Member (in western part of area only)	0–1,400± (Wasatch Formation: 500–2,000±)	Wasatch formation is principally interbedded light-gray fine-grained sandstone and dark-gray to brown shale containing lenticular beds of carbonaceous shale and coal. Moncrief and Kingsbury Conglomerate Members consist of lenses of poorly sorted conglomerate interbedded with light-gray medium- to coarse-grained sandstone and greenish-gray siltstone and shale.	Yields small quanitities of water to many stock and domestic wells and moderate quantities to one irrigation well. Water generally is under artesian pressure, and many wells flow.
		Wasatch Formation: Kingsbury Conglomerate Member (in western part of area only)	0–800		
	Paleocene	Fort Union Formation	1,200±–3,900	Interbedded light-gray and light-brown fine-grained sandstone and darker gray shale containing beds of carbonaceous shale and, in the southern part of area, thin beds of coal.	Yields small quantities of water to stock and domestic wells drilled in or near areas of outcrop and probably yields water to several deep flowing wells in the Powder River valley. Generally deeply buried in rest of area.
		Lance Formation	1,950–2,200	Light-gray fine- to medium-grained sandstone and dark-gray shale containing some thin lenticular beds of carbonaceous shale.	Yields small quantities of water to a few stock and domestic wells drilled in or near areas of outcrop. Generally deeply buried in rest of area.
		Bearpaw Shale	200±	Dark-greenish-gray shale containing some thin beds of light-gray fine-grained sandstone in upper part.	Ground-water possibilities not known; probably poor because of generally low permeability.
		Parkman Sandstone	720±	Light-gray fine- to medium-grained sandstone containing some interbedded dark-gray sandy shale in upper and lower parts.	Ground-water possibilities not known, but probably would yield at least small quantities of water to wells. Generally deeply buried in area.

Cretaceous	Upper Cretaceous	Cody shale	Upper shale member	930	3,600±	Dark-gray noncalcareous shale containing a few thin partings of light-gray fine-grained sandstone in lower part.	Ground-water possibilities not known; probably poor because of low permeability.
			Shannon Sandstone Member	200±		Principally a light-greenish-gray fine-grained sandstone containing many thin partings of dark-gray shale.	Ground-water possibilities not known. Sandstone probably would yield small quantities of water to wells. Generally deeply buried in area.
			Sandstone and shale member	1,070		Dark-gray shale containing interbedded layers of light-gray fine-grained sandstone and siltstone.	Ground-water possibilities not known; probably generally poor because of low permeability and poor quality of water.
			Niobrara Shale Member	985		Grayish-black calcareous shale containing a few thin beds of bentonite.	
			Carlile Shale Member	155		Dark-gray to grayish-black noncalcareous shale; sandy in lower part.	
			Greenhorn Calcareous Member	140		Light-gray fine-grained sandstone in upper part; grayish-black calcareous shale in lower part.	
			Lower shale member	65–80		Dark-gray to grayish-black noncalcareous shale.	
		Frontier Formation		480–515		Dark-gray shale and interbedded light-gray fine-grained sandstone; upper 30–40 ft contains beds of fine- to medium-grained sandstone.	
	Lower Cretaceous	Mowry Shale	Light-gray siliceous shale member	325	525	Light-gray siliceous shale and siltstone; weathers light silvery gray; contains many thin beds of bentonite and some fine-grained sandstone.	Ground-water possibilities not known, but probably poor because of low permeability and expected poor quality of water.
			Black shale member	200		Grayish-black shale containing many thin beds of bentonite and some very fine grained sandstone.	
		Newcastle Sandstone		40–50		Light-gray fine- to medium-grained friable sandstone.	Ground-water possibilities not known; probably would yield small to moderate quantities of water to wells. Generally deeply buried, except in outcrop area.
		Skull Creek Shale		175		Grayish-black shale containing some thin beds of brown siltstone in lower part.	Ground-water possibilities not known, but probably poor because of low permeability.

TABLE 2.—*Generalized section of the geologic formations in northern and central Johnson County, Wyo.*—Continued

System	Series	Stratigraphic unit	Thickness (feet)	Physical character	Water-bearing character
Creaceous—Continued	Lower Cretaceous—Continued	Cloverly Formation	155	Dark-gray shale and interbedded brown siltstone. A light-gray fine- to coarse-grained well-sorted sandstone bed 15–45 ft thick occurs at base.	Basal sandstone probably would yield water to wells. Generally deeply buried, except in outcrop area.
Jurassie	Upper Jurassic	Morrison Formation	185	Variegated shale and claystone; some lenticular beds of light-gray fine-grained sandstone in lower part.	Ground-water possibilities not known; sandstone beds in lower part of Sundance Formation and in upper part of Chugwater Formation probably would yield small supplies to stock and domestic wells. Generally are deeply buried, except in outcrop areas. Rest of formations not considered potential sources of water because of low permeability and probable poor quality of water.
		Sundance Formation	280	Grayish-green sandy shale; 30–40 ft of light-gray fine-grained sandstone at base.	
	Middle Jurassic	Gypsum Spring Formation	120–185	Red shale and claystone containing some light-gray thin-bedded limestone in upper part and limy gypsum in lower part.	
Triassic		Chugwater Formation	750–800	Reddish-brown fine- to medium-grained poorly sorted sandstone, siltstone, and shale. A persistent ledge-forming bed of limestone occurs in upper part.	
Permian		Gypsum and red-shale sequence	180–250	Red shale and siltstone containing thick beds of gypsum in upper part.	
Carboniferous: Pennsylvanian		Tensleep Sandstone	280–355	Light-yellowish-gray to white fine- to medium-grained crossbedded sandstone; contains a few thin beds of pink, purple, and light-yellow dolomite.	Yields small to moderate quantities of water to several springs and reportedly yields large quantities to one irrigation well. Generally deeply buried, except in outcrop area.
		Amsden Formation	250–300	Light-gray cherty dolomite and red and purple shale containing some sandstone and limestone near top and base.	Ground-water possibilities not known; probably would yield some water from sandstone beds and from dolomite, where fractured or cavernous. Generally deeply buried, except in outcrop area.
Carboniferous: Mississippian		Madison Limestone	550–665	Light-yellowish-brown to white limestone, dolomitic limestone, and dolomite.	Ground-water possibilities not known; probably would yield moderate to large quantities of water from fissured and cavernous zones. Generally deeply buried, except in outcrop area.
Ordovician	Upper Ordovician	Bighorn Dolomite	150–395	Yellowish-gray massive dolomite that becomes thin bedded in upper part. A white very fine grained to fine-grained sandstone bed 55–65 ft thick at base.	

Cambrian	Upper and Middle Cambrian	Gallatin and Gros Ventre Formations	550–645	Light-gray thin-bedded limestone in upper part; green micaceous shale in middle part; reddish-brown medium- to coarse-grained sandstone in lower part.	Ground-water possibilities not known; sandstone probably would yield water to wells. Generally deeply buried, except in outcrop area.
	Middle Cambrian	Flathead Sandstone	260–345	Light-yellowish-gray sandstone containing some interbedded green shale and siltstone; reddish-brown coarse-grained sandstone at base.	
Precambrian				Red and gray granite and gneiss.	Yield small quantities of water to several springs in Bighorn Mountains.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING CHARACTERISTICS

Geologic maps in U.S. Geological Survey Bulletins 1027–B (Hose, 1955) and 1078 (Mapel, 1959) were adapted for the geologic map accompanying this report. Much of the following discussion of the geology of the project area also was extracted from these publications, and the reader is referred to them for a more detailed description of the geology and mineral resources of northern and central Johnson County.

The discussion of the water-bearing characteristics of aquifers in the project area is based, as far as available data permit, upon records of wells. The discussion of potential aquifers that had not been developed at the time of the investigation is based principally upon hydrologic studies made in other areas where these formations yield water. In this report the comparative terms "small," "moderate," and "large," as applied to quantities of water, have been given arbitary values of less than 50 gpm (gallons per minute), 50–300 gpm, and more than 300 gpm, respectively.

ROCKS OF PRE-MISSISSIPIAN AGE

Rocks of pre-Mississippian age in Johnson County are too deeply buried, or generally crop out in areas that are too inaccessible, to be considered economical sources of ground water. Except for one well (47–83–7bc), which apparently taps the Flathead Sandstone of Middle Cambrian age (driller's log, table 8, p. 88), and several springs, which yield water from Precambrian granite in the Bighorn Mountains (table 6), no attempts have been made to develop water from these formations because, at most places, there are several productive aquifers at shallower depths. Chemical analysis of water from spring 50–84–10da (table 5) and specific conductances of water from several other springs (table 6) show that water from the granite is only slightly mineralized and is probably soft.

MISSISSIPPIAN SYSTEM

LOWER MISSISSIPPIAN SERIES

The Mississippian System in Johnson County is represented by rocks considered to be of Early Mississippian age. No Upper Mississippian strata have been recognized, and limestone of Early Mississippian age is overlain unconformably by sandstone and shale of Pennsylvanian age.

MADISON LIMESTONE

Outcrop and distribution

The Madison Limestone crops out in the upper slopes of the Bighorn Mountains, where it and the underlying Bighorn Dolomite form a prominent steeply dipping hogback that extends nearly the entire length of the eastern mountain front. Except in its outcrop area, the formation is deeply buried throughout Johnson County. Depths to the formation a short distance east of the mountain front range from about 1,000 feet in the southern part of the project area to more than 11,000 feet in the foothills northwest of Buffalo, where the rocks dip nearly vertically. Depths to the formation may be even greater in areas of downfaulting. The log of an oil-test hole drilled about 3 miles south of Buffalo indicates that, if the test hole had been sufficiently deep, it would have reached the top of the Madison at a depth of about 15,300 feet.

Lithology and thickness

The Madison consists of a thick sequence of light-yellowish-brown to white limestone, dolomitic limestone, and dolomite. The lower unit is principally thin- to thick-bedded dolomite and dolomitic limestone, the middle unit is composed of limestone and dolomitic limestone that locally contain numerous chert nodules and stringers, and the upper unit is principally a finely crystalline thin- to thick-bedded cherty limestone containing solution cavities in its middle part. (See fig. 5.)

FIGURE 5.—Outcrop of Madison Limestone in canyon of North Fork Crazy Woman Creek, showing cavernous zones that may yield large quantities of water at depth.

The formation ranges in thickness from about 550 feet in the southern part of the project area to 665 feet in the northern part. This thickness apparently persists rather uniformly eastward across the Powder River Basin; comparable thicknesses of Pahasapa Limestone, in part the stratigraphic equivalent of the Madison, have been logged in deep oil-test holes drilled adjacent to the Black Hills on the east side of the basin. A section of Madison Limestone measured by Mapel (1959, p. 18–19) follows.

Section of the Madison Limestone in the SW¼ sec. 25, T. 52 N., R. 84 W.

[Adapted from Mapel (1959, p. 18–19)]

	Thickness (feet)
Amsden Formation.	
Unconformity.	
Madison Limestone:	
Limestone, white to light-gray, finely crystalline; thin- to medium-bedded in upper part, becoming thick-bedded in lower part; contains lenses and nodules of gray chert; large solution cavities occur near middle of section	252
Concealed	18
Dolomite, white, dense to earthy, thin-bedded	26
Limestone, light-gray, finely crystalline, dolomitic, thin-bedded	125
Limestone, mottled purple and green, finely to coarsely crystalline, in part oolitic	16
Limestone, light-gray, dense to finely crystalline, dolomitic, thin-bedded	15
Limestone, light-gray, dense to finely crystalline, thin- to medium-bedded	21
Dolomite and dolomitic limestone, light-gray to light-yellowish-brown, dense to finely crystalline, thin- to thick-bedded	193
Total measured thickness	666
Unconformity(?).	
Bighorn Dolomite.	

Water-bearing characteristics

The Madison Limestone had not been developed as a source of water in Johnson County at the time of the investigation (1963). Most of of the major flowing wells in the vicinity of Tensleep, Wyo., on the west flank of the Bighorn Mountains, tap the Madison (Lowry, 1963, table 1) and reportedly yield 1,100–2,800 gpm. Flows from less productive wells in the Madison are reportedly as low as 84 gpm. In the eastern part of the Powder River structural basin, along the west flank of the Black Hills, the Pahasapa Limestone yields water to several wells that flow more than 500 gpm. Drillers' logs indicate that the larger flows are derived from solution cavities or fracture zones that generally occur near the top of the Pahasapa. Undoubtedly, wells of large capacity could be developed in the Madison in Johnson County; but, except in or near the outcrop area, drilling to the great depths required would generally be uneconomical. The Madison Limestone is the best potential source of large quantities of ground water in the project area.

The Madison Limestone probably is completely saturated downdip from the outcrop of the overlying Amsden Formation, and the water is under artesian pressure. Wells drilled in the foothills in the southern part of the area should reach the top of the Madison at depths ranging from 1,000 to 1,500 feet and may flow. The success of such wells will depend upon the presence of fractured and fissured zones or of solution cavities; otherwise, the limestone is too dense to have a high permeability. Probably, however, the Madison was fractured by the crustal movement that accompanied the uplift of the Bighorn Mountains, so that the formation may have a relatively high permeability in some sectors.

In the northern part of the project area, the dip of beds at some places is nearly vertical, and the rocks are extensively faulted and fractured. In much of this sector the depth to the Madison is several thousand feet. Drilling to the Madison, however, probably would not be necessary in most places because the overlying Tensleep Sandstone will normally yield adequate supplies of water for most purposes.

Water in the Madison Limestone in or near areas of outcrop on the east flank of the Bighorn Mountains should be at least as good as that yielded by wells in the vicinity of Tensleep on the west side of the Bighorns, where Madison water generally contains only a moderate amount of dissolved solids, is of the calcium bicarbonate type, and is very hard. The mineralization of the water may be expected to increase with depth and distance from the recharge area, however, because ground water normally increases in mineral content as it moves through the rocks.

PENNSYLVANIAN SYSTEM

AMSDEN FORMATION

The Amsden Formation overlies the Madison Limestone and consists mainly of 250–300 feet of interbedded gray cherty dolomite and red and purple shale but has some sandstone and limestone near the top and base. It is mapped with the overlying Tensleep Sandstone, which also is of Pennsylvanian age. The Amsden is not considered to be a potential source of large quantities of ground water, because it is relatively impermeable; however, it may be a source of additional water if the supply in the overlying Tensleep proves to be inadequate. Several wells drilled in the vicinity of Tensleep penetrated the Amsden, but they were continued into the underlying Madison to obtain larger supplies.

TENSLEEP SANDSTONE

Outcrop and distribution

The Tensleep Sandstone is exposed on the east flank of the Bighorn Mountains, where it forms a prominent dip slope that rises abruptly from the adjacent foothills. The eroded edge characteristically forms a protective bluff above the softer shale of the underlying Amsden Formation. The outcrop, which is relatively broad in the southern part of the project area, narrows abruptly near the middle of T. 49 N., R. 83 W., and is absent at some places in the northern part of the county, where faulting has caused the formation to be buried. The Tensleep persists in the subsurface eastward across the Powder River structural basin and crops out on the west flank of the Black Hills uplift as the Minnelusa Formation. In the southern part of the project area, the depth to the formation increases eastward to as much as 12,000 feet within 10 miles from the outcrop. In the northern part of the area, where the dip of beds generally is steeper and downfaulting has occurred locally, the depth increases more rapidly.

Lithology and thickness

The Tensleep is principally a light-yellowish-gray to white sandstone containing a few thin beds of pink, purple, and light-yellow dolomite. The sandstone is fine to medium grained, well sorted, and generally friable, except where more resistant dolomitic layers occur. It is thick bedded and characteristically has large-scale crossbedding. Apparently, the formation contains few, if any gypsum and anhydrite beds like those that are common in the Minnelusa Formation in the eastern part of the Powder River structural basin. The following stratigraphic section, 280 feet thick, measured by Mapel (1959, p. 23–24), is reprentative of the Tensleep Sandstone throughout most of the project area. Hose (1955, p. 108–109) described a 355-foot section of Tensleep Sandstone in the southern part of the project area, where the unit contains a smaller proportion of dolomite and dolomitic sandstone. The thickness of the formation in northern and central Johnson County probably ranges between these two measured thicknesses.

Section of the Tensleep Sandstone in the SW¼ sec. 6, T. 52 N., R. 83 W.

[Adapted from Mapel (1959, p. 23–24)]

	Thickness (feet)
Gypsum and red shale sequence	
Unconformity	
Tensleep Sandstone:	
Sandstone, white to light-yellow, fine- to medium-grained, friable, thick-bedded, crossbedded, jointed and fractured	44
Sandstone, pink and yellow, dolomitic, thin-bedded	6
Sandstone, white to light-yellow, fine- to medium-grained, friable, crossbedded	6
Sandstone, purple, medium-grained, dolomitic, firmly cemented, thin-bedded	6
Dolomite, purple, finely crystalline, thin- to medium-bedded	9
Sandstone, pink, fine- to medium-grained, dolomitic, hard, slabby	11
Sandstone, white, fine- to medium-grained, friable, medium- to thick-bedded, crossbedded	76
Dolomite, pink and red, silty and sandy, thin-bedded	6
Sandstone, yellow, fine-grained, dolomitic, firmly cemented, very thin bedded	3
Sandstone, white to light-yellowish-gray, fine- to medium-grained, friable, thick-bedded, crossbedded; some interbedded dolomite in lower part	82
Dolomite, yellow, hard, thin-bedded	2
Sandstone, white and yellow, fine- to medium-grained, friable to firmly cemented, thin-bedded, crossbedded	12
Sandstone and dolomite; sandstone is white, fine to medium grained, friable	17
Total measured thickness	280
Amsden Formation.	

Water-bearing characteristics

Only three of the wells inventoried apparently tap the Tensleep Sandstone. (See drillers' logs, table 8.) Well 46–83–22dd, which is 258 feet deep and starts in the gypsum and red-shale sequence, bottomed in 2 feet of sandstone, probably marking the top of the Tensleep, and reportedly yields 600 gpm by pumping. Unfortunately, this yield could not be verified, because the pump was not in operation at the time of the investigation. Chemical analysis of water from this well (table 5) indicates that at least some of the water is from the overlying gypsum and red-shale sequence; but unless extensively fractured and fissured, these strata would not be expected to yield more than small quantities of water. Likewise, the thin section of sandstone penetrated probably would not yield the amount of water reported unless it, too, was fractured. The water level in the well was 56 feet below the land surface when measured in April 1961.

Well 47–83–15cd is in the outcrop area of the Tensleep and penetrates nearly 300 feet of the unit. The driller's log indicates that a water-bearing zone was penetrated at a depth of 286 feet; the water level was 64 feet below the land surface when measured in August 1960. A specific-conductance test of the water shows it has a relatively low dissolved-solids content. A 5-hour bailing test of the completed well reportedly indicated a drawdown of 15 feet at a discharge of about 5 gpm. Because the well penetrates only a few feet of water-bearing strata, a deeper well would probably yield appreciably greater quantities of water.

Well 49–83–27dc, which penetrates only about 115 feet of Tensleep Sandstone, reportedly yields 33 gpm. Greater production might be obtained by deeper drilling, because as much as 200 feet of saturated Tensleep may lie below the bottom of the well. Depth to water in the well could not be measured.

The Tensleep Sandstone also yields water to several flowing wells on the west flank of the Bighorns. Measured flows from wells tapping the formation in the vicinity of Tensleep range from about 10 to 462 gpm, and the flow of one spring is reportedly 900 gpm (Lowry, 1963, table 1).

The Tensleep Sandstone is probably second only to the Madison Limestone as a potential source of irrigation water in Johnson County. The formation generally is saturated, but only locally does it lie within an economical drilling depth for most purposes. Field observations indicate that the formation has a fairly high permeability, which would be much greater where the sandstone is fractured and jointed. (See fig. 6.)

Drilling in the Tensleep Sandstone should be done in the outcrop area of the unit or only a short distance east of the outcrop of the overlying gypsum and red-shale sequence because the steep dip of beds along the east flank of the Bighorn Mountains causes the formation to lie at great depths throughout the rest of the area. Consequently, most wells necessarily will be in places where the soil or terrain is not suitable for irrigation; however, canals or pipe lines could be used to carry the water by gravity from the well site to places more suitable for the cultivation of crops. If more than one well is required to obtain the quantity of water desired, care should be taken to determine the proper spacing of the wells so that interference between them it not excessive. This interference may cause a serious local decline in pressure and an accompanying decrease in yield. To reduce the danger of excessive interference, one or more of the wells might be deepened to tap the Madison Limestone, in which artesian pressures normally are greater than they are in the Tensleep.

FIGURE 6.—Outcrop of Tensleep Sandstone in canyon of North Fork Crazy Woman Creek; the fractures, joints, and bedding planes may yield moderate to large quantities of water at depth.

Chemical analyses of water samples from two wells and one spring are given in table 5. The water from well 46–83–22dd probably is contaminated by water from the overlying gypsum and red-shale sequence. Water from wells drilled in the Tensleep Sandstone in or near its outcrop area will generally be suitable for most uses, although the water is likely to be very hard. Deeper wells drilled at greater distances from the recharge area will probably yield more highly mineralized water.

UNDIFFERENTIATED ROCKS OF PERMIAN, TRIASSIC, AND JURASSIC AGE

The Tensleep Sandstone is overlain by a thick sequence of rocks that comprises, in ascending order, an unnamed sequence of gypsum and red shale of Permian age, the Chugwater Formation of Triassic age, the Gypsum Spring Formation of Middle Jurassic age, and the Sundance and Morrison Formations of Late Jurassic age. Outcrops generally weather to grass-covered slopes and ridges and, except for the conspicuous red band formed by the Chugwater Formation along the base of the Bighorn front, are poorly exposed. The total thickness of these rocks in Johnson County is about 1,600 feet.

None of the wells inventoried penetrate these formations, but wells tapping sandstone in the Morrison, Sundance, and Chugwater Formations would probably yield small quantities of water acceptable for stock and domestic use. The water is generally under artesian pressure and will rise in wells that penetrate water-bearing beds.

The chemical quality of the water is probably somewhat better than that of water from these formations in the eastern part of the Powder River structural basin, where concentrations of calcium and sodium sulfate limit the suitability of the water for some uses. Wells drilled in northern and central Johnson County will generally be nearer areas of reacharge, so that the water will have had less opportunity to dissolve these undesirable minerals from the aquifers.

Water from the Gypsum Spring Formation and the gypsum and red-shale sequence is probably so highly mineralized that its suitability is marginal even for stock use. Thus wells penetrating these formations should be cased or plugged back to prevent contamination of water in underlying or overlying aquifers.

CRETACEOUS SYSTEM

LOWER CRETACEOUS SERIES

CLOVERLY FORMATION

The Cloverly Formation is the basal unit of the Cretaceous System in Johnson County and conformably overlies the Morrison Formation of Jurassic age. Waagé (1959, fig. 5) postulated that the Cloverly Formation in the Bighorn Basin is probably the lithogenetic equivalent of the Inyan Kara Group in the eastern Powder River structural basin. Love (1945) extended use of the name Cloverly from the Bighorn Basin to the western Powder River basin. The Inyan Kara Group is the principal source of ground water for many wells in the Black Hills region.

Outcrop and distribution

The Cloverly crops out as a narrow band of sandstone and shale that persists, except where locally concealed by faults, along the entire east side of the Bighorn Mountains. The resistant sandstone beds are conspicuous as low rocky ridges rising above grass-covered slopes underlain by intervening shale. The formation is probably present at depth throughout the Powder River structural basin, although it is not recognizable in samples from some deep oil-test holes drilled near the center of the basin, where the predominance of shale may cause it to be indistinguishable from the overlying Skull Creek Shale.

Lithology and thickness

The Cloverly Formation consists of a basal sandstone unit, averaging about 30 feet in thickness, overlain by a sequence of dark-gray to brownish-black shale and brown siltstone that grades vertically into the overlying Skull Creek Shale. Mapel (1959, p. 36) placed the contact with the Skull Creek at the top of the uppermost persistent bed of brown siltstone. The basal sandstone is light gray to light yellowish gray, fine to coarse grained, generally well sorted, and crossbedded. It becomes increasingly fine grained in its upper part and grades into the overlying siltstone and shale. The formation is about 155 feet thick in the project area, which is about half the average thickness of the Inyan Kara Group exposed in the Black Hills. A section measured by Hose (1955, p. 104) in the southern part of the project area follows.

Section of the Cloverly Formation in sec. 25, T. 49 N., R. 83 W.

[Adapted from Hose, (1955, p. 104)]

	Thickness (feet)
Skull Creek Shale	
Cloverly Formation:	
Siltstone, brownish-gray, calcareous, thin-bedded to slabby; forms ledge	5½
Shale and siltstone, light- to dark-gray, calcareous; some beds are ferruginous; contain iron-stained siltstone concretions in upper part	112
Sandstone, light-yellowish-gray, medium-grained, well-sorted, lenticular	2
Shale, brownish-black, carbonaceous	9
Mostly concealed; appears to be mainly gray silty sandstone	17
Sandstone, very light gray, fine-grained, well-sorted, calcareous, thin-bedded, crossbedded	8
Sandstone, light-yellowish-gray, medium- to coarse-grained, fairly well sorted, crossbedded	3
Total measured thickness	156½
Morrison Formation.	

Water-bearing characteristics

No wells in the project area are known to tap the Cloverly Formation. Areas of outcrop are narrow, and the beds dip steeply (dips range from about 20° in the southern part of the area to nearly vertical in the northern part). Thus, the formation lies at excessive drilling depths for stock water a short distance east of the outcrop. The basal sandstone of the Cloverly probably is the only potential source of more than small quantities of water of good quality between the Tensleep Sandstone and the Newcastle Sandstone.

Drilling in the Cloverly should not be terminated until the gray, green, and red shale of the underlying Morrison Formation is reached, because, owing to the steep dip of the beds, the apparent thickness of the basal sandstone may be appreciably greater than the 28 feet measured in the outcrop. Some additional water can probably be obtained from the underlying Morrison Formation, but the increase in yield generally would not warrant the expense of a deeper hole; rather, drilling into the Cloverly at another site would probably be more advisable.

Wells drilled where the Cloverly lies within an economical drilling depth will probably yield water that is suitable for most uses. Water from the Inyan Kara Group on the east side of the Powder River Basin, however, generally contains more iron than is desirable in water for domestic use.

SKULL CREEK SHALE

The Skull Creek Shale consists of about 175 feet of grayish-black marine shale containing some thin lenticular beds of brown silstone in the lower part. The formation grades vertically into the underlying Cloverly Formation and the overlying Newcastle Sandstone. The Skull Creek is relatively impermeable and is not considered to be an aquifer in the project area.

NEWCASTLE SANDSTONE

Outcrop and distribution

The Newcastle Sandstone (familiarly known to oil-well drillers as the Muddy sand or Muddy) crops out in the southern part of the project area as a fairly prominent sinuous ridge between the adjacent Skull Creek and Mowry Shales. Where the sandstone is relatively nonresistant, outcrops are concealed beneath a grass or pine cover. In the northern part of the area, downfaulting has at many places caused the formation to be buried beneath deposits of Tertiary age. The Newcastle generally is readily identified in deep oil-test holes and serves as a dependable marker bed throughout the Powder River Basin.

Lithology and thickness

The Newcastle is principally a light-gray fine- to medium-grained standstone containing thin partings of black shale near the top and base, which in some places cause the contact with underlying and overlying formations to be gradational. It generally is friable and thin bedded to slabby but commonly is crossbedded. The thickness of the formation ranges between 40 and 50 feet in the project area. The following section measured by Mapel (1959, p. 40) illustrates the predominantly sand character of the Newcastle in Johnson County.

Section of the Newcastle Sandstone in the center of the SE¼ sec. 31, T. 52 N., R. 83 W.

[Adapted from Mapel (1959, p. 40)]

	Thickness (feet)
Mowry Shale	
Newcastle Sandstone:	
Sandstone, gray, fine- to medium-grained, friable	8
Sandstone, light-gray to white, fine-grained, thin-bedded, cross-bedded	28
Sandstone and shale, interlaminated; becomes more shaly toward base	3
Bentonite, gray	1
Total measured thickness	40
Skull Creek Shale.	

Water-bearing characteristics

The authors were not able to find any wells in the project area that tap the Newcastle Sandstone. Examinations of Newcastle outcrops, however, indicated that it has a relatively high permeability and, where saturated, should yield small to moderate quantities of water to wells.

Wells drilled to penetrate the Newcastle should be in or, generally, only a short distance east of the outcrop area. Water levels in wells drilled east of the contact with the overlying Mowry Shale should rise to within a few feet of the land surface; wells in low areas might flow. If insufficient water is obtained from the Newcastle Sandstone, supplemental supplies could probably be developed in some sectors by drilling an additional 400–500 feet, depending upon the dip, to tap the basal sandstone of the Cloverly Formation.

No data are available on the chemical quality of water in the Newcastle Sandstone in the project area. Water from wells drilled in or near the outcrop, however, should be suitable for most uses, whereas water from deep wells will probably be rather highly mineralized.

MOWRY SHALE

The Mowry Shale consists of about 525 feet of light-gray to grayish-black siliceous shale containing some thin beds of siltstone and light-gray sandstone and many thin beds of bentonite. It lies comformably on the Newcastle Sandstone. The formation is not considered to be a potential source of water either in Johnson County or elsewhere in the Powder River Basin.

UPPER CRETACEOUS SERIES

FRONTIER FORMATION AND CODY SHALE

Overlying the Mowry Shale is about 4,000 feet of predominantly dark-gray and black marine shale containing subordinate amounts of interbedded siltstone and fine-grained sandstone. The rocks comprise, in ascending order, the Frontier Formation and the Cody Shale. Except possibly for the Shannon Sandstone Member of the Cody Shale, these rocks are not considered to be potential aquifers in places where other sources are available. In some areas where other sources are not available, however, sufficiently deep wells may yield adequate supplies of water for stock use. In prospecting for water in the outcrop of the Frontier Formation and Cody Shale, sites that are underlain by alluvial deposits and that may receive recharge from surface runoff, such as along small streams or draws, should be tested first. Supplies obtained from the alluvium may be small and ephemeral, but they might be a welcome supplement to any water developed from the underlying bedrock.

The chemical quality of the water probably will range from marginal for a domestic supply to unfit for stock consumption. The analysis of water from a well (50–83–36aa) drilled in the Cody Shale is given in table 5.

SHANNON SANDSTONE MEMBER OF THE CODY SHALE

Outcrop and distribution

The Shannon Sandstone Member lies approximately 1,000 feet below the top of the Cody Shale. It persists in a poorly exposed outcrop along much of the west margin of the project area, where it generally underlies smooth grass-covered slopes. In some places in the northern part of the area, the formation has been displaced by faulting and is concealed beneath younger beds.

Lithology and thickness

The Shannon is principally a light-greenish-gray fine-grained friable sandstone about 215 feet thick that contains many thin partings of dark-gray shale. The sandstone becomes more shaly in its upper and lower parts and grades into overlying and underlying shaly members of the Cody Shale. A section measured by Hose (1955, p. 93–94) in the southern part of the project area is considered to be representative of the Shannon Sandstone Member in both lithology and thickness.

Section of the Shannon Sandstone Member of the Cody Shale in secs. 13 and 14, T. 49 N., R. 83 W.

[Adapted from Hose (1955, p. 93-94]

	Thickness (feet)
Cody Shale:	
Upper shale member.	
Shannon Sandstone Member:	
Sandstone and shale, interbedded; sandstone is very light gray, fine to medium grained, very thin bedded; shale is dark gray, sandy	76
Sandstone, pale-olive, very fine grained; contains many thin partings of dark-gray shale, especially in lower part	139
Total measured thickness	215
Sandstone and shale member.	

Water-bearing characteristics

The Shannon Sandstone Member, although fairly thick and persistent, probably would not yield more than small quantities of water to wells in Johnson County because of its generally low permeability. It is, however, the best potential source of ground water in the area lying between outcrops of the Newcastle Sandstone and the Parkman Sandstone, and it generally should yield adequate supplies for a stock well.

Analysis of water from oil-test holes in the Shannon Sandstone Member in secs. 17, 21, and 28, T. 48 N., R. 82 W., show that the water is unsuitable for most domestic uses and of poor quality for stock use. It has a dissolved-solids content ranging from 2,100 to 3,300 ppm and is of a sodium bicarbonate or sodium chloride type. Wells drilled into the Shannon in or near outcrops will undoubtedly yield water of better quality than will wells tapping the member where it lies deeper in the Powder River Basin.

PARKMAN SANDSTONE

Outcrop and distribution

The parkman Sandstone crops out in a series of ledges and ridges of resistant sandstone that rise prominently above outcrops of the underlying Cody Shale and overlying Bearpaw Shale. It serves as a convenient marker bed in logging oil-test holes throughout much of the western and central Powder River structural basin. Farther east the sandstone becomes more shaly and loses its identity in the upper part of the Pierre Shale.

Lithology and thickness

The Parkman Sandstone is light gray, generally fine to medium grained, and weakly to firmly cemented. The formation is about 720 feet thick. Beds are thin to moderately thick and commonly are crossbedded. Interbedded dark-gray shale in the lower part of the formation becomes increasingly abundant toward the base, and the contact

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with the underlying Cody Shale is gradational. A thin persistent bed of white sandstone, which marks the top of the formation in Johnson County, forms a sharp and conspicuous lithologic break with the overlying Bearpaw Shale. Hose (1955, p. 92–93) described a section of the Parkman Sandstone exposed near the central part of the outcrop in the project area. The section is considered to represent the average thickness of the formation.

Section of the Parkman Sandstone in sec. 13, T. 49 N., R. 83 W.

[Adapted from Hose (1955, p. 92–93)]

	Thickness (feet)
Bearpaw Shale.	
Parkman Sandstone:	
Sandstone, white, fine-grained, friable, crossbedded	8
Shale, pale- to moderate-brown, carbonaceous	25
Sandstone, very light gray, fine- to medium-grained, friable, medium-bedded	130
Shale and sandstone, interbedded; shale is dark greenish gray, silty; sandstone is very light gray, very fine grained, thin bedded	45
Sandstone and shale, interbedded; sandstone is very light gray, very fine to fine grained, moderately thick bedded, crossbedded; shale is dark greenish gray	85
Sandstone, very light gray, fine- to medium-grained, thin- to thick-bedded, crossbedded	283
Sandstone and shale, interbedded; becomes more shaly toward base; sandstone is very light gray, fine grained, thin bedded, crossbedded; shale is dark gray	145
Total measured thickness	721
Cody Shale.	

Water-bearing characteristics

The Parkman Sandstone has not been tapped by many wells in the project area. Only three of the wells inventoried yield water from the formation, but there may be others in the area that were not visited by the authors. The wells range from 105 to 150 feet in depth and apparently penetrate only the lower part of the formation, as indicated by their location on the outcrop and by the lithologic descriptions in the drillers' logs. (See logs of wells 46–82–9ad, 48–82–18ad, and 48–82–20bc, table 8.)

Well 46–82–9ad penetrated water-bearing sandstone at a depth of about 130 feet, and the water rose in the hole to within 5 feet of the surface. The well reportedly yielded 6 gpm with a drawdown of 27 feet when test bailed; thus, the permeability of the saturated zone penetrated at this site is very low. The yield of the well and the artesian head might have been increased appreciably if a greater thickness of saturated sandstone had been penetrated. Well 48–82–18ad yielded only 3.5 gpm with 35 feet of drawdown during a bailing test. No data are available on the yield of well 48–82–20bc.

The thick beds of sandstone that make up the bulk of the Parkman in the southern part of the project area will probably yield at least moderate quantities of water to properly constructed wells. Wells drilled in the outcrop should be located along its east margin, where possible, to insure penetration of a maximum thickness of saturated material. Water levels, in general, should be close to the land surface, and wells in some areas might flow. Yield and artesian head normally will increase with depth of penetration.

In most of the northern part of the project area, rocks of the Parkman dip vertically or are slightly overturned to the east. The success of wells drilled in them is unpredictable, because the movement of ground water downdip may cause the rocks below the outcrop to be drained to a considerable depth. Also, a drill hole started in the upturned edge of a shaly unit could conceivably continue in shale for several hundred feet without penetrating a water-bearing bed. Small-diameter test holes are advisable to prospect the area before a production well is attempted.

Water from well 46–82–9ad contains more dissolved solids and sulfate than is desirable in a domestic supply, but it is usable where water of better quality is unobtainable. It is of much better quality, however, than that from the underlying Cody Shale or that from the overlying Lance Formation. (See table 5.)

BEARPAW SHALE

The Bearpaw Shale consists of a relatively thin sequence of fine-grained marine rocks that was deposited conformably on the Parkman Sandstone. The formation is about 200 feet thick and is composed principally of dark-greenish-gray shale, containing a few thin laminae of light-gray fine-grained sandstone in the upper part, that grades upward into the sandstone and shale of the overlying Lance Formation. The Bearpaw is not considered to be a potential source of ground water in the project area.

LANCE FORMATION

The Lance Formation lies gradationally above the Bearpaw Shale. The Fox Hills Sandstone, which lies between the Bearpaw Shale and the Lance Formation in the southern part of Johnson County, has not been recognized in the project area (Hose, 1955, p. 65; Mapel, 1959, p. 59). The lower part of the unit mapped as Lance may be the stratigraphic equivalent of deposits laid down during Fox Hills time.

Outcrop and distribution

The Lance Formation is exposed principally in the southern part of the project area. The outcrop parallels the Bighorn Mountain front in a band that ranges in width from about 2 miles at the south boundary of the project area to less than a quarter of a mile near the middle of the area, where the dip of beds is nearly vertical. In the northern part, downfaulting and overlap by younger strata cause the formation to be concealed at many places. The Lance generally is poorly exposed, and its terrane is little different from that of the adjacent Bearpaw Shale and Fort Union Formation. Consequently the location of contacts on the geologic map is only approximate in many places. The Lance is exposed around the periphery of much of the Powder River structural basin in Wyoming, and its outcrops extend northward into southern Montana.

Lithology and thickness

The Lance Formation consists of a sequence of interbedded light-colored sandstone and dark shale containing a few thin beds of carbonaceous shale in the upper part. In some places the formation can be divided into two fairly distinct units: a lower unit 100–200 feet thick composed of light-gray fine-grained thin- and even-bedded sandstone that becomes shaly toward the base, and an upper unit of light-gray to light-yellowish-gray fine- to medium-grained lenticular sandstone and interbedded dark-gray shale. Lenticular deposits of carbonaceous shale, which become thinner and less numerous in the northern part of the project area, occur throughout the formation.

The thickness of the Lance in outcrops along the Bighorn Mountain front ranges from about 1,950 to 2,200 feet and is probably somewhat greater toward the middle of the Powder River structural basin. Exposures along the east side of the basin, in the vicinity of the Black Hills, are appreciably thinner, ranging from about 500 to 1,000 feet in thickness.

The following section of Lance strata was measured by R. K. Hose a short distance north of Billy Creek anticline.

Section of the Lance Formation in sec. 29, T. 49 N., R. 82 W.

[Adapted from Hose (1955, p. 91)]

	Thickness (feet)
Lance Formation:	
Sandstone and shale, interbedded; sandtsone is very light gray, fine grained, friable, thin to thick bedded, crossbedded; shale is dark gray and dark olive gray	1,330
Sandstone, very light gray, fine- to medium-grained, medium- to thick-bedded, crossbedded; contains a few thin beds and partings of dark-gray shale	355
Shale, moderate-brown, silty, carbonaceous; contains thin lenses of light-gray fine-grained sandstone	8
Sandstone, very light gray, very fine grained to fine-grained, thin- to medium-bedded; contains a few thin partings of moderate-brown carbonaceous shale	62
Concealed	46
Sandstone, very light gray, fine-grained, friable, thin-bedded, crossbedded; contains laminae of dark-gray shale	76
Concealed	31
Sandstone, very light gray, very fine grained, thin-bedded; contains many thin partings of dark-gray shale	20
Mostly concealed; appears to be mainly interbedded dark-greenish-gray shale and light-gray fine-grained sandstone	42
Total measured thickness	1,970
Bearpaw Shale.	

Water-bearing characteristics

The Lance Formation yields water to a few wells in the southwestern part of the project area, but elsewhere it generally is too deeply buried to be an economical source of water. Only six of the wells inventoried during the investigation pentrate the Lance, but undoubtedly there are others tapping the formation. Elsewhere in the Powder River structural basin, the Lance generally yields adequate supplies of water for stock and domestic use from relatively shallow depths. Yields of wells differ from place to place, depending on the number, thickness, extent, and permeability of water-bearing sandstone beds penetrated, and moderate supplies might be obtained in some sectors from deep wells penetrating a thick section of saturated material.

In the southern part of the project area, where the dip of beds is relatively gentle, the Lance would probably yield adequate supplies of water to stock and domestic wells nearly everywhere. The saturated thickness of the formation increases eastward toward the contact with the overlying Fort Union Formation, where the Lance attains its full thickness and may be completely saturated or contain water under sufficient artesian pressure to rise to within a short distance of the land surface.

In the northern part of the project area, the Lance strata dip nearly vertically at most places. (See cross section *A–A′*, fig. 4.) Prospecting for water in this sector is unpredictable, because the success of wells depends on whether the hole is drilled in a predominantly sandy or shaly unit. Consequently, the construction of water wells in the Lance Formation north of T. 49 N. should generally be preceded by preliminary test drilling to determine the depth to water and the potential yield from the aquifer.

To obtain the maximum amount of water from the Lance Formation, the well should be drilled as deeply into the formation as is economically feasible, and casing should be perforated at each significant water-bearing bed. Well sites should be selected in topographically low areas to keep drilling depths and pumping lifts to a minimum. Some wells tapping the formation east of the Lance–Fort Union contact may flow.

Analyses of water from two wells drilled in Lance outcrops indicate that the water is too highly mineralized to be suitable for domestic use and ranges from fair to poor for stock consumption (table 5). The analysis of only two water samples, however, does not permit a generalization of the quality of the water in the Lance Formation in Johnson County. Analyses of water from the Lance in other areas indicate that the quality differs from well to well, ranging from acceptable for a domestic supply, where no other source is available, to poor for stock consumption. The situation is probably similar in Johnson County.

TERTIARY SYSTEM

The Tertiary System in Johnson County comprises rocks of Paleocene, Eocene, and possibly Oligocene age; no deposits of Miocene or Pliocene age have been identified in the project area. Deposits of Oligocene(?) age are not shown on the geologic map because they crop out in the mountain uplands in small isolated patches and are of little or no significance as potential sources of ground water.

PALEOCENE SERIES

FORT UNION FORMATION

The Fort Union Formation lies gradationally above the Lance Formation. Along the east side of the Powder River structural basin, the Fort Union has been divided into three units. In ascending order, they are the Tullock, the Lebo Shale, and the Tongue River Members (Love and Weitz, 1951). These units have not been identified in Johnson County, although Hose (1955, p. 66) described, but did not map, a three-fold facies of the formation exposed in the southern part of the project area. Mapel (1959, p. 61) postulated that in the northern part of the project area all the middle unit and part of the lower unit identified by Hose were removed by erosion before the upper unit was deposited, and he described only two members of the formation, separated by an angular unconformity. Because of the hydrologic similarity of the units, Fort Union strata are mapped simply as the Fort Union Formation. In the Southern part of the project area, the Fort Union is overlain with apparent conformity by the fine-grained facies of the Wasatch Formation; but in the northern part of the area, near the Bighorn Mountains, the Fort Union is overlain unconformably by the conglomeratic facies of the Wasatch.

Outcrop and distribution

The Fort Union crops out in the southern part of the project area in a band about 4 miles wide that gradually narrows northward because of an increase in dip and the progressive overlap by the Wasatch Formation. In places the Fort Union is completely concealed by the Wasatch. Outcrop areas are generally characterized by sharp-crested and gullied ridges and narrow twisting ravinelike valleys. Some have been reduced to badlands that are unsuitable even for stock grazing. Except where eroded to badlands, the formation is poorly exposed, and the contacts with the underlying Lance Formation and the overlying Wasatch are difficult to locate.

Lithology and thickness

The Fort Union Formation is composed of a thick sequence of interbedded sandstone, siltstone, and shale that contains some thin to thick beds of carbonaceous shale and coal in the southern part of the area. The sandstone is generally light gray to light brown, fine grained and friable. Beds are characteristically shaly and lenticular and grade laterally and vertically into adjacent siltstone and shale. In some places, lenticular beds of conglomerate with a matrix of coarse-grained sandstone occur near the middle of the formation.

The exposed thickness of the Fort Union ranges from about 3,900 feet in the southern part of the project area to about 1,200 feet in the northern part, where erosion has removed about 2,600 feet of the formation. Along the west margin of the outcrop area, the formation has been eroded to a thin edge that wedges out against upturned strata of the Lance Formation.

Water-bearing characteristics

Wells drilled in the outcrop of the Fort Union Formation normally yield adequate supplies of water for stock and domestic use. The water is generally under artesian pressure, which probably increases with depth downdip from the Lance–Fort Union contact. For example, well 48–82–11bb, which is 420 feet deep, flows; but well 48–82–2cc, only a short distance away and at approximately the same altitude, is 130 feet deep and has a water level that is 50 feet below the land surface. Depth to water in wells tapping the Fort Union also varies with the altitude of the well site.

Several flowing wells tap the upper part of the Fort Union along the lower reaches of the Powder River in Johnson County. There the formation lies at a relatively shallow depth, and it crops out in the river valley about 4 miles north of the Johnson-Sheridan County line. Drillers' logs of water wells in this sector do not distinguish between Wasatch and Fort Union, and such a distinction probably cannot be made on the basis of drill cuttings.

The flows of these wells are generally small (measured yields ranged from 1 to 17 gpm); however, two wells reportedly flow 40 gpm, and one flows 60 gpm. No records of the artesian pressures are available, but field observations indicate that the pressures are not great. Measurement of artesian pressures was not possible during the investigation, because few of the wells are equipped with control valves. The construction of most wells makes it inadvisable to shut in the flow because of the danger of causing leakage around the outside of the casing and of causing loss of water into overlying aquifers in which artesian pressures probably are lower than the pressure in the producing zone.

Prospecting for water in the outcrop of the Fort Union Formation should be done first, if possible, along stream valleys, where water levels normally are nearer the surface, rather than on the slopes or crests of ridges. Careful selection of well sites may result in flowing wells in some places. Wells that would yield more than small amount of water probably cannot be constructed anywhere in the Fort Union without drilling to great depth, and pumping lifts might be prohibitive. Wells drilled in the extreme western part of the outcrop area may have to penetrate the underlying Lance Formation to obtain sufficient water for a stock supply, because there the Fort Union is thin and may be drained. Because of the eastward dip of the beds, the saturated thickness of the Fort Union increases toward the contact with the overlying Wasatch Formation, and depths to water should generally decrease accordingly. As in the Lance Formation, wells should be drilled as deeply as economics permit, so that the maximum amount of water available can be obtained. Casing should be perforated at each potential water-bearing bed below the water table.

Water from wells drilled in the Fort Union Formation differs greatly in type and degree of mineralization; its quality ranges from acceptable for domestic use to fair for stock supplies. Chemical analyses of water from nine wells are given in table 5.

EOCENE SERIES

WASATCH FORMATION

The Wasatch Formation in Johnson County can be divided into a fine-grained facies and a conglomeratic facies. The fine-grained facies, principally sandstone and shale, makes up the Wasatch in the Powder River Basin; the conglomeratic facies, which occurs along the Bighorn Mountain front, comprises the Kingsbury Conglomerate and Moncrief Members of the Wasatch. In the project area both the Kingsbury Conglomerate Member and the Moncrief Member grade to the south and east into the basin facies (fine-grained facies) of the Wasatch Formation. The Kingsbury Conglomerate Member lies with an angular unconformity on the Fort Union Formation in the southern part of the project area and progressively overlaps older rocks northward. Eastward the angle of discordance decreases, and the fine-grained facies of the Wasatch lies with apparent conformity on the Fort Union Formation. The Kingsbury, in turn, is overlain with angular unconformity by the Moncrief Member.

Outcrop and distribution

The Kingsbury Conglomerate and Moncrief Members of the Wasatch Formation crop out along much of the west margin of the Powder River structural basin in the project area. They underlie the high ridges and terraces that in places abut against the east flank of the Bighorn Mountains. The rocks are generally concealed beneath a thin soil and grass cover, so that good exposures are rare except where streams have cut deeply into the formations. The basin facies of the Wasatch, which extends over the rest of the project area, underlies a former plains surface that has been deeply and irregularly dissected by streams. Sandstone-capped ridges, mesas, and buttes separated by narrow steep-sided valleys and ravines characterize much of the outcrop area. East of Buffalo, rocks adjacent to burned out coal beds were altered by the intense heat to hard bright-red clinker, which forms a spectacularly colorful capping on many ridges and buttes.

Lithology and thickness

The bulk of the Wasatch Formation consists of interbedded light-gray sandstone, darker gray and brown shale, and coal. The Kingsbury Conglomerate and Moncrief Members are composed of lenticular beds of conglomerate interbedded with light-gray medium- to coarse-grained sandstone and greenish-gray siltstone and shale. The conglomerate beds contain pebbles, cobbles, and boulders as much as 10 feet in diameter. The sandstone beds, which are the principal source of water in the Wasatch Formation, are light to yellowish gray, generally fine grained, and friable. They are characteristically lenticular, thin bedded, and cross laminated.

The combined thickness of the Kingsbury Conglomerate and Moncrief Members of the Wasatch Formation in the northern part of the project area is about 1,000–2,000 feet (Mapel, 1959, pl. 3). Near the middle of the project area, where the Moncrief Member is absent, the Kingsbury Conglomerate Member ranges in thickness from 400 to 600 feet (Hose, 1955, p. 67). Logs of oil-test holes drilled in the eastern part of the project area indicate that the thickness of the basin facies of the Wasatch ranges from about 600 feet in sec. 21, T. 50 N., R. 80 W., to nearly 1,400 feet in sec. 14, T. 52 N., R. 78 W. (See table 8.) However, the log of oil-test hole 52–77–21ca, in the valley of the Powder River, indicates that the Wasatch is only 740 feet thick at that test site.

Water-bearing characteristics

Sandstone beds in the Wasatch Formation yield water to many stock and domestic wells in the Powder River structural basin. In some places water has reportedly been obtained from the thicker and more persistant coal beds, which apparently transmit water through interconnecting networks of fractures and joints. The Kingsbury Conglomerate and Moncrief Members yield water to a few wells in the foothills adjacent to the Bighorn Mountains, but, because of the fine material that is generally intermixed with the coarser fragments, these units probably are only slightly more permeable than the sandstone of the Wasatch to the east. (See fig. 7.) Probably neither the fine-grained nor the conglomeratic facies of the Wasatch will yield more than moderate quantities of water to wells.

About 65 percent of the wells inventoried yield water from the Wasatch Formation. Some of them flow, but most are equipped with small-discharge cylinder or jet pumps. Depths of the wells range from 25 to 1,294 feet, but the average depth is about 280 feet. The average depth of flowing wells, however, is somewhat greater—approximately 340 feet. The depth to the water level in nonflowing wells ranges from about 1 foot to more than 400 feet and averages 65 feet.

Little is known of the potential yields of wells in the Wasatch Formation, but normally the wells yield adequate supplies for stock and domestic use. Measured yields of flowing wells range from less than 1 to 7.5 gpm, and the maximum reported flow is about 15 gpm. Larger yields could probably be obtained from most flowing wells by pumping. One well (51–82–33dd), possibly tapping the Moncrief Member, flows 7.5 gpm and yielded 70 gpm with a drawdown of 46 feet during a pumping test made by the authors. The well is probably capable of yielding larger quantities of water, with a proportionate increase in drawdown.

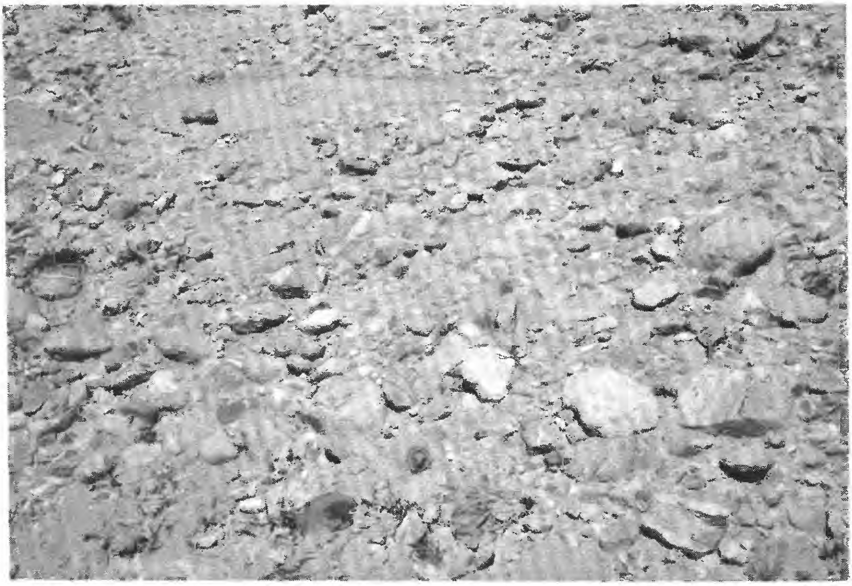


FIGURE 7.—Boulder conglomerate of Moncrief Member of Wasatch Formation in roadcut on north side of U.S. Highway 16 about 5 miles west of Buffalo, Wyo. Hat in lower center illustrates size of boulders.

The results of the pumping test made at well 51–82–33dd are given in the following table. The data are applicable only to that part of the aquifer tested at the site of the pumped well and are not necessarily indicative of the water-bearing potential of the formation elsewhere.

Results of pumping test on well 51–82–33dd

[Moncrief(?) Member of the Wasatch Formation; Sept. 2, 1961]

Duration of pumping	3¾
Average rate of discharge gpm	70
Drawdown in well ft	46
Specific capacity of well gpm per foot of drawdown	1.5
Saturated thickness of aquifer penetrated ft	145
Coefficient of transmissibility gallons per day per foot	2,500
Average field coefficient of permeability gallons per day per square foot	17

Most wells in Johnson County are equipped with wind-powered cylinder pumps that normally discharge water at rates that are both too low and too erratic to allow a satisfactory pumping test. Wells equipped with jet pumps are used principally for domestic supplies and are customarily sealed for sanitary reasons. Few of the flowing wells are equipped with control valves, and, because of the construction of the wells, attempts to measure shut-in pressure were inadvisable. The yields and drawdowns of some wells in the Wasatch Formation are given in table 7. The average specific capacity of these wells is 0.23 gpm per foot of drawdown, which is much less than that of well 51–82–33dd. Most of these data are from drillers' records of bailing tests made at the time the wells were completed and generally are only approximate.

Depth to water in the Wasatch Formation is relatively shallow in the western part of the outcrop area, but it generally increases eastward because the upper part of the formation is disected and drained by many deep narrow valleys. Wells on ridges and divides may penetrate several tens of feet of nearly dry strata before tapping a water-bearing bed. Owing to the irregularity of the terrain and the discontinuity of aquifers, prediction of the depth to water at any particular site is difficult. One or more small-diameter test holes should be drilled to determine the availability and depth of water at places where more than a stock or domestic supply is desired. In the southwestern part of the project area, where the Wasatch Formation wedges out against the Fort Union Formation, and along the lower reaches of the Powder River, where the Wasatch apparently is relatively thin, additional water can be obtained by drilling into the underlying Fort Union.

The water in the Wasatch Formation differs greatly in chemical quality throughout the project area, but generally it is unsuitable for most domestic uses because of high dissolved-solids content and excessive hardness. Analyses indicate that water from some wells is of poor quality even for stock consumption (table 5).

QUATERNARY SYSTEM

The Quaternary System is represented in Johnson County principally by alluvial deposits of unconsolidated silt, sand, and gravel that underlie the flood plains and bordering terraces of major streams. Along the upper reaches of these streams and on the divides between the streams, remnants 10–30 feet or more thick of older terraces stand 130–350 feet above the floors of present stream valleys. Near the mountains, broad pediments are covered with thin deposits of silt, sand, gravel, and boulders that merge basinward with the high terrace deposits. On the upland surfaces of the Bighorn Mountains, at altitudes ranging from 8,000 to 10,000 feet, thick glacial deposits extensively cover the floors of ice-carved valleys.

Deposits underlying the higher terraces and those covering the pediments probably are soon drained of any recharge from precipitation and are not considered to be potential sources of water, except where small ephemeral springs and seeps issue from them at their contact with underlying less permeable rock. These deposits play a part, however, in retarding runoff and increasing the amount of water that reaches the underlying aquifers.

Glacial moraines yield water to numerous springs and seeps in the uplands. One large spring (53–86–27cd) reportedly yields a dependable supply of about 400 gpm. Because of the generally inaccessibility of the region in which these glacial deposits occur, they are not considered to be significant sources of water in the project area.

ALLUVIAL DEPOSITS OF STREAM VALLEYS

Outcrop and distribution

Deposits of stream-laid clay, silt, sand, and gravel underlie most of the stream valleys in Johnson County. They range in thickness from only a veneer in the upland valleys and narrow canyons to several tens of feet in the valleys of the Powder River and Crazy Woman Creek. Only the thicker and more extensive alluvial deposits are considered to be potential sources of moderate to large supplies of ground water in the project area. On the geologic map (pl. 1) they are shown underlying the valleys of the Powder River and Crazy Woman, Clear, and Piney Creeks and their major tributaries.

Lithology and thickness

Alluvium exposed in the valleys of the Powder River and the lower reach of Crazy Woman Creek is composed principally of clay and fine sand containing pebbles and cobbles of fine- to medium-grained sandstone. The lower part of the alluvial deposits, however, commonly contains lenses of coarse sand and gravel that differ in thickness and extent (table 3) and mark the position of buried former stream channels. Deposits along the upper reaches of Crazy Woman Creek and along Clear and Piney Creeks are likely to be coarser because they lie near the source of the material, which is principally the coarse-grained and resistant rocks that form the east flank of the Bighorn Mountains.

Little information is available on the thickness of alluvium in the major stream valleys, because few wells in the project area have been drilled in these deposits. Two wells (50–82–6ad and 51–82–36aa) in Clear Creek valley penetrated 26 feet of sand and boulders and 30 feet of silt and sand, respectively, without reaching bedrock. A series of test holes was augered by the Geological Survey across accessible parts of the valley of the Powder River at three different locations to determine the thickness of the underlying alluvium (fig. 8). A complete profile could not be obtained, however, as the river could not be crossed. The location of the lines of test holes is shown on plate 1, and the logs are given in table 3. The maximum thickness penetrated was 29 feet near the middle of the valley in the SE¼ sec. 20, T 51 N., R. 77 W. More closely spaced test holes might have located buried

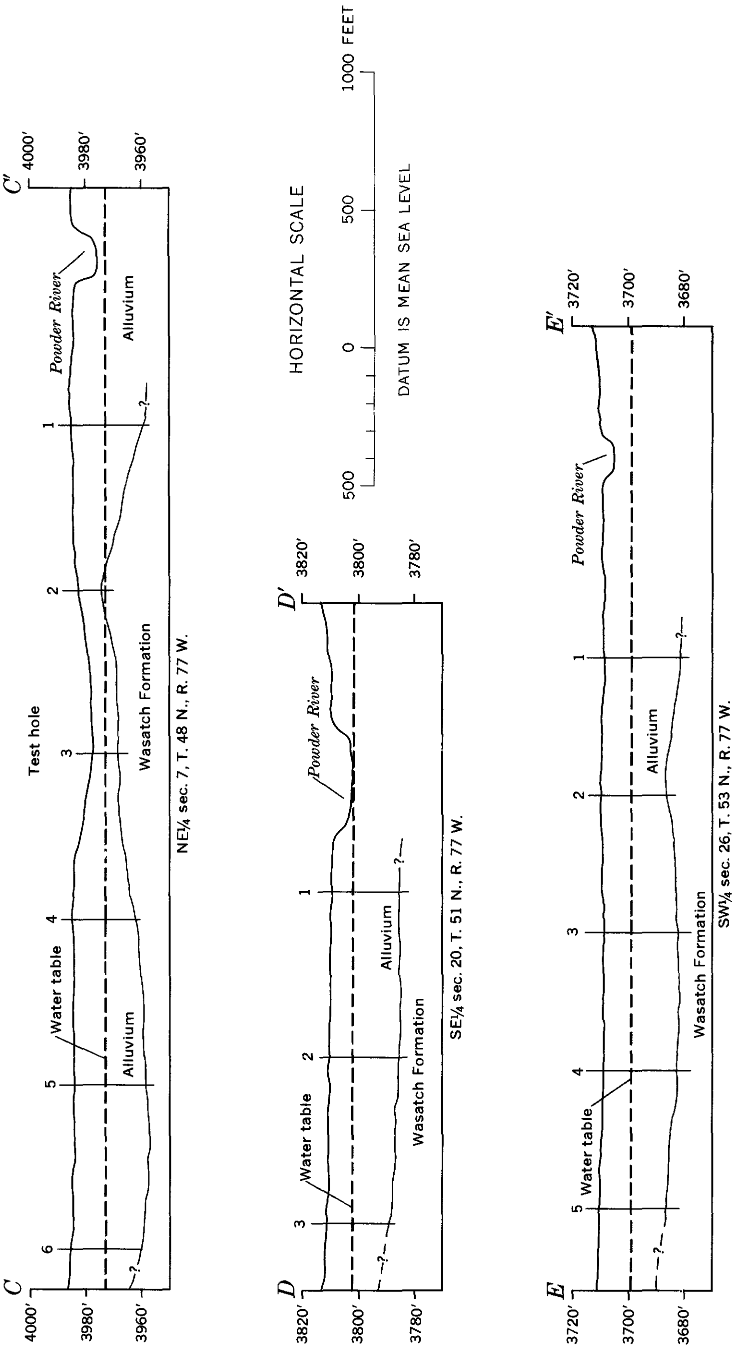


FIGURE 8.—Cross sections of alluvium in the valley of the Powder River, northern Johnson County, Wyo. Test holes are numbered in the order drilled. Location of sections shown on plate 1.

channels at somewhat greater depth. Additional data on the thickness of alluvial deposits along the Powder River were obtained from drillers' logs of several wells drilled in sec. 20, T. 49 N., R. 77 W., to supply water for highway construction. There, the maximum thickness penetrated was 31 feet; the log of one of the wells (49–77–20ba) is given in table 8. The driller's log of well 46–78–13bd indicates 47 feet of sand and gravel in that part of the Powder River valley, and the log of well 53–77–24db, 102 feet of sand and gravel. Well 52–78–16cb, in the valley of Crazy Woman Creek, penetrated 54 feet of alluvium before reaching the underlying Wasatch Formation. Wells penetrating more than 40 feet of alluvium are probably on bordering terraces that, in places, stand a considerable distance above the main valley floor.

TABLE 3.—*Sample logs of test holes augered in alluvium of the Powder River, northern Johnson County, Wyo.*

Material	*Thickness (feet)*	*Depth (feet)*
SECTION *C–C′* IN NE¼ SEC. 7, T. 48 N., R. 77 W.		
Test hole 1		
Alluvium:		
Silt, light-brown, sandy	5	5
Gravel	1	6
Silt, sandy, containing lenses of medium gravel	4	10
Gravel (water at 13.5 ft)	3. 5	13. 5
Silt, some medium gravel	1. 5	15
Silt containing lenses of medium to coarse gravel	5	20
Clay, brownish-gray, silty	3	23
Gravel	2	25
Wasatch Formation:		
Shale, blue, sandy	1	26
Test hole 2		
Alluvium:		
Sand, brownish-gray, very fine	5	5
Sand, very fine; contains lenses of gravel	5	10
Test hole 2—Continued		
Wasatch Formation:		
Shale, blue, sticky (water at 11.0 ft)	3	13
Test hole 3		
Alluvium:		
Silt and fine sand (water at 4.5 ft)	5	5
Sand, dark-brown, fine to medium, and silt	4. 5	9. 5
Wasatch Formation:		
Shale carbonaceous	. 5	10
Test hole 4		
Alluvium:		
Silt, brownish-gray	5	5
Sand, silt, and some gravel	5	10
Sand, medium to coarse, silty; contains gravel lenses (water at 12.3 ft)	12. 5	22. 5
Wasatch Formation:		
Shale, blue	. 5	23
Test hole 5		
Alluvium:		
Silt	5	5
Clay, silt, and fine sand	5	10

TABLE 3.—*Sample logs of test holes augered in alluvium of the Powder River, northern Johnson County, Wyo.*—Continued

Material	*Thickness (feet)*	*Depth (feet)*
Test hole 5—Continued		
Alluvium—Continued		
Sand, fine to coarse; contains some silt and gravel lenses (water at 12.3 ft)	5	15
Sand, fine to coarse; some clay and silt	5	20
No sample (gravel?)	5	25
Gravel	2	27
Wasatch Formation:		
Shale, blue	1	28
Test hole 6		
Alluvium:		
Silt, brownish-gray	5	5
Silt and sand containing lenses of gravel (water at 13.1 ft)	10	15
Silt and sand; some gravel	5	20
Silt and sand	5	25
Wasatch Formation:		
Shale, blue-gray	1	26
SECTION *D–D'* IN SE¼ SEC. 20. T. 51 N., R. 77 W.		
Test hole 1		
Alluvium:		
Clay, silt, and sand	5	5
Sand, silty (water at 7.3 ft)	5	10
Sand and silt containing some gravel lenses	14	24
Wasatch Formation:		
Shale, blue	1	25
Test hole 2		
Alluvium:		
Clay, silt, and sand (water at 8.7 ft)	10	10
As above; contains some lenses of fine gravel	5	15
Gravel, fine to medium, silty	5	20
Test hole 2—Continued		
Alluvium—Continued		
Silt and sand	5	25
Clay, dark-brown; some gravel in lower part	4	29
Wasatch Formation:		
Shale, blue, sticky	2	31
Test hole 3		
Alluvium:		
Silt, brownish-gray, and some very fine gravel	5	5
Clay and silt, brownish-gray (water at 9.3 ft)	5	10
Sand, fine	5	15
Silt and green sandy clay	7	22
Wasatch Formation:		
Shale, reddish-brown, carbonaceous	2	24
SECTION *E–E'* IN SW¼ SEC. 26 T. 53 N., R. 77 W.		
Test hole 1		
Alluvium:		
Silt, clayey	5	5
Sand, silty and clayey; gravel lense at 10 ft (water at 9.6 ft)	10	15
Clay, sandy	13	28
Wasatch Formation:		
Shale, blue	4	32
Test hole 2		
Alluvium:		
Silt, brownish-gray, and very fine sand (water at 9.9 ft)	10	10
Sand, fine to coarse; contains some silt and gravel	5	15

TABLE 3.—*Sample logs of test holes augered in alluvium of the Powder River, northern Johnson County, Wyo.*—Continued

Material	*Thickness (feet)*	*Depth (feet)*
Test hole 2—Continued		
Alluvium—Continued		
Silt containing lenses of fine to coarse sand	5	20
Silt, sand, and medium gravel	3	23
Wasatch Formation:		
Shale, blue	2	25
Test hole 3		
Alluvium:		
Silt, brownish-gray, clayey	5	5
Silt, dark-brown, sandy	5	10
As above; contains some lenses of gravel (water at 10.3 ft)	17	27
Wasatch Formation:		
Shale, blue-gray, sticky	3	30
Test hole 4		
Alluvium:		
Silt, clayey	5	5
Silt and some fine sand (water at 9.4 ft)	15	20
Sand and some clay and silt	6	26
Wasatch Formation:		
Shale, bluish-black, sticky	4	30
Test hole 5		
Alluvium:		
Clay and silt; some sand in lower part (water at 10.4 ft)	20	20
Sand, silt, and some coarse gravel	3	23
Wasatch Formation:		
Shale, blue	4	27

Water-bearing characteristics

Few wells in the project area tap alluvial deposits, because, throughout most of the region, bedrock aquifers are generally considered to be more dependable sources of water. Small supplies can probably be obtained from alluvium at most places in the major stream valleys, and moderate to large supplies, adequate for small-scale irrigation, might be developed in some places where the alluvium is thick and permeable. Well 50–82–6ad, which is actually an infiltration gallery in the alluvium of Clear Creek, provides water by gravity flow to Buffalo at a reported rate of 250 gpm. Drilled wells having comparable yields can probably be constructed at some locations along Piney Creek and the upper reaches of Crazy Woman Creek, but withdrawal of large quantities of water from the alluvium might reduce streamflow in these localities.

Well 49–77–20ba, one of several supplying water for highway construction from the alluvium of the Powder River, was discharging approximately 60 gpm when visited by the authors. The drawdown could not be determined, owing to the cascading of water into the well through perforations in the casing. A second well reportedly yields 90 gpm. Possibly wells of even larger yield might be developed where the alluvium is thicker and more permeable. Yields from alluvium in Powder River valley and in the lower reaches of Crazy Woman Creek valley, however, probably will not be adequate for more than small-scale irrigation.

Before a large-diameter irrigation well is constructed in alluvial deposits, drilling of small-diameter test holes across the trend of the valley is generally advisable. The purpose of test drilling is to locate the thickest and most permeable water-bearing beds, which normally occupy former stream channels that subsequently were buried beneath more recent alluvium. Unless the test drilling is carefully planned and systematically done, however, the results may not warrant the expense. The test holes, where possible, should be regularly spaced along a straight line. If the holes are drilled to the underlying bedrock and properly logged, a section across the valley fill can be drawn; such a section would show the location of the buried channel and the lithologic characteristics of the material penetrated.

If the alluvium does not yield the quantity of water desired, additional small supplies can generally be developed from the underlying Wasatch, Fort Union, or Lance Formations. No appreciable increase of yield, however, can be expected to result from drilling into the underlying bedrock.

Water in the alluvium along the Powder River, and probably also along the lower reach of Crazy Woman Creek, contains high concentrations of minerals dissolved from the material through which the water moves. The alluvium is recharged in some areas by effluent seepage of moderately to highly mineralized water from the Wasatch Formation. For example, water from well 49–77–20ba is unsuitable for domestic use and of marginal suitability for stock use; its application as irrigation water generally should be restricted to use by plants having high salt tolerance. Toward the headwaters of streams, the quality of the water in alluvial deposits may be expected to gradually improve. Thus, water in the alluvium along the upper reaches of Crazy Woman Creek and in the valleys of Clear and Piney Creeks is normally of much better quality than that in the alluvium along the lower reaches. Even in the upper reaches, however, the dissolved-solids content may rise appreciably during late summer and early fall, as seepage from surface water applied for irrigation leaches minerals from the soil and gradually increases the mineralization of water in the alluvium.

GROUND WATER AND ITS RELATION TO GEOLOGIC CONDITIONS

ARTESIAN AND WATER-TABLE CONDITIONS

The geologic structure of the Bighorn Mountains and the adjacent Powder River Basin promotes artesian conditions throughout Johnson County (fig. 9). Most of the rocks dip rather steeply eastward

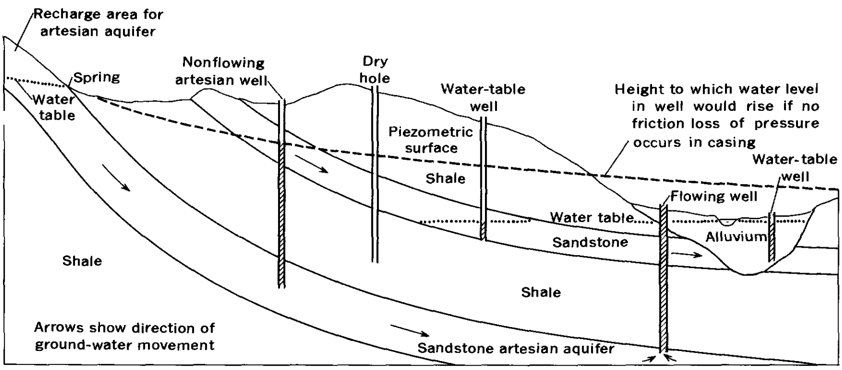


FIGURE 9.—Artesian and water-table conditions and their effect on the success of wells drilled in Johnson County.

away from the crest of the Bighorns and are composed largely of relatively permeable sandstone interbedded with nearly impermeable shale. Water entering the permeable beds in the outcrop area moves downdip by gravity between the confining layers. The water thus confined is under artesian pressure and will rise in wells that penetrate the permeable beds. Where wells penetrate water-bearing beds of coal or other carbonaceous material or tap an aquifer closely associatd with them, the presence of hydrocarbon gases in the aquifer may supply a "gas lift" that causes the water level to rise higher than it would if only artesian pressure were in effect. Some artesian wells in the project area probably flow solely because of the added impetus of "gas lift." The effect of gas on water levels in wells is described more fully in the chemical-quality section of this report.

The imaginary surface defined by the level of water in wells is called the piezometric surface. A piezometric surface fluctuates in response to changes in the relation of recharge to discharge; it rises when recharge exceeds discharge and declines when the reverse prevails. Monthly measurements were made of the water level in 16 wells tapping the Wasatch Formation to determine the magnitude and trend, if any, of fluctuations of the piezometric surface. Hydrographs of the water levels in three wells that reflect changes in regional recharge and in three wells that reflect changes in local recharge are given in figure 10.

Figure 11 is a composite graph of monthly precipitation at three weather stations during the period 1959–61: at Buffalo, 5 miles west of Buffalo, and at the Metz Ranch. The relation between precipitation and water levels in the wells shown in figure 11 cannot be correlated

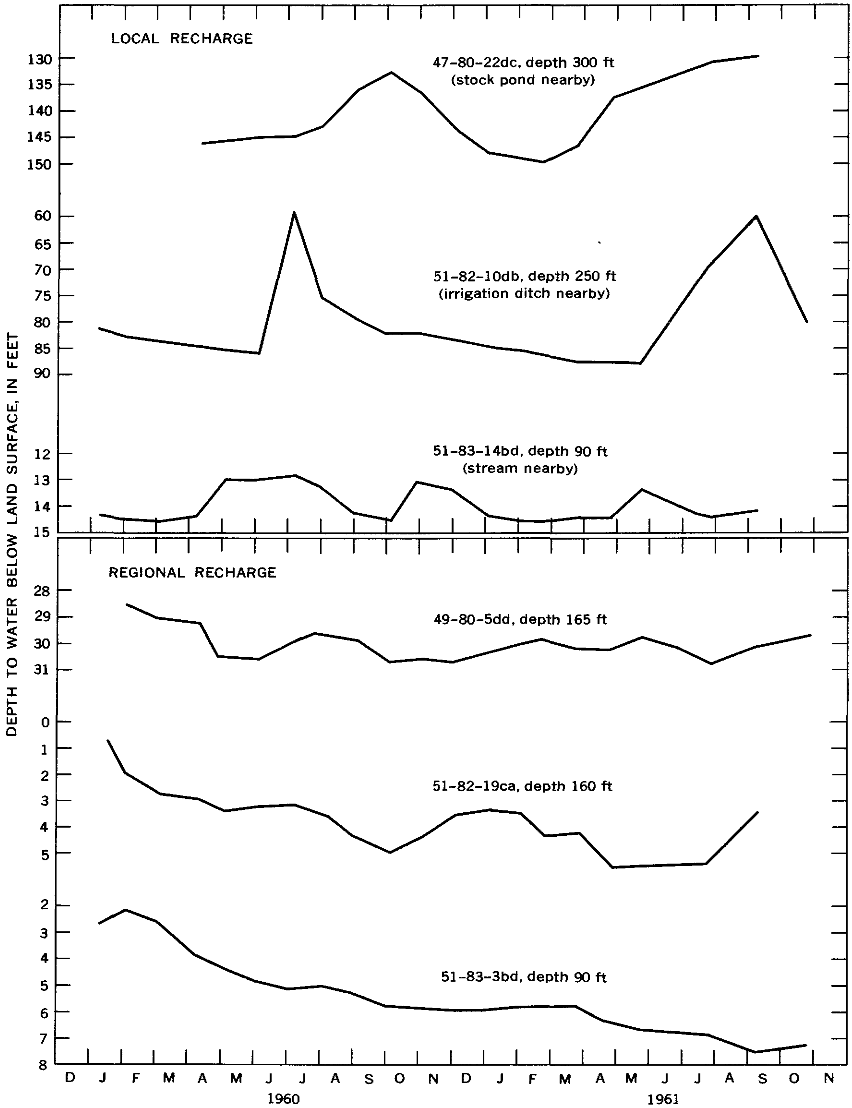


FIGURE 10.—Effect of local recharge and of regional recharge upon water levels in project area.

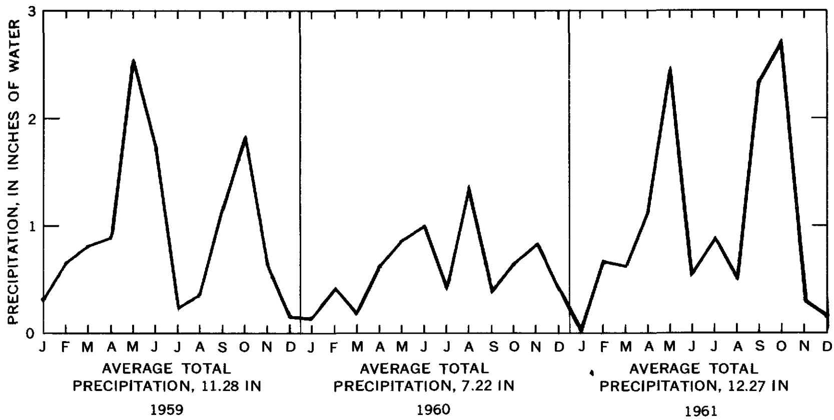


FIGURE 11.—Precipitation at three weather stations in the vicinity of Buffalo, Wyo., years 1959–61. From records of the U.S. Weather Bureau.

precisely because of the short record of water-level measurements and because the effect of precipitation, or lack of it, is not reflected immediately by changes in ground-water levels. The time lag normally increases with distance from the area of recharge.

A comparison of figures 10 and 11 suggests that water levels in early 1960 reflect the nearly normal amount of precipitation during 1959. Levels generally declined during 1960 and much of 1961, probably because of far below normal precipitation throughout 1960. At the close of 1961, water levels in most wells were in an upward trend as a result of the resumption of a nearly normal rate of precipitation in May of that year. By March 1962 the water level in well 49–80–5dd was 27.71 feet below the land surface, which is the highest level for the period of record, probably because above-normal amounts of rainfall in September and October 1961.

Table 4 contains monthly records of water-level measurements made in six observation wells during the period of investigation. Since the completion of the fieldwork, these wells have been incorporated in an expanded net of observation wells in Johnson and Sheridan Counties, in which water levels are measured semiannually.

Water-table conditions exist where water in the zone of saturation in an aquifer is not confined between less permeable beds and the water is under atmospheric pressure. In the project area these conditions are restricted mainly to unconsolidated alluvial deposits in the major stream valleys and their tributaries. Water levels in alluvial deposits generally fluctuate in response, principally, to seasonal variations in streamflow; they normally rise during periods of heavy runoff and decline as the runoff subsides. The magnitude of fluctuation depends largely on the permeability of the alluvial material.

TABLE 4.—*Records of water levels in observation wells in northern and central Johnson County, Wyo.*

[Water levels, in feet below land surface]

Well	Depth (feet)	1960												1961												1962
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mar.
Cody Shale																										
47-82-18cc	450	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	18.11	19.05	19.85	19.59	18.95	18.24	-----	19.71	19.76	-----	-----	-----	19.52
Wasatch Formation																										
48-77-8ac	465	-----	-----	-----	41.12	41.10	40.19	41.23	41.20	40.99	41.20	41.22	41.26	41.27	40.89	40.88	40.95	41.15	41.05	41.35	41.35	41.44	41.32	-----	-----	40.26
49-80-5dd	165	-----	28.55	29.00	30.29	30.45	30.50	29.88	29.65	29.84	30.66	30.55	30.65	-----	29.96	29.80	30.14	30.20	29.59	30.12	30.40	30.14	-----	29.64	-----	27.71
50-81-22dd	362	-----	4.30	-----	4.55	4.47	4.80	-----	13.74	7.70	9.91	10.10	6.95	5.85	5.50	5.01	4.42	4.59	4.62	4.78	5.28	5.62	-----	4.62	-----	4.10
51-77-17cc	165	-----	-----	-----	-----	-----	-----	-----	75.13	74.47	74.34	74.25	73.74	74.62	76.19	75.59	74.15	74.45	74.62	74.37	74.58	74.59	-----	74.33	-----	74.55
51-83-10ac	275	31.20	31.28	31.27	30.90	31.33	31.41	31.48	31.48	31.42	31.47	31.44	31.16	31.44	31.46	31.45	31.44	31.37	31.56	-----	30.91	32.05	-----	32.07	-----	32.24

Water-level measurements made in one shallow well in the alluvium of the Powder River during the spring and summer of 1962 illustrates the effect of streamflow on the water table in the underlying valley fill.

Well 49–77–20ba

Date of measurement	Mar. 25, 1962	June 22, 1962	Sept. 24, 1962
Depth to water below land surface ft	6. 52	3. 76	8. 55
Mean daily discharge of the Powder River at Arvada, Wyo., during 5-day period prior to water-level measurement cubic feet per second	313	7, 152	167

The early spring measurement was made before the snowpack in the Bighorn Mountains had begun to yield melt water to streams rising on the east slope. The June measurement was made shortly after heavy rains had augmented the seasonal runoff and raised stream levels throughout the project area. The low water level in the alluvium in late September reflects the diversion of surface water for irrigation in the upper reaches of the Powder River and its tributaries and the discharge of ground water by evapotranspiration.

Several observation wells were drilled north of Lake De Smet by the Reynolds Mining Corp. to measure the fluctuation of the water table in response to changes in storage of water in the lake. The distance from the lake shore ranges from about a quarter of a mile for well 52–82–6bc to nearly a mile for well 52–83–1dc. Hydrographs of water levels in four of the wells and their relation to water levels of the lake are shown in figure 12. Apparently, water levels in the observation wells fluctuate directly with the lake level, rising when surface water is diverted into the lake and declining when water is released.

DEPTH TO WATER-BEARING STRATA

Depths to water-bearing strata differ greatly throughout the project area, ranging from less than 10 feet in the alluvium of the Powder River and other major stream valleys to more than 400 feet in well 48–76–29ac, drilled in the Wasatch Formation in the extreme eastern part of Johnson County. One test hole penetrated 1,100 feet of Cody Shale without obtaining water and was abandoned. Most of the wells tap relatively deep-lying aquifers in which water is under sufficient pressure to flow or to rise appreciably in the hole. Drillers' logs (table 8) indicate that many wells did not penetrate water-bearing zones for several tens of feet, and some, for several hundreds of feet. Because of the general lenticularity and small areal extent of sandstone beds in the Wasatch and Fort Union Formations, one cannot predict at

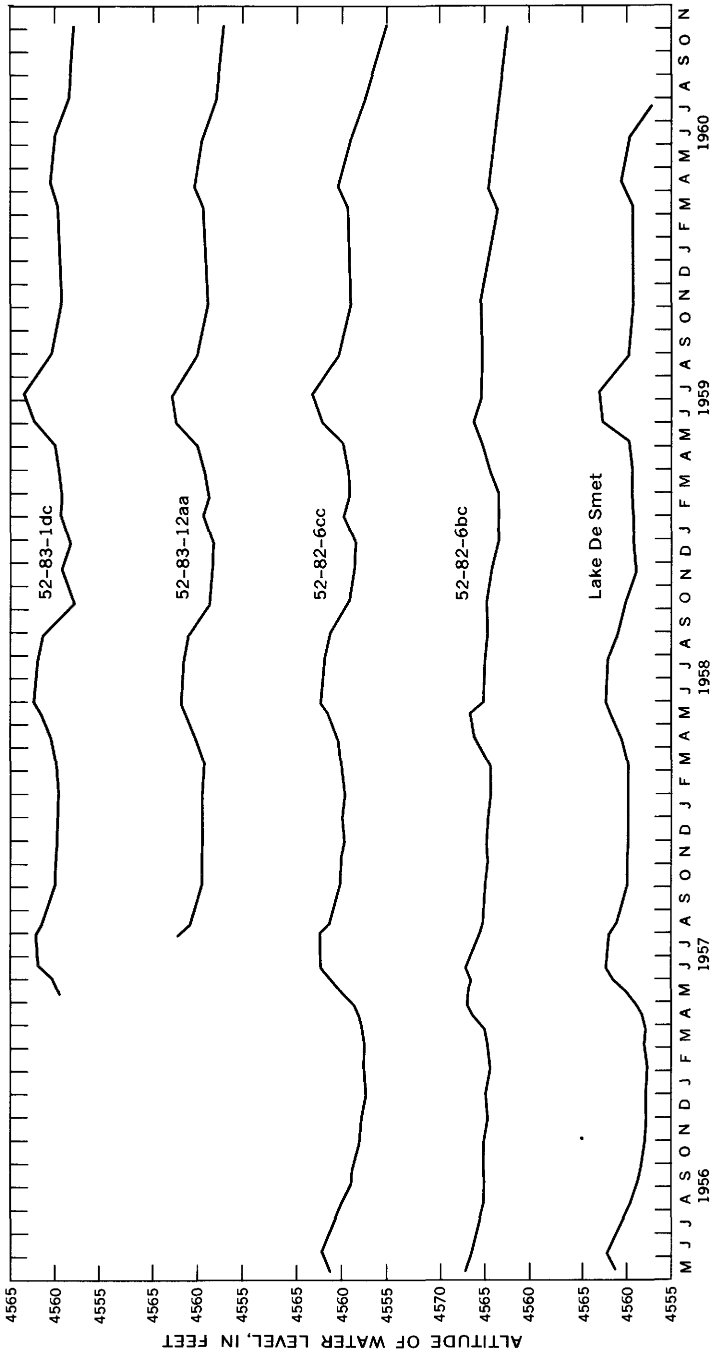


FIGURE 12.—Relation of the water table in observation wells in the vicinity of Lake De Smet to the level of the lake. From records of Reynolds Mining Corp.

what depths a water-bearing unit may be tapped or estimate the artesian rise. The irregularity of the land surface further complicates prospecting for ground water in the Wasatch and Fort Union Formations.

Water levels in wells throughout the project area do not coincide with a regional water table because of widespread artesian conditions; thus, depths to water differ greatly and commonly have no apparent relation to the altitude of the well. For example, wells 50–81–22dd and –23cc, which are only about a quarter of a mile apart and at nearly the same altitude, have water levels that are 4 and 284 feet below the land surface, respectively. (See table 7.)

RECHARGE

Ground water in the project area is derived chiefly from direct precipitation on the Powder River drainage basin; smaller amounts are derived by infiltration of water from streams flowing across outcrops and from seepage of surface water diverted for irrigation on the bottom lands along the upper reaches of Crazy Woman, Clear, French, Rock, and Piney Creeks. Seepage from Lake De Smet recharges the adjacent alluvium and, probably, the underlying bedrock. Most of the precipitation runs off or evaporates, owing to the generally low permeability of the soil and underlying bedrock and to the sparseness of vegetal cover, and only a small fraction eventually reaches the ground-water reservoirs. The older rocks flanking the Bighorn Mountains are recharged almost entirely by rain and melt water from snow on the mountains.

DISCHARGE

Ground water moves out of the project area as streamflow derived from effluent seepage and springs, as discharge from wells, as underflow through aquifers, and as evapotranspiration. Ground-water contribution to the flow of streams and the withdrawal of water from wells are probably the major modes of discharge. Ground-water movement out of the area through deep artesian aquifers is probably minor, because the deepest part of the Powder River structural basin is along the west margin of the project area; thus, water in artesian aquifers normally would be expected to move into Johnson County rather than out of it. Evapotranspiration losses are small except where the water table is at or near the land surface, as in the bottom lands along the Powder River and Crazy Woman Creek and their major tributaries or where open bodies of water such as Lake De Smet and the perennial reaches of streams are supplied in part by ground water.

SPRINGS AND SEEPS

Numerous springs issuing from the granitic core of the Bighorn Mountains and from the permeable sedimentary rocks overlapping it probably contribute appreciably to the perennial flow in the upper reaches of the forks of Crazy Woman Creek and to that in Clear Creek and its tributaries, French, Rock, and Piney Creeks. The cavernous Madison Limestone and Bighorn Dolomite are probably the principal contributing aquifers, although springs and seeps issue also from outcrops of the Tensleep Sandstone. Much of this ground-water discharge is utilized for irrigation on the lowlands bordering the mountains, and little of it moves out of Johnson County as surface runoff except during the winter. Irrigation water that is not evaporated or transpired returns to the ground-water reservoir in the alluvium and adjacent bedrock by downward seepage.

Small quantities of ground water are discharged from springs and seeps in the Wasatch and Fort Union Formations where stream valleys have cut into water-bearing beds. Flows are characteristically small, and the water generally is soon evaporated and transpired. Where outlets are buried beneath alluvium, however, and evaporation is thus inhibited, ground-water discharge from the adjacent bedrock may contribute substantially to underflow in the valleys of major streams such as the Powder River and the lower reaches of Crazy Woman Creek.

WELLS

Most of the wells in the project area tap either the Wasatch Formation or the Fort Union Formation. Deeper lying aquifers and surface alluvial deposits contribute only a small part of the water discharged to wells. Wells range in depth from 30 to about 1,300 feet, and in diameter, from 2 to 6 inches. They are generally cased to prevent caving of the wallrock and, in places, to shut out water of unsuitable quality. The casing may be set down to the bottom of the hole and perforated opposite the aquifer, or it may be set only down to the top of the aquifer, so that the rest of the hole is uncased. Many of the deep flowing wells contain 2-inch casing that is merely suspended inside a 4-inch surface casing and cemented at the surface to prevent leakage between the casings. A few shallow dug wells yield water from alluvium along the upper reaches of Crazy Woman and Clear Creeks and their major tributaries.

The discharge from wells is small in relation to the amount of ground water available because of the small number of wells, the small capacity of most of the pumps, and the generally small yield of flowing wells. During the investigation, 128 flowing wells were inventoried, and the measured or reported yields of 69 of these wells ranged from less than 1 gpm to 60 gpm; the average yield of the 69 wells was about 7 gpm. Undoubtedly there are other flowing wells that were not visited. Thus, if one assumes that there are 130 flowing wells in the project area discharging an average of 7 gpm each, the total discharge from flowing wells in the project area would be at least 1,300,000 gallons per day (900 gpm), and probably would be more. Consequently, the uncontrolled flows from these artesian wells contribute appreciably to the total amount of ground water withdrawn. In addition to the flowing wells, about 500 pumped wells were operated in the project area in 1963. A rough approximation of the combined yield of all these pumped wells is about 700,000 gallons per day, or about half the discharge of the flowing wells.

EVAPOTRANSPIRATION

Evapotranspiration is the term commonly used in discussing the combined natural processes of evaporation from land and water surfaces and transpiration by plants. These processes normally are mutually operative, because where the water table is sufficiently close to the land surface to permit evaporation from the capillary fringe (a zone above the water table that is only partly saturated with water raised by capillary action in the soil), conditions are generally most favorable for plant growth. Transpiration is the process by which water is extracted from the soil by plant roots and is subsequently discharged into the atmosphere as vapor from leaf surfaces. Plants that obtain all or most of their water from ground-water reservoirs are called phreatophytes. Climatic conditions in Johnson County are conducive to a high rate of evapotranspiration.

Records of the U.S. Weather Bureau show that the average rate of evaporation from the surface of lakes and other open bodies of water in Johnson County ranges from 28 inches (estimated) per year on the crest of the Bighorn Mountains to about 42 inches per year in the Powder River structural basin. (See Kohler and others, 1959, pl. 2.) Culler (1961, table 3), in his study of the hydrology of stock-water reservoirs in the upper Cheyenne River basin, estimated that the average rate of evaporation from stock ponds and reservoirs in the eastern part of the Powder River Basin is 4.82 feet per year. In other words, at least 3½ and perhaps as much as 4½ acre-feet of water may be evaporated each year from an acre of free-water surface at altitudes prevailing in the basin. This loss of water constitutes a draft on ground-water reservoirs that discharge into surface bodies of water.

Except for Lake De Smet and the perennial reaches of streams, few surface-water bodies of any great extent are recharged wholly or in part by ground water. Before inlet and outlet canals connecting Lake

De Smet with Piney Creek were dug, the water in the lake evidently was supplied principally by ground water and was highly mineralized. The draft upon ground water must have been appreciable, because the water table at some distance from the lake fluctuates markedly in direct response to changes in lake level. (See fig. 12.) The diversion from Piney Creek undoubtedly reduces the draft on ground water and, at times, contributes recharge to the ground-water reservoir.

The climatic factors of low relative humidity, high temperature, and light precipitation that prevail in most of Johnson County during the summer cause phreatophytes to draw heavily on ground water. Mower and Nace (1957, table 6) estimated that ground-water consumption by cottonwoods in the Malad Valley of southern Idaho was 4.5 feet per year for areas of 100 percent density of foliage. This area has a climate comparable to that of the western part of the Powder River structural basin, although the length of the growing season in the Malad Valley is appreciably shorter, averaging about 100 days as compared with about 125 days at Buffalo and a somewhat longer season in the eastern part of Johnson County. No attempt was made during this investigation to evaluate the quantity of water consumed by cottonwoods and willows in the valley of Powder River, but it probably is several acre-feet per day during the growing season. Transpiration does not cease during the nongrowing season, but the rate is greatly reduced; and many ephemeral streams that are dry during the summer begin to flow shortly after the first killing frost.

Most phreatophytes (principally willow and cottonwood trees) in the valleys of major streams in Johnson County have little economic value except as wind breaks, as shelter for livestock, and as inhibiters of runoff and resulting land erosion. In places, however, dense stands of cottonwoods provide vastly more cover than would be required to provide the benefits described, and the trees use large amounts of ground water. The elimination of superfluous trees would reduce the draft on the ground-water reservoir and result in a generally higher water table in the alluvium. A higher water table would result in the discharge of larger quantities of ground water to streams and thus provide additional surface water for irrigation and stock watering. The decreased depth to water would probably promote a denser growth of native grasses and alfalfa on unirrigated land, especially where these plants are no longer forced to compete with trees for moisture and sunlight.

RECOVERY AND UTILIZATION OF GROUND WATER

Springs and seeps

Springs and seeps contribute to the flow of many streams in northern Johnson County, particularly those rising on the east flank of the

Bighorn Mountains, where the Tensleep Sandstone and Madison Limestone crop out or the granitic core of the Bighorns is exposed. A few small springs and seeps discharge in the foothills near the base of the Moncrief and Kingsbury Conglomerate Members of the Wasatch Formation, where downward percolation is impeded by less permeable beds. Many seeps reportedly issue from fractures in exposed coal beds in the Wasatch, but the yields are generally insignificant.

Only a comparatively few springs are utilized, however, because most others are in relatively inaccessible areas that serve as range for stock or outdoor recreation. Table 6 contains records of springs for which data were available or could be obtained by the authors from field observations. The discharges of most springs fluctuate in response to seasonal precipitation and were probably at or near their lowest at the time measurements or estimates were made. The yield of one large spring (53–86–27cd), however, which issues from morainal deposits overlying the granite of the Bighorn Mountains, reportedly remains fairly constant throughout the year.

Wells

Data for selected representative wells are given in table 7, and the location of the wells is shown on plate 1. Drillers' logs of water wells and oil-test holes are given in table 8.

Most of the wells furnish water for stock and domestic supplies. Nonflowing wells are generally equipped with cylinder pumps powered by wind or gasoline, but some domestic wells, where electricity is available, are equipped with jet pumps. Only four wells are known to be equipped with turbine pumps, and one of these wells reportedly yields sufficient water for moderately large scale irrigation. Water for the community of Buffalo is obtained partly from an infiltration gallery and partly from flow in Clear Creek. The infiltration gallery consists of about 900 feet of 15-inch and 500 feet of 24-inch perforated pipe buried 15–25 feet deep in the alluvium between two forks of Clear Creek. The water flows by gravity from a 350,000-gallon settling and storage tank directly into the community water lines. The yield from the gallery is reportedly about 250 gpm, but it probably varies with the surface flow in Clear Creek.

POTENTIAL SOURCES OF LARGE SUPPLIES OF GROUND WATER

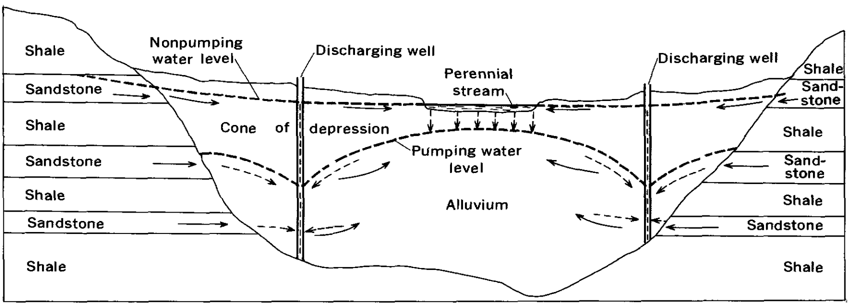
Most aquifers in the project area either consist of fine-grained clastic rocks of relatively low permeability or are too deeply buried to be tapped economically for most purposes. In the northern part of the project area, the development of large quantities of ground water would probably be confined principally to alluvium in the valleys of Piney and Clear Creeks. The alluvium along the upper reaches of these streams is probably composed in large part of lenses of relatively coarse sand and gravel interbedded with finer sand and silt. Where the sand and gravel is saturated, it should readily yield large quantities of water to wells. The proportion of coarser material decreases downstream, and the likelihood of developing large supplies of water from the alluvium diminishes with distance from the mountain front.

The alluvium along the Powder River and the lower reach of Crazy Woman Creek is predominantly silt and fine sand but contains subordinate amounts of coarse sand and gravel. Downstream, the sand and gravel become progressively less abundant. The relatively low permeability of these deposits precludes the possibility of large yields from wells; 150–200 gpm would probably be the maximum yield at most places. To obtain maximum yields, wells will require proper screening and, in some instances, gravel packing.

Water from the alluvium of the Powder River, and probably from the lower reach of Crazy Woman Creek, is highly mineralized and can safely be used for irrigating only very salt tolerant plants on well-drained land. Water from wells in the valleys of Piney and Clear Creeks should be suitable for most irrigation uses, although return seepage of surface water applied to the bottom lands may result in an appreciably higher dissolved-solids content in ground water during the summer.

In the southern part of the project area, moderate to large supplies of ground water might be developed from the alluvium along the Powder River and the upper reaches of Crazy Woman Creek, from the Tensleep Sandstone, and probably from the underlying Madison Limestone. Alluvial deposits along the forks of Crazy Woman Creek probably contain an appreciable thickness of saturated coarse sand and gravel that should persist, though in gradually decreasing amounts, for some distance down stream from the confluence of the forks with Crazy Woman Creek proper. The alluvium in the upper reaches of the Powder River also should contain a larger proportion of sand and gravel and thus be capable of yielding larger quantities of water than should the alluvium in the lower reaches. Except in the Powder River valley and perhaps in the lower part of the valley of Crazy Woman Creek, water from the alluvium probably is generally suitable for most uses, but the return flow of surface water diverted for irrigation may cause the quality to change seasonally.

In considering the possibilities of developing large supplies of ground water from alluvium along streams that currently are providing most of the water for irrigation, one should be aware that most of the surface water available during the irrigation season has been appropriated by long-granted water rights and by applications awaiting adjudication. Water withdrawn from storage in the alluvium would largely be replaced by the downward seepage of streamflow, and surface-water rights might be infringed upon. Figure 13 is a



Solid arrows show direction of ground-water movement when wells are not discharging; dashed arrows show direction of movement after pumping begins. As the water table declines, an increasing amount of streamflow is diverted into the ground-water reservoir by downward seepage

FIGURE 13.—Effect of pumping wells on the water table in the alluvium and possible effect on flow of nearby stream.

diagrammatic sketch illustrating the possible effect that heavy pumping from alluvium may have on streamflow.

The Tensleep Sandstone reportedly yields 600 gpm to an irrigation well at the foot of the Bighorn Mountain front. The well apparently penetrates only the uppermost few feet of the formation, so that deeper penetration probably would have increased the yield considerably. Wells of equal or greater yield can probably be drilled in favorable areas, particularly where the permeability of the rock is increased by fractured or fissured zones. Because of its steep dip, the Tensleep can be tapped by wells at an economical depth for most purposes only in its outcrop area or in a narrow belt, generally less than 1 mile wide, paralleling the east margin of the outcrop. Water from the Tensleep Sandstone is of good quality for irrigation use and of acceptable quality for domestic supply.

The Madison Limestone had not been tapped by wells in the project area at the time of the investigation, but the cavernous character of its outcrops suggests that it is a potential source of large quantities of water. The formation yields large flows from cavernous zones to several wells in the vicinity of Tensleep on the west flank of the Bighorn Mountains. Water from wells tapping the Madison in or near the outcrop should be of suitable quality for all uses.

CHEMICAL QUALITY OF GROUND WATER

REPORTING OF CHEMICAL-QUALITY DATA

Concentrations of dissolved chemical constituents in a water are generally expressed in parts per million (ppm). A part per million is one unit weight of a constituent in 1 million unit weights of water. The specific conductance of water is a measure of the ability of the water to conduct an electrical current and is related to the amount and the chemical type of dissolved material. Because the specific conductance is directly related to the amount of dissolved material, it can be used for estimating the total mineralization. The pH is the degree of acidity or alkalinity of a water. A pH progressively higher than 7 denotes increasing alkalinity, and a pH progressively lower than 7 denotes increasing acidity. Percent sodium and sodium-adsorption ratio are chemical-quality determinations that are of special significance in evaluating the suitability of a water for irrigation.

CHEMICAL QUALITY OF WATER IN RELATION TO USE

DOMESTIC USE

The U.S. Public Health Service (1962) recently revised the recommended chemical-quality standards for water used for drinking and culinary purposes on interstate carriers. On the basis of these standards, most water samples analyzed for this report contained excessive amounts of some constituents; some samples are unsuitable for domestic use under any circumstances. Notable exceptions were water from Precambrian rocks, the Tensleep Sandstone, and the alluvium of upper Clear Creek, and one sample from the Wasatch Formation. Some of the recommended limits for chemical constituents in drinking water are as follows:

Constituent	*Recommended maximum concentration (ppm)*
Iron (Fe)	0.3
Manganese (Mn)	.05
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	[1] .8–1.7
Nitrate (NO_3)	45
Dissolved solids	500

[1] Recommended limits for fluoride are based on the annual average of maximum daily air temperatures. For example, when the average is 50.0°–53.7°F, the recommended upper limit is 1.7 ppm; when the average is between 79.3°F and 90.5°F, the upper limit is 0.8 ppm.

Hardness, a property of water familiar to many people, is caused principally by high concentrations of calcium and magnesium. Arbitrarily, the hardness of water is classified as follows: 60 ppm or less, soft; 61–120 ppm, moderately hard; 121–180 ppm, hard; and 181 ppm or more, very hard.

AGRICULTURAL USE

Although investigations relating the chemical quality of water to its suitability for agricultural purposes have been few, guidelines generally considered reliable have been proposed (Beath, in Miller, 1956; Beath and others, 1953; Eaton, 1950; Scofield, 1936; U.S. Salinity Laboratory Staff, 1954). The following information was extracted largely from the published results of these investigations. Many water supplies that do not meet these requirements fully have been used for many years for agricultural purposes.

Irrigation use

Many chemical properties of water affect its suitability for irrigation. The two main criteria for determining a suitable supply are the dissolved-solids content and the sodium concentration relative to the calcium and magnesium concentrations. Also, the concentrations of bicarbonate, boron, and selenium are significant under certain conditions.

Irrigation water having a high dissolved-solids content (salinity) tends to upset the salt balance in the soil, and the result is retardation of plant growth. As a rule, the higher the salinity of a water, the less suitable the water is for irrigation use.

When the concentration of sodium in an irrigation water is higher than that of calcium and magnesium, the sodium tends to replace calcium and magnesium adsorbed on soil colloids. Soil colloids then tend to disperse and restrict the movement of air and water through the soil, and the result is a soil having poor tilth and permeability. The sodium-absorption-ratio (SAR) is frequently used as an indicator of the hazard entailed in using water having a high sodium content. Percent sodium also is useful in evaluating the suitability of water for irrigation. The U.S. Salinity Laboratory Staff (1954) classified the suitability of water for irrigation on the basis of the salinity and the sodium hazard.

Carbonate and bicarbonate, when present in sufficient concentrations, also may make water unsuitable for irrigation use. The carbonates of calcium and magnesium tend to precipitate, so that the relative proportion of sodium in the soil solution increases. The effect is the same as that produced by applying irrigation water of initially high sodium content. The harmful effects of excessive concentrations of carbonate and bicarbonate are often measured and expressed as "residual sodium carbonate" (Eaton, 1950). In classifying water according to residual sodium carbonate value, the U.S. Salinity Laboratory Staff (1954, p. 81) concluded that less than 1.25 epm (equivalents per million) is probably safe, 1.25–2.5 epm is marginal, and more than 2.5 epm is not suitable.

Boron, although an essential plant nutrient, is toxic to some plants. According to Scofield (1936), water used to irrigate sensitive crops is regarded as excellent with respect to boron if it contains less than 0.33 ppm and as unsuitable if it contains more than 1.25 ppm. For irrigation of semitolerant crops, water is classed as excellent if it contains less than 0.67 ppm boron and as unsuitable if it contains more than 2.50 ppm. For tolerant crops, water containing less than 1.00 ppm is classed as excellent, and that containing more than 3.75 ppm is unsuitable.

When even small amounts of selenium are present in irrigation water, it may accumulate in vegetation in sufficient quantities to be toxic to humans and animals if the vegetation is eaten. Beath (in Miller, 1956) suggested the following relations between concentrations of selenium and degree of toxicity.

Selenium content of water (ppm)	*Effect*
0.00–0.10	No plant toxicity expected.
0.11–0.20	Toxicity may accumulate over a long period of time.
0.21–0.50	Probable toxic accumulation in plants if conditions are favorable.
>0.50	Definite toxicity.

Stock watering

Investigations of the relation of water quality to the health of stock have not been numerous; therefore, rigid criteria for evaluating the suitability of a stock-water supply are difficult to establish. Although stock can safely consume water considered unfit for human consumption, a sufficiently high dissolved-solids content may cause poor growth, sickness, and even death. Beath and others (1953) suggested the following classification as a guide for the evaluation of stock water.

Dissolved solids (ppm)	*Classification*
<1,000	Good.
1,000–3,000	Fair (usable).
3,000–5,000	Poor (usable).
5,000–7,000	Very poor (questionable).
>7,000	Not advisable.

Harmful effects to stock have been attributed to selenium, sulfate, and fluoride in water supplies, but no limiting concentrations for these substances have been generally agreed upon; however, water containing 0.4–0.5 ppm selenium is reportedly nontoxic to cattle (California State

Water Pollution Control Board, 1952, p. 351). A high iron content may make water unpalatable to stock.

INDUSTRIAL USE

Water-quality requirements for specific industrial uses will not be discussed in this report. Reports by Moore (1940) and by the California State Water Pollution Control Board (1952) contain information on industrial water-quality standards and may be consulted for criteria applicable to a specific use. Although water-quality requirements range widely, generally water that is suitable for domestic use is also suitable for industrial use or can be made so by treatment. For many uses, water having uniform quality and temperature is as desirable as water having special chemical characteristics.

CHEMICAL QUALITY OF WATER IN RELATION TO SOURCE

The amount and kind of chemical constituents in ground water depend principally on the type of rock through which the water has moved and the length of time the water was in contact with the rock. Other factors affecting the quality of ground water are temperature, pressure, and dissolved substances already in the water when it entered the aquifer. Chemical analyses of water from 31 selected wells and 3 springs are given in table 5.

ROCKS OF PRECAMBRIAN AGE

Measurements of specific conductance of water from several springs issuing from rocks of Precambrian age (table 6) indicate that the dissolved-solids content of the water is less than 100 ppm. An analysis of water from springs 50–84–10da is given in table 5. The water is of a calcium bicarbonate type and has a dissolved-solids content of 63 ppm. The water is of excellent quality for most uses. Because the Precambrian rocks in the project area are resistant to the solvent action of water, water in these rocks probably has similar chemical characteristics at most locations.

TENSLEEP SANDSTONE

Analyses of three samples of water from the Tensleep Sandstone are given in table 5. Water from spring 46–83–3bd and well 49–83–27dc is of a magnesium bicarbonate type and contains less than 300 ppm dissolved solids. Water from well 46–83–22dd is of a calcium magnesium sulfate type and has a dissolved-solids content of 956 ppm. The different chemical character and higher dissolved-solids content of water from well 46–83–22dd are probably due to water entering the well from an overlying gypsum and red-shale sequence. Water from the Tensleep Sandstone at most locations, however, will

TABLE 5.—*Chemical analyses of ground water in northern and central Johnson County, Wyo.*

[Results in parts per million except as indicated. Analyses by U.S. Geological Survey except as indicated]

Well	Depth (feet)	Yield (gpm)[1]	Date of collection	Temperature (° F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Calculated	Dissolved solids: Residue on evaporation at 180° C	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium-adsorption ratio	Specific conductance (micromhos at 25° C)	pH	Color (units)[2]	Hydrogen sulfide (H_2S)
Rocks of Precambrian age																												
50-84-10da	Spring	3.0	Oct. 27, 1960	38	17	0.05	0.01	9.6	2.4	3.6	1.2	47	0	5.3	0.0	0.1	0.7	0.01	----	63	34	0	18	0.3	92	7.0	5	----
Tensleep Sandstone																												
46-83-3bd	Spring	30	Oct. 24, 1960	46	7.8	0.04	0.00	43	30	1.1	0.8	279	0	5.3	0.2	0.1	0.9	0.02	----	223	231	2	1	0	411	7.7	2	----
46-83-22dd[3,4]	258	600	Not known	----	----	1.1	----	135	60	70	2.8	343	0	415	13	----	.0	.13	----	956	585	303	21	1.3	1,260	7.5	--	----
49-83-27dc	245	33	July 31, 1962	47	9.5	----	.00	35	41	3.0	1.5	302	0	13	3.0	.2	----	----	----	255	256	8	2	.1	477	8.0	--	----
Frontier Formation																												
46-83-13ca	70	10	Oct. 24, 1960	55	29	2.9	0.28	177	70	299	6.2	175	0	1,250	4.4	1.5	0.4	0.58	1,920	2,020	731	587	47	4.8	2,430	7.1	5	----
Cody Shale																												
50-83-36aa[3]	270	----	Not known	----	----	----	----	298	573	2,350	17	500	0	7,830	227	----	1.6	2	----	12,580	3,100	2,690	62	18	12,980	8.0	--	----
Parkman Sandstone																												
46-82-9ad	150	6	May 24, 1961	48	11	0.22	----	62	14	366	3.3	359	0	690	12	0.3	4.3	0.48	1,340	1,360	212	0	79	11	1,930	8.1	2	----

Lance Formation																												
48-82-9ad	186	10	Oct. 19, 1961	----	12	5.1	0.27	481	125	191	5.6	278	0	1,780	64	0.1	0.5	0.14	2,800	3,060	1,710	1,480	19	2.0	3,160	7.0	3	0.5
51-83-4bc	205	------	Aug. 31, 1961	57	15	6.3	.26	389	134	172	4.2	464	0	1,430	7.4	.3	.0	.16	2,380	2,650	1,520	1,140	20	1.9	2,800	7.7	2	.0
Fort Union Formation																												
46-82-14ad	205	------	Oct. 30, 1962	48	----	9	----	600	198	39	----	484	0	1,870	8.0	----	----	----	-----	3,250	2,310	1,910	4	0.4	3,150	7.5	--	----
47-82-13db	323	5	Oct. 20, 1961	49	6.8	8.8	0.17	325	110	358	11	134	0	1,800	63	0.1	4.4	0.16	2,740	2,950	1,260	1,150	38	4.4	3,270	7.0	2	0.0
48-77-25db	605	2.0	Oct. 27, 1960	56	9.8	.26	.04	5.7	.5	216	2.1	566	0	16	10	1.4	.0	.07	-----	544	16	0	96	24	879	7.6	6	----
48-82-11bb	420	1	Oct. 29, 1962	----	----	.06	----	78	31	236	----	271	0	568	22	----	----	----	-----	1,090	323	101	61	5.7	1,560	8.1	--	----
49-77-21ba	600	1.2	Oct. 27, 1960	56	11	.56	.00	5.6	1.9	256	2.1	591	50	2.3	11	1.6	.4	.09	-----	635	22	0	96	24	1,030	8.8	6	----
50-77-29dc	575	2	July 31, 1962	61	9.8	.24	.00	6.4	.2	333	2.4	828	24	4.6	14	3.6	----	----	-----	794	17	0	97	35	1,300	8.3	--	.5
51-77-20ca	580	.6	Oct. 27, 1960	54	9.3	.18	.05	4.6	1.1	213	2.8	571	0	2.0	13	1.3	.0	.06	-----	529	16	0	96	23	860	7.9	3	.6
51-77-20cc	758	7.7	Aug, 31, 1961	60	10	.18	.02	7.0	2.6	410	4.5	1,120	0	.3	13	3.1	.0	.14	1,000	1,020	28	0	96	34	1,600	8.0	0	.5
52-77-3ab	828	17.0	Oct. 26, 1960	63	11	.45	.04	14	3.4	500	4.6	1,350	0	1.5	23	.6	.0	.07	1,220	1,250	49	0	95	31	1,900	8.0	3	----
Wasatch Formation																												
46-77-31bal	203	15	May 23, 1961	----	9.6	0.15	0.00	4.2	0.4	121	1.2	117	5.9	149	10	0.5	0.0	0.10	-----	364	12	0	95	15	583	8.3	1	----
46-80-19ab	225	2	Oct. 24, 1961	49	7.4	.11	.00	52	14	330	4.0	196	0	690	33	.4	3.8	.07	1,230	1,260	188	27	79	10	1,800	7.3	3	0.0
46-80-20bb	370	5	do	49	7.4	.07	.14	118	35	510	5.4	185	0	1,360	22	.2	3.6	.06	2,150	2,190	438	286	71	11	2,840	7.1	3	.0
49-81-33bb	255	3	Oct. 20, 1961	----	10	.72	.10	117	44	141	5.4	169	0	593	12	.1	3.6	.09	1,010	1,070	474	335	39	2.8	1,400	7.0	3	.9
49-82-2bb	318	15	do	49	12	1.6	.00	75	40	36	5.0	349	0	139	4.5	.0	2.8	.10	-----	486	351	65	18	.8	779	7.5	5	.6
50-79-19bc	600	8.0	Oct. 27, 1960	48	12	.42	.63	156	45	181	3.2	443	0	569	19	.3	4.8	.09	1,210	1,260	573	210	41	3.3	1,670	7.5	11	----
50-82-11cb	460	1.8	Oct. 19, 1961	51	15	2.7	.20	183	48	175	4.3	277	0	780	7.3	.1	5.6	.21	1,350	1,340	652	421	37	3.0	1,710	7.3	2	1.0
51-79-16ba	164	------	Oct. 26, 1960	50	8.7	.19	.03	27	11	202	2.9	453	0	183	10	.6	.0	.09	-----	672	113	0	79	8.3	1,060	7.7	3	----
51-82-33dd	145	7.5	Oct. 27, 1960	48	13	.72	.04	76	10	296	1.9	479	0	484	7.8	.1	1.4	.08	1,130	1,170	232	0	73	8.5	1,650	8.0	5	----
52-79-12cc	160	------	Oct. 26, 1960	49	7.9	.20	.06	5.1	2.3	235	1.6	638	0	1.3	12	1.3	.0	.12	-----	598	22	0	96	22	960	7.6	5	----
52-82-13db	246	10	Oct. 23, 1961	48	13	13	.43	321	313	660	25	477	0	3,020	19	.3	16	.53	4,620	4,920	2,090	1,700	40	6.3	5,060	6.8	55	.5
52-83-22ca	510	.5	Oct. 20, 1961	50	9.3	1.6	.10	100	51	61	6.4	399	0	243	6.2	.2	6.2	.10	-----	687	461	134	22	1.2	1,140	7.5	0	1.6
53-82-33bb	60	20	Oct. 23, 1961	49	15	.87	.04	93	59	104	8.5	488	0	284	4.5	.4	5.5	.15	-----	812	474	74	32	2.1	1,290	7.5	0	.8
Glacial deposits																												
53-86-27cd	Spring	400	Oct. 28, 1960	38	21	.22	.00	10	3.2	4.7	1.0	58	0	3.3	0.0	0.0	0.1	0.01	-----	82	38	0	21	0.3	99	6.7	2	----
Alluvium																												
49-77-20ba	32	60.0	Oct. 27, 1960	53	11	5.0	2.4	302	87	287	8.5	271	0	1,220	194	0.4	0.8	0.21	2,240	2,370	1,110	888	36	3.7	2,860	7.4	7	----
50-82-6ad	26	250	Oct. 30, 1962	50	----	----	----	22	5.2	5.7	----	96	0	10	0	----	----	----	-----	106	77	0	14	.3	174	7.3	--	----

[1] Yields measured by authors given in gallons and tenths; others were estimated or reported.
[2] Platinum-cobalt scale (Hazen, 1892).
[3] Analysis by Wyoming State Department of Agriculture, Laramie, Wyo.
[4] Sample probably contaminated by water from overlying gypsum and red-shale sequence.

probably have a chemical quality similar to that of water from spring 46–83–3bd and well 49–83–27dc. The water will be very hard, but otherwise it will be suitable as a domestic supply. As a source of water for stock and irrigation use, the Tensleep Sandstone can be expected to yield water of good quality.

FRONTIER FORMATION

Well 48–83–13ca yields water from the Frontier Formation. The water is of a sodium calcium sulfate type and has a dissolved-solids content of 2,020 ppm. (See table 5.) Iron, manganese, sulfate, and dissolved-solids contents exceed recommended maximum concentrations for water used domestically. Because of a very high salinity hazard, the water cannot be recommended for irrigation except on salt-tolerant crops under special circumstances. Water supplies developed for stock use will be of fair quality, although a high iron content may make the water unpalatable.

CODY SHALE

Water from the Cody Shale was obtained from well 50–83–36aa. The water is of a sodium sulfate type and has a dissolved-solids content of 12,580 ppm. (See table 5.) It is unusable for domestic, irrigation, and stock purposes. The Cody Shale will probably yield water of poor quality to most wells throughout the project area, but the dissolved-solids content of water from all wells may not be as high as that of water from well 50–83–36aa.

PARKMAN SANDSTONE

Water from the Parkman Sandstone was obtained from well 46–82–9ad. The water is of a sodium sulfate type and has a dissolved-solids content of 1,360 ppm (table 5). It is usable as a domestic supply, although sulfate and dissolved-solids contents exceed the maximum allowable concentrations recommended by the U.S. Public Health Service (1962). The water is of fair quality for stock supply, but its high salinity and high sodium hazards limit its use for irrigation to crops having a high salt tolerance and grown on well-drained soils.

LANCE FORMATION

Water from the Lance Formation was obtained at two locations: well 48–82–9ad, which yields a calcium sulfate type water that has a dissolved-solids content of 3,060 ppm, and well 51–83–4bc, which yields a similar type of water that has a dissolved-solids content of 2,650 ppm (table 5). The chemical characteristics of the water from well 51–83–4bc are illustrated graphically in figure 14. Water from the Lance Formation is unsuitable for domestic use because of

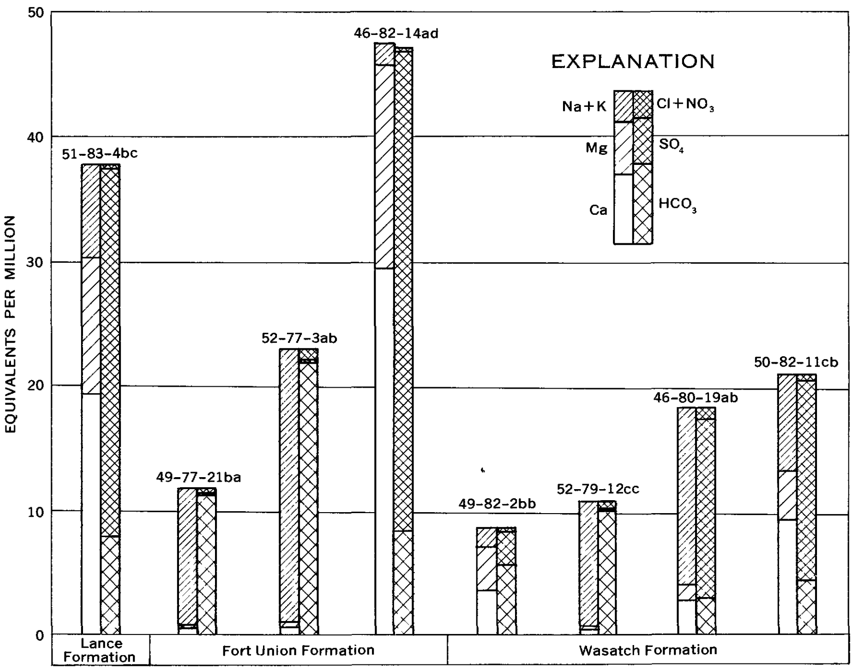


FIGURE 14.—Chemical characteristics of water from the Lance, Fort Union, and Wasatch Formations in northern and central Johnson County, Wyo.

high iron, manganese, sulfate, and dissolved-solids contents. On the basis of dissolved-solids content, the water is fair to poor for stock use, but the high iron content may make the water unpalatable even to stock. The water is unsuitable for irrigation under ordinary conditions because of a very high salinity hazard.

FORT UNION FORMATION

Chemical analyses of nine samples of water from the Fort Union Formation are given in table 5. Iron content ranges from 0.06 to 19 ppm; sulfate content, from 0.3 to 1,870 ppm; and hardness, from 16 (soft) to 2,310 ppm (very hard). Dissolved-solids content ranges from 529 to 3,250 ppm. The chemical characteristics of water from three wells in the Fort Union Formation are presented graphically in figure 14.

The quality of water in the Fort Union Formation seems to be related to the depth of the water-bearing zone. Of the wells sampled, those deeper than about 500 feet yield water of a sodium bicarbonate type having a dissolved-solid content of 1,250 ppm or less. The water is soft and contains only small amounts of sulfate. Water from wells less than 500 feet deep is of a sodium sulfate, calcium-sodium sulfate, or calcium sulfate type having a dissolved-solids content as high as 3,250 ppm. The water is very hard. Wells 46–82–14ad and 47–82–13db yield water having iron contents of 19 and 8.8 ppm, respectively. Both wells are less than 500 feet deep.

Water from depth of more than 500 feet is probably affected by two chemical reactions as the water moves through the rocks: cation-exchange softening and sulfate reduction. Riffenburg (1925) cited cation-exchange softening as affecting the quality of water in the Fort Union Formation in Montana. The reduction of sulfate in water of the Fort Union Formation is indicated by the relatively high bicarbonate concentrations in comparison to the sulfate concentrations, and by the occurrence of hydrogen sulfide and hydrocarbon gases in the water at many locations.

Although cation-exchange softening is a likely cause of the high percentage of sodium in the water from wells more than 500 feet deep, sulfate reduction may indirectly increase the percentage of sodium. Under favorable conditions, the reduction of sulfate may result in the formation of nearly insoluble calcium and magnesium carbonates, which precipitate (Eaton, 1936, p. 515).

Foster (1950) suggested that carbon dioxide originating in carbonaceous material promotes high sodium bicarbonate concentrations in water. Carbon dioxide, when adsorbed by water, enables the water to dissolve calcium carbonate, thereby increasing the bicarbonate concentration. If water that contains calcium carbonate comes in contact with cation-exchange materials, the dissolved calcium may be exchanged for sodium. The exchange not only increases the proportion of sodium in solution, but allows even greater amounts of bicarbonate to be held in solution.

Gas accompanies water discharged from wells penetrating beds of coal and other carbonaceous material in the Fort Union Formation. A sample of gas was collected from well 51–77–20cc in accordance with techniques suggested by the Chemical and Geological Laboratories, Casper, Wyo. A chemical analysis of the gas was made by that laboratory using a gas chromatograph. The percentage composition of the gas was as follows:

Gas	*Percentage composition (by volume)*
Oxygen (O_2)	0.56
Nitrogen (N_2)	11.56
Carbon dioxide (CO_2)	.47
Methane (CH_4)	87.38
Ethane (C_2H_6) and higher paraffin hydrocarbons	.03

Free hydrogen sulfide also occurs in the gas, but the quantity could not be determined by chromatographic analysis. Samples of water from some wells were analyzed for dissolved hydrogen sulfide. (See table 5.) Well 51–77–20cc discharged 0.3 liter of gas per liter of water.

Most of the gas probably originates in the coal or in other carbonaceous material. Analyses of gas contained in coal (Chamberlin, 1909) are similar in many respects to the analysis of gas obtained from well 51–77–20cc in Johnson County. Lewis (1934) stated that carbon dioxide and methane contained in coal are being formed continuously, primarily by internal molecular adjustments during transitions from rank to rank in the coal series. Ethane and propane have been obtained from coal, but generally as a result of heating. Although coal and carbonaceous material are probably the principal sources of the gas discharged from water wells, the ethane and higher paraffin hydrocarbons might be in natural gas that has migrated upward from pre-Tertiary rocks. Natural gas generally contains a higher percentage of ethane and propane than does gas obtained from coal.

Moore (1950) stated that the nitrogen in coal comes partly from plant constituents but mainly from air that has been imprisoned in the coal. Some of the nitrogen discharged with the water from well 51–77–20cc, however, may have been carried down by percolating ground water. Most of the oxygen in the air imprisoned in coal probably combines with carbon and hydrogen during the alteration of the vegetal matter from which the coal is formed. Nevertheless, oxygen has been obtained from coal, and Lewis (1934, p. 33) stated that free oxygen is sometimes observed in coal in small quantities. The oxygen in the gas from well 51–77–20cc may have been present in percolating ground water that was at one time in contact with the atmosphere. Despite the fact that both oxygen and nitrogen have been detected in coal and that both may be present in percolating ground water, the oxygen, and some of the nitrogen, that was detected in the samples may have resulted from air contamination when the samples were collected.

Gas accumulates in fractures and in places of increased porosity in the coal, and it also may migrate to adjacent strata. Gas in an aquifer affects the height to which water will rise in a well and may provide the "lift" necessary to bring the water to the surface. Where the quantity of gas in an aquifer is small, all the gas may be dissolved in the water. A gradual decrease in pressure as the water moves upward from the aquifer allows the dissolved gas to be liberated. With liberation, the gas expands; and as the gas expands, the specific gravity of the gas-water mixture decreases, and a lifting action is created. Because of this effect, probably several wells in the project area flow that otherwise would not. Some of the wells may flow because of the pressure of free gas in the aquifer.

Water from the Fort Union Formation is used principally for domestic and stock purposes. According to the U.S. Public Health Service (1962), the water does not meet suggested domestic standards with respect to dissolved-solids content, although it is usable. The iron content of the water differs from well to well and may exceed the 0.3-ppm suggested as the maximum allowable in water for domestic use. Hydrogen sulfide imparts an unpleasant odor to most supplies, but, like carbon dioxide, it is not physiologically harmful in water. No reference in the literature could be found that cited harm to human beings or stock as a result of drinking water containing the quantities of hydrocarbon gases likely to be in solution at atmospheric pressure. At the time of this investigation (1963), water from the Fort Union Formation was not being used for irrigation. The water is unsuitable as an irrigation supply either because of a very high salinity hazard or because it contains an excessive amount of "residual sodium carbonate" (Eaton, 1950). The quality of water from the Fort Union Formation ranges from good to poor for stock use.

WASATCH FORMATION

Chemical analyses of 13 samples of water from the Wasatch Formation are given in table 5. Dissolved-solids content ranges from 364 to 4,920 ppm; iron content, from 0.07 to 13 ppm; sulfate content, from 1.3 to 3,020 ppm; and hardness, from 12 (soft) to 2,090 ppm (very hard). The chemical characteristics of the water from four wells drilled in the Wasatch Formation are shown graphically in figure 14. Approximately half the wells sampled yield water in which sodium constitutes more than 50 percent of the cations. The rest of the wells yield water in which the two most abundant cations are calcium and magnesium, sodium and calcium, or sodium and magnesium. Bicarbonate makes up more than 50 percent of the anions in water from 5 of the 13 wells sampled, whereas sulfate composes more than 50 percent of the anions in water from the rest of the wells. Water containing bicarbonate as the predominant anion generally has a dissolved-solids content of less than 1,000 ppm, whereas water containing sulfate as the predominant anion generally has a dissolved-solids content greater than 1,000 ppm. The diversity of quality of water from the Wasatch Formation may be attributed to local differences in recharge, soil, and lithology. Cation-exchange softening and sulfate reduction probably affect the water in some localities.

Small quantities of gas are discharged with water from several wells in the Wasatch Formation. The quantity of hydrogen sulfide in solution in water at the well head was determined for eight wells.

(See table 5.) Carbon dioxide, methane, and higher paraffin hydrocarbon gases are probably present also, particularly where coal or other carbonaceous material occur. No analyses of free gas at the well head were made because of unsuitable sampling conditions.

Water from the Wasatch Formation is principally used for domestic and stock supplies. Water from only 2 of the 13 wells sampled meets suggested domestic standards with respect to dissolved-solids content. Concentrations of iron, manganese, and sulfate are high also, mainly in water having a dissolved-solids content greater than 1,000 ppm. Approximately three-fourths of the wells sampled yield very hard water. In most places, however, water from the Wasatch Formation is usable for domestic purposes if no other supply is available. Although sufficient water could be obtained from the Wasatch from properly constructed wells, the water would generally be unsuitable for irrigation of anything but salt-tolerant crops grown on well-drained soils. A chemical analysis of water from a test hole should be made before a large-diameter irrigation well is constructed. The quality of the water ranges from good to fair for stock use.

GLACIAL DEPOSITS

Spring 53–86–27cd yields water for domestic and stock use from glacial deposits. The water is a calcium bicarbonate type and has a dissolved-solids content of 82 ppm. (See table 5.) Because glacial deposits occur only in the mountains, water from these deposits will probably continue to be used only for domestic and stock purposes, although the quality of the water is excellent for all but specialized industrial uses.

ALLUVIAL DEPOSITS

Well 49–77–20ba yields calcium-sodium sulfate water containing 2,370 ppm dissolved solids. (See table 5.) The water is of poor quality for domestic use because it is very hard and has high iron, manganese, sulfate, and dissolved-solids contents. The water has a very high salinity hazard, so that its use for irrigation must be restricted to very salt-tolerant crops under special circumstances. The water is of fair quality for stock use. The quality of water from well 49–77–20ba probably is typical of that of water in alluvial deposits in the eastern part of the project area.

Water from well 50–82–6ad (infiltration gallery) is a calcuim bicarbonate type having a dissolved-solids content of 106 ppm. The water is of excellent quality for domestic, irrigation, and stock uses. Water from this well, mixed with water from Clear Creek, is the public supply of the community of Buffalo. The alluvium is recharged by Clear Creek, which contains water of excellent quality at

Buffalo. In general, alluvial deposits in the western part of the project area contain water of better quality than do alluvial deposits in the eastern part, mainly because the quality of recharge water is better.

CONCLUSIONS

Ground water in northern and central Johnson County occurs under both artesian and water-table conditions. Most of the aquifers, however, are artesian, owing to the structural influence of the Bighorn uplift. Water-table conditions exist mainly in the alluvium in major stream valleys and in the outcrop areas of artesian aquifers.

At the present time (1963) the Wasatch Formation is the principal source of ground water in the project area, because it lies at or near the surface in much of the county. The depth of wells drilled in the Wasatch ranges from less than 100 to more than 1,000 feet, but the average depth is nearer 300 feet. Yields from the fine-grained facies of the Wasatch are generally small and are barely adequate for stock and domestic use. Wells drilled in the Kingsbury Conglomerate and Moncrief Members may be more productive locally, but insufficient data were obtained to permit an evaluation of the permeability of these coarse-grained facies. They probably will not yield more than moderate supplies. The Fort Union Formation may be slightly more permeable than the fine-grained facies of the Wasatch, but only small yields can generally be expected.

Sufficiently deep wells drilled in the Lance Formation may yield moderate supplies of water in some places, but pumping costs would probably be prohibitive for most purposes because of high pumping lifts. The Parkman Sandstone might yield moderate quantities of water to properly constructed wells, but only locally can the formation be developed economically owing to the steep dip of the beds, which causes the unit to be deeply buried in much of the project area. The Shannon Sandstone Member of the Cody Shale is of little importance as an aquifer in most of the area; however, it is the only potential source of ground water between outcrops of the Parkman Sandstone and the Newcastle Sandstone. The Shannon will probably yield only enough water for stock or domestic wells in most localities. Both the Newcastle Sandstone and the basal sandstone of the Cloverly Formation seem to be sufficiently permeable to yield moderate supplies of water to wells, and a properly constructed well tapping both aquifers would yield even larger quantities of water. The importance of these aquifers is minimized, however, because recharge areas are small and because depths to the formation are great in most of the project area. area.

The development of ground-water supplies adequate for irrigation use is unlikely, except from the Tensleep Sandstone and the Madison Limestone and possibly from coarse alluvium that may occur along the upper reaches of major streams. Both the Tensleep and Madison are at great depths except in or near their outcrop areas. Some wells drilled into the formations may flow, but unless the aquifer is fractured or cavernous, the flow probably will not be adequate for irrigation and will have to be augmented by pumping. Careful test drilling in the alluvium of Piney Creek and in the upper reaches of Crazy Woman and Clear Creeks may locate saturated deposits of coarse sand and gravel that are sufficiently thick and permeable to yield moderate to large quantities of water to wells. The development of large quantities of water from the alluvium in these places, however, might appreciably reduce the flows of adjacent streams.

In general, ground water from Precambrian rocks, the Tensleep Sandstone, and glacial deposits is of good quality for domestic, irrigation, and stock uses. Water of similar quality is obtained from alluvial deposits in the western part of the project area. The Frontier Formation, the Lance Formation, and alluvial deposits in the eastern part of the project area yield water of poor quality for domestic use and of fair to poor quality for stock use. The water is unsuitable for irrigation under ordinary conditions because it has a very high salinity hazard. Water from the Parkman Sandstone is usable as a domestic supply but has limited suitability for irrigation because of its high salinity and sodium hazards. Water from the Parkman Sandstone is of fair quality for stock use. Water from the Cody Shale is unsuitable for most uses.

Water from the Fort Union Formation is usable as a domestic supply, although the dissolved-solids content exceeds the recommended maximum. Hydrogen sulfide occurs in the water at most places and imparts an unpleasant odor to domestic water supplies. The water is unsuitable for irrigation use because of high sodium and bicarbonate contents; it ranges from good to poor for stock use.

Water from the Wasatch Formation is usable for domestic purposes, although it generally does not meet suggested domestic-water standards with respect to iron, manganese, sulfate, and dissolved-solids contents. Hydrogen sulfide also is an objectionable constituent in water from several wells. Water from the Wasatch Formation is unsuitable for irrigation use except where used on salt-tolerant crops grown on well-drained soils. The water is good to fair for stock use.

RECORDS OF SPRINGS, WATER WELLS, AND OIL-TEST HOLES

Tables 6 and 7 contain records of 21 springs and 278 wells, respectively, that were inventoried during the investigation. Many of the data were obtained from well owners or tenants, well drillers, or records of the Johnson County Agricultural Stabilization and Conservation Office at Buffalo. The depth to water and the depth of the well were measured by the authors where possible. The location of the springs, wells, and oil-test holes is shown on plate 1.

TABLE 6.—*Records of springs in northern and central Johnson County, Wyo.*

[Discharge: E, estimated; M, measured; R, reported. Use of water: D, domestic; S, stock. Remarks: Ca, chemical analysis in table 5]

Location	Owner or tenant	Discharge (gpm)	Quality	Specific conductance (micromhos at 25°C) [1]	Temperature °F	Use of Water	Approximate altitude of spring (feet)	Date of Inventory	Remarks
				Moraine deposits					
53-86-27cd	Spear-O-Wigwam	400R	Good	110	38	D, S		Sept. 29, 1960	Ca, dependable supply. Water issues from moraine deposits overlying granite.
				Wasatch Formation					
50-83-12ca	Northern Wyoming Land Co	0.2M	Poor			S	6,300	Jan. 14, 1960	
53-83-27cc	T. Jefferies	2-3E	Good		52	D, S	5,915	do	Dependable supply.
				Tensleep Sandstone					
46-83-3bd	Adrian Bros	30E	Good	411	46	D, S		Aug. 24, 1960	Ca, dependable supply.
-22ac	L. D. Ramsbottom	170M	do	90	43	D, S	5,500	do	Dependable supply.
				Precambrian granite					
47-84-4ca	Esponda Co	3.2M	Good		39	D, S	8,790	Aug. 25, 1960	
49-84-7ad	A. Hansen	4.4M	do	100	41	D	8,300	Aug. 30, 1960	
-14ac	Wyoming Highway Camp		do	70	53	D	8,450	do	
-18dd	U.S. Forest Service	11.2M	do	50	37	S	8,630	do	
-27ab	do	1.0M	do	50	40	D	8,500	Oct. 20, 1960	
50-83-5ba	do	1.0M	do		48	S	7,020	Oct. 17, 1960	
-5bb	do	.3M	do			S	6,900	do	Dependable supply.
-6cb	do	2E	do		44	S	7,300	do	
50-84-2ab	do	Dry				S	8,600	Aug. 6, 1960	Usually dependable supply.
-10ac	do	1.6M	Good	115	43	D	7,300	Aug. 29, 1960	
-10da	do	3.0M	do		42	D	7,300	do	Ca, dependable supply.
-10db	do	2E	do		46	S	7,240	do	
-11cb	do	1.5M	do	110	46	S	7,250	Aug. 30, 1960	
-15db	do	3.2M	do	70	39	S	7,600	Sept. 6, 1960	
-23ba	do	Dry				S	7,600	Oct. 20, 1960	Usually dependable supply.
-27ba	South Fork Inn	3.5M	Good	70	36	D		May 7, 1960	

[1] The concentration of dissolved solids generally ranges from 55 to 75 percent of the specific conductance.

TABLE 7.—*Records of water wells and oil-test holes in northern and central Johnson County, Wyo.*

Well: See text for description of well-numbering system.
Type of well: Dr, drilled; Du, dug.
Depth of well: Measured depths given in feet and tenths below land surface; reported depths given in feet.
Character of material: G, gravel; S, sand; Sh, shale; Ss, sandstone.
Geologic source (symbols listed alphabetically): €f, Flathead Sandstone; Kc, Cody Shale: Kf, Frontier Formation; Kl, Lance Formation; Kp, Parkman Sandstone; Pt, Tensleep Sandstone; Qal, alluvium: Tfu, Fort Union Formation; Tw, basin facies of Wasatch Formation; Twk, Kingsbury Conglomerate Member of Wasatch Formation.
Method of lift and type of power: C, cylinder: Cf, centrifugal; F. artesian flow; Gf, gravity flow; J, jet; N, none; T, turbine; E, electric; G, gasoline or gas; H, hand operated; N, none; W, wind.
Use of water: D, domestic; I, irrigation; N, none; P, public supply; S, stock.
Water level: Measured depths given in feet and hundredths; reported depths given in feet; +, artesian head not known.
Remarks: Ca, chemical analysis in table 5; D, discharge, in gallons per minute (M, measured; R, reported); DD, drawdown, in feet, while discharging at preceding rate; L, log of well in table 8; T, temperature of water, in degrees Fahrenheit.

Well	Owner or tenant	Year constructed	Type	Depth (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift and type of power	Use of water	Distance to water level above (+) or below land surface (feet)	Date of measurement	Remarks
46-77-7cc	G. Irigaray	1946	Dr	210	194	6-4	Ss	Tw	F	S	+	Apr. 11, 1961	D3.2M, T56.
-9ad	L. Falxa	1946	Dr	247	134	6-2	Ss	Tw	C, W	S	26.80	Oct. 12, 1959	
-14aa	J. Iberlin and Sons	1959	Dr	330	290	4	Ss	Tw	C, W	S	170.93	Nov. 3, 1960	D8R, DD25R.
-19dd	G. Irigaray	1951	Dr	290	77	4	Ss	Tw	F	S	+	Apr. 11, 1961	D3.5M, D7.5R, 1951.
-27ba	do	1957	Dr	336	336	4	Ss	Tw	C, W	S	108.77	do	D5R, DD60R.
-31ba1	do	1947	Dr	203	109	6-2	Ss	Tw	F	S	+	do	Ca, D15R.
-31ba2	L. Falxa	1947	Dr	289	277	4	Ss	Tw	C, W	S	104.76	do	D3R, DD100R.
46-78-12ac	do	1955	Dr	387	387	2	Ss	Tw	F	S	+	do	D2.9M.
-12db	do		Dr	240	22	6	Ss	Tw	C, W	S	148.11	Oct. 12, 1959	
-13bd	do	1956	Dr	486	486	4-2	Ss	Tw	F	S	+	do	D2.7M, L.
-15ac	do	1951	Dr	270	175	2	Ss	Tw	F	S	+	do	D4.0M.
-18dc	F. W. Hesse	1957	Dr	540	280	4	Ss	Tw	C, W	S	110.15	Aug. 18, 1960	D3.5R, DD70R.
-30cd	do	1958	Dr	262	262	4	Ss	Tw	C, W	S	86.38	do	D2.4R, DD25R.
46-79-20bb	H. L. Provence	1954	Dr	44	44	7	Ss	Tw	C, W	S	19	Apr. 22, 1954	
-22ad	do	1956	Dr	200	200	4	Ss	Tw	C, W	S	22	July 25, 1956	D4R, DD128R.
-26bd	F. W. Hesse	1960	Dr	300	300	4	Ss	Tw	C, G	S	72.34	Aug. 18, 1960	D8R, DD200R.
-33ad	C. Eklund	1956	Dr	346	346	4	Ss	Tw	C, G	S	23.26	Nov. 10, 1960	D4R, DD128R.
-35cd	F. W. Hesse	1954	Dr	131	131	6	Ss	Tw	C, G	S	49.32	Aug. 18, 1960	D20R, DD25R.
46-80-4bb	J. Zezas	1952	Dr	240	237	6.4	Ss	Tw	C, G	S	18.61	June 7, 1960	
-8ac	F. Crain	1952	Dr	250	250	4	Ss	Tw	C, G	S	10.96	Nov. 10, 1960	D5R, DD141R.
-19ab	Christensen Bros.	1950	Dr	225	225	4	Ss	Tw	C, W	S	+	Oct. 24, 1961	Ca, D2E; water reported suitable for stock.
-20bb	do	1950	Dr	370		4	Ss	Tw	C, W	S	4	do	Ca, D5E; water reportedly poor for stock.

46-80-24ca	C. Eklund	1951	Dr	31	31	8	Ss	Tw	C, W	S	8.49	Nov. 10, 1960	
-25bc	do	1951	Dr	300	300	4	Ss	Tw	C, W	S	15.20	do	D5R, DD40R.
-26bd	do	1951	Dr	25	25	8	Ss	Tw	C, W	S	8	Mar. 23, 1951	D4R, DD11R.
-28bd	H. Christensen	1946	Dr	377		6	Ss	Tw	N	N	105.32	do	
46-81-13bb	F. Crain	1943	Dr	150	150	6	Ss	Tw	C, W	S	39.21	May 11, 1960	
-18cd	J. K. Wright and son	1950	Dr	375	375	6-4	Ss	Tfu	C, W	S	150	Sept. 30. 1950	D2.5R, DD150R, L.
-26cd	A. F. Lund	1958	Dr	150	150	6	Ss	Tw	C, W	N	148.40	May 11, 1960	
46-82-9ad	L. D. Ramsbottom	1953	Dr	150	150	4	Ss	Kp	C, W	S	4.63	Jan. 5, 1961	Ca, D6R, DD27R,L.
-14ad	H. Gerard	1928	Dr	205	100	6	Ss	Tfu	C, W	S	70	Oct. 31, 1962	Ca.
-22bb	M. K. Howie	1940	Dr	170	144	4	Ss	Kl	C, W	S	62.72	Jan. 5, 1961	D7R, DD35R.
-31ac	D. Adrian	1955	Dr	336	336	4	Sh	Kc	C, G	S	6.03	do	D6R, DD17R, L.
-33dc	do	1954	Dr	240	240	4	Sh	Kc	C, G	S	24.80	May 24, 1961	D3R, DD151R.
-35bc	B. T. Pheasant	1955	Dr	202	202	4	Ss	Kl	C, G	S	65	May 31, 1955	D4.5R, DD105R, L.
46-83-13ca	D. Hammond		Dr	70	69	4	Ss	Kf	J, E	D	8.62	Oct. 12, 1960	Ca, D10E.
-22dd	L. D. Ramsbottom	1954	Dr	258	258	10	Ss	Pt(?)	T, E	I	56.20	Apr. 21, 1961	Ca, D600R, L.
47-76-31cd	J. Iberlin and Sons	1955	Dr	160	150	7-6	Ss	Tw	C, G	S	121.59	Nov. 16, 1959	D27.5R.
47-77-24dc	do	1960	Dr	253	253	4	Ss	Tw	C, W	S	120.28	Oct. 5, 1960	D7R, DD45R, L.
-34dd	J. L. Brooks	1960	Dr	264	264	4	Ss	Tw	C, W	S	119.25	November 1960	D8R, DD71R.
47-78-5bb	J. Iberlin	1950	Dr	184	184	4	Ss	Tw	C, W	S	129.30	Mar. 7, 1960	
-18ca	do	1940	Dr	333	333	6	Ss	Tw	C, W	S	69.02	Oct. 12, 1959	D4R, DD100R.
-22dd	L. Falxa	1946	Dr	271	210	6-4	Ss	Tw	C, W	S	12.12	do	D30R, DD39R.
-23ad	do	1939	Dr	330	184	5	Ss	Tw	C, W	N	68.74	do	D5R, DD100R.
-24db	do	1947	Dr	235	200	6-4	Ss	Tw	F	S	+	do	D10R, DD65R, L; flow 0.25M.
-28da	J. L. Brooks	1959	Dr	450	406	4	Ss	Tw	C, W	S	150.78	Dec. 1, 1959	D7R, DD30R, L.
47-79-6dd	J. Camino and Sons	1959	Dr	90	90	6	Ss	Tw	C, W	S	30	Nov. 1, 1959	
-10ab	do	1955	Dr	315	315	4	Ss	Tw	C, W	S	28	August 1955	D5R, DD197R.
-15da	do	1949	Dr	510	510	4-2	Ss	Tw	C, W	S	155	November 1949	D4R, DD130R, L.
-21dd	L. Falxa	1946	Dr	220	32	6	Ss	Tw	C, W	S	25.49	Oct. 12, 1959	
-32bd	Irigaray and Son	1955	Dr	464	464	6-4	Ss	Tw	C, G	S	66.50	Apr. 11, 1961	D4R, DD210R, L.
-35dc	L. Falxa	1956	Dr	400	388	2	Ss	Tw	F	D,S	+	Dec. 1, 1959	D2.7M.
47-80-16ba	Smith Bros	1955	Dr	220	220	4	Ss	Tw	C, G	S	65.58	Nov. 19, 1959	D16R, DD80R.
-20da	do	1955	Dr	328	300	4	Ss	Tw	C, G	S	2	May 1955	
-22dc	do	1959	Dr	300	298	6	Ss	Tw	C, G	S	146.33	Apr. 13, 1960	D3R, DD55R, L.
-32cd	O. Struck		Dr	76.5		4	Ss	Tw	N	N	55.17	do	
-33cb	J. Zezas	1955	Dr	263	263	4	Ss	Tw	C, G	S	12	August 1955	D15R, DD48R.
47-81-17ca	R. H. Purdy	1959	Dr	170	164	6	Ss	Tw	C, W	S	50	August 1959	D10R, DD75R.
-25cd	Will Bros	1948	Dr	370	359	4	Ss	Tw	C, W	S		Dec. 10, 1959	L.
-25dc	S. Will	1960	Dr	367	367	4	Ss	Tw	C, W	S	40	June 1960	D8R, DD80R.
-31ca	R. H. Purdy	1959	Dr	285	285	4-3	Ss	Tfu	C, G	S	75	October 1959	D3R, DD25R, L.
47-82-13db	T. Barker	1941	Dr	323	225	6	Ss	Tfu	C, W	S	11	June 1941	Ca, D5R, DD70R, L.
-18cc	E. U. Snider	1955	Dr	450	450	4	Sh	Kc	N	N	18.11	Jan. 5, 1961	D4R, DD165R, L; observation well.
47-83-7bc	L. Ridley	1958	Dr	189	155	6	Ss	Ꞓf(?)	C, G	D	76.00	Oct. 14, 1960	L.
-15cd	J. F. Greub	1960	Dr	300	50	4	Ss	Pt	C, W	S	64.41	Aug. 30, 1960	D5R, DD15R, L, T 57; specific conductance 835.

TABLE 7.—*Records of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Well	Owner or tenant	Year constructed	Type	Depth (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift and type of power	Use of water	Distance to water level above (+) or below land surface (feet)	Date of measurement	Remarks
48-76-16ab	The California Co	1958	Dr	7,750					N	N			L; oil test, about 0.5 mile east of project area.
-20ba	Pure Oil Co	1952	Dr	13,861					N	N			L; oil test.
-29ac	S. Harriet	1940	Dr	465		7	Ss	Tw	N	N	400+	June 1, 1960	Dry at 400 ft.
48-77-8ac	C. Marton	1940	Dr	465			Ss	Tw	C, W	S	41.12	Apr. 15, 1960	Observation well.
-15db	do	1946	Dr	165	160	6	Ss	Tw	N	N	33.93	do	Do.
-25da	S. Harriet		Dr	280	264	4	Ss	Tw	C, W	S	157.98	do	D6R, DD75R, T55.
-25db	Harriet Bros	1952	Dr	605	590	1½	Ss	Tfu	F	S	+	do	Ca, D2M, L; original flow 6 gpm.
48-78-32bd	J. Iberlin	1942	Dr	261	207	6	Ss	Tw	C, W	S	49.59	Nov. 10, 1961	
-32ca	do	1946	Dr	308		4	Ss	Tw	C, W	S	97.40	do	D3R.
-35db	do	1948	Dr	365	246	4	Ss	Tw	N	N	96.54	do	D1.5R, DD135R, L.
48-79-17aa	J. Iberlin and Sons	1954	Dr	430	410	4	Ss	Tw	C, W	S	124.46	do	D2.5R, DD37R.
-26cc	J. Camino	1940	Dr	405	357	5	Ss	Tw	C, W	S	200	May 1940	D5R, DD50R.
-29ca	J. Camino and Son	1959	Dr	390	373	4	Ss	Tw	C, G	S	125	April 1950	D8R, DD40R.
-34cb	do	1957	Dr	260	260	4	Ss	Tw	C, G	S	90	do	D8R, DD70R.
48-81-2ab	Smith Bros	1956	Dr	574	490	4-2	Ss	Tw	F	S	+	July 1956	D2R, L.
-2ba	J. H. Winchester	1956	Dr	400	400	4	Ss	Tw	C, G	S	25	September 1956	D8R, DD75R.
-5ac	P. Urizaga Est	1955	Dr	335	335	2	Ss	Tw	F	S	+	July 1955	D4R, L.
-7bc	M. U. Cabilade	1960	Dr	212	212	4	Ss	Tw	C, G	S	99.40	April 1960	D8R, DD20R.
-10ba	S. S. Doyen	1956	Dr	380	380	4	Ss	Tw	C, W	S	100	September 1956	D4R, DD75R.
-12dd	Smith Bros	1957	Dr	400	400	4-2	Ss	Tw	F	S	+	October 1957	D2R, L.
-14dc	S. S. Doyen	1955	Dr	420	420	4	Ss	Tw	C, W	S	27.12	Nov. 10, 1961	D5R, DD116R.
-16bd	J. Zezas	1958	Dr	286	286	4	Ss	Tw	F	S	+	October 1958	D3R.
-22bd	S. S. Doyen	1957	Dr	720	466	4-2	Ss	Tw	F	S	+	Nov. 10, 1960	D1.0M.
48-82-2cc	C. Gammon		Dr	130	120	4	Ss	Tfu	C, E	S	49.61	Oct. 27, 1960	D7R, DD50R.
-9ad	T. and E. Moore	1956	Dr	186	186	4	Ss	Kl	C, G	S	55	September 1956	Ca, D10R, DD15R, L.
-10cb	M. K. Herman	1955	Dr	152	152	4	Ss	Kl	C, G	S	28.48	Nov. 13, 1959	D10R, DD54R, L.
-11bb	J. Gammon	1953	Dr	420	420	4-2	Ss	Tfu	C, E	D	+	Oct. 30, 1962	Ca, D1R.
-18ad	B. E. Taylor	1947	Dr	124	122	4	Ss	Kp	C, W	S	55	April 1947	D3.5R, DD35R, L.
-20bc	R. Purdy	1947	Dr	105	100	4	Ss	Kp	C, W	S		Mar. 8, 1960	L.

49-75-29bc	The California Co	1957	Dr						N	N			L; oil test, about 5 miles east of project area.
-29ca	do	1958	Dr	12,214					N	N			L; oil test, about 5 miles east of project area.
49-76-13dd	Farmers Union Central Exchange.	1957	Dr	7,097					N	N			L; oil test, about 4 miles east of project area.
-17ca	H. Jones	1947	Dr	404	375	6	Ss	Tw	F	S	+	Feb. 11, 1960	D45R, DD45R; weak flow.
49-77-5da	P. Etchemendy	1960	Dr	395	392	2	Ss	Tw	F	S	+	Jan. 3, 1961	D2.2M, T56; specific conductance 930; water contains gas.
-9ba	H. Jones	1955	Dr	606	606	2	Ss	Tfu(?)	F	S	+	Feb. 11, 1960	D3.3M, L, T55.
-11cd	do	1960	Dr	930	920	2	Ss	Tfu(?)	F	S	+	do	D2.3M, T56.
-13db	do	1960	Dr	630	630	2	Ss	Tfu(?)	F	S	+	Mar. 28, 1960	D3.4M, T56; specific conductance 890.
-15cc	do	1947	Dr	230	226	6-4	Ss	Tw	F	S	+	Feb. 11, 1960	D2.4M, L.
-20ba	Industrial Pipeline Co	1960	Dr	31.5	31	16	S, G	Qal	T, G	I	7.15	Apr. 19, 1961	Ca, D60M, L; one of 7 wells supplying water for highway construction.
-20bc	do	1960	Dr	615	613	6-2	Ss	Tfu(?)	F	D	+	July 29, 1960	D3.OM, T55.
-21ba	H. Jones	1959	Dr	600		4-2	Ss	Tfu	F	S	+	Dec. 1, 1959	Ca, D1.2M.
49-78-11cd	T. Dixon		Dr	400	400	4	Ss	Tw	C, W	N	112.64	Nov. 30, 1960	
49-79-9cc	R. Leath	1955	Dr	623	623	2	Ss	Tw	F	S	+	September 1955	D4R, L.
-25dd	C. Marton	1946	Dr	200	200	4	Ss	Tw	C, W	S	135	October 1946	D2OR, DD25R.
49-80-5dd	Esponda Co	1951	Dr	165	162	4	Ss	Tw	C, W	N	29.80	Feb. 24, 1961	L; observation well.
-23ac	do	1942	Dr	145		5	Ss	Tw	C, E	D	4	May 1942	
-30bb	G. Webber		Dr	292	280	6	Ss	Tw		S	60	Nov. 23, 1959	D6R, DD180R.
49-81-3ac	G. Hakert	1955	Dr	320	320	6	Ss	Tw	C, W	S	51.89	Sept. 12, 1960	D5R, DD125R.
-8bc	M. Hakert	1940	Dr	218	218	6	Ss	Tw	C, W	S	123.52	do	D5R, DD40R.
-13cb	A. Curutchet	1956	Dr	492	492	4	Ss	Tw	C, G	S	3	July 1956	D3.5R, DD137R. L.
-15ba	P. Bordarrampe	1955	Dr	265	265	4	Ss	Tw	F	S	+	November 1955	D3R.
-20ba	E. O. Henderson	1957	Dr	560	250	4	Ss	Tw	C, G	S	24.20	Nov. 9, 1959	D7R, DD103R.
-25dd	G. O. Webber	1955	Dr	265	265	4	Ss	Tw	F	S	+	May 1955	D2R.
-26ac	P. Bordarrampe	1956	Dr	322	322	4	Ss	Tw	C, G	S	10	June 1956	D4R, DD70R.
-28cd	J. H. Winchester	1960	Dr	260	260	4	Ss	Tw	F	S	+	Oct. 19, 1960	D6M, T55; specific conductance 890.
-31bd	P. Urizaga		Dr	187	187	6	Ss	Twk	N	N	108.66	Apr. 15, 1960	
-33bb	J. H. Winchester	1955	Dr	255	248	4	Ss	Tw	F	S	+	May 1955	Ca, D3R, L.
49-82-2bb	D. Elsom	1955	Dr	318	318	4	Ss	Twk	C, W	S	7.56	Nov. 23, 1960	Ca, D15R, DD74R.
-3da	do	1955	Dr	115	100	4	Ss	Twk	C, W	S	45.49	do	
-10bb	do	1955	Dr	330	330	4	Ss	Twk	C, G	S	47.57	do	D6R, DD70R.
-10cd	do	1956	Dr	336	336	4	Ss	Tfu	C, G	S	41.92	do	D4R, DD123R.
-20ba	L. Tass	1960	Dr	228	228	4	Ss	Kl	C, G	S	4.88	Sept. 28, 1960	D15R, DD98R, T55.
-24ad	D. Elsom and Sons	1959	Ds	865	480	4-2	Ss	Tw	C, G	S	9.28	Nov. 23, 1960	D14R, DD55R, L.
49-83-27dc	A. Dressler	1956	Dr	245	238	7	Ss	Pt	C, G	S		April 1956	Ca, D33R, L.

TABLE 7.—*Records of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Well	Owner or tenant	Year constructed	Type	Depth (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift and type of power	Use of water	Distance to water level above (+) or below land surface (feet)	Date of measurement	Remarks
50-76-8ad	C. E. Brehm	1959	Dr	7,016					N	N			L; oil test.
-22bd	Carter Oil Co.	1958	Dr	6,833					N	N			L; oil test, about 1.5 miles east of project area.
-23aa	Tennessee Gas Transmission Co.	1957	Dr	7,200					N	N			L; oil test, about 3 miles east of project area.
50-77-3bb	Dixon and Wagoner	1957	Dr	1,010	1,010	4-2	Ss	Tfu	F	S	+	Nov. 9, 1959	D4.5M, T56.
-9bc	O. L. Walker	1958	Dr	560	560	4	Ss	Tfu(?)	F	S	+	June 25, 1958	D34R, L.
-11cb	do	1954	Dr	580	580	4-2	Ss	Tfu(?)	F	S	+	December 1954	D4R.
-12dc	do	1955	Dr	1,000	970	4-2	Ss	Tfu(?)	F	S	+	August 1955	D7R, L.
-28cc	P. Etchemendy	1959	Dr	630	630	2	Ss	Tfu(?)	F	S	+	Dec. 3, 1959	D3.6M, T57.
-29dc	do	1961	Dr	575	574	2	Ss	Tfu	F	S	+	Aug. 1, 1962	Ca, D2E, L.
-31cd	Moorhead Ranch	1955	Dr	618			Ss	Tfu(?)	F	S	+	Oct. 1, 1960	D1.3M, T56.
-32ca	C. Bugher Estate	1956	Dr	724	724	2	Ss	Tfu(?)	F	S	+	Dec. 3, 1959	D1.0M.
50-78-16bd	U. M. Ranch	1941	Dr	380	325	4	Ss	Tw	C, W	S	210	September 1941	
-20ad	T. Dixon	1957	Dr	1,000	520	6-4	Ss	Tw, Tfu(?)	C, W	S	55	March 1957	D8R, DD45R.
-24dd	P. Etchemendy	1955	Dr	755	70	4	Ss	Tw, Tfu(?)	C, W	S	4.89	Dec. 3, 1959	D10R, DD46R.
-26bb	T. Dixon	1942	Dr	380	375	4	Ss	Tw	C, W	S	340	September 1942	D8R, DD15R.
50-79-4da	H. Moorhead	1947	Dr	301	278	4	Ss	Tw	C, W	S	250	May 1947	D2.5R, DD25R.
-6aa	Moorhead Ranch	1957	Dr	260	85	4	Ss	Tw	C, W	D	22	Feb. 19, 1957	D6R, DD48R.
-6bc	do	1950	Dr	248	248	4	Ss	Tw	C, W	S	150	June 1956	
-19bc	Marton Bros.	1956	Dr	600		4	Ss	Tw	C, G	S	165	Oct. 27, 1960	Ca, D8M.
50-80-6aa	F. Hepp	1950	Dr	210	188	4	Ss	Tw	C, W	S	51.32	Nov. 11, 1960	D5R, DD76R.
-6ca	do	1956	Dr	260	260	6-4	Ss	Tw	C, W	S	102-04	Nov. 11 1960	
-21bb	British-American Oil Producing Co.	1959	Dr	9,570					N	N			L; oil test.
-26ad	F. Hepp	1957	Dr	205	205	4	Ss	Tw	C, G	S	71.07	Aug. 25, 1960	D8R, DD85R.
-33cb	Esponda Co.	1952	Dr	100	65	4	Ss	Tw	C, W	S	20.00	Feb. 24, 1961	
50-81-5dd	Northern Wyoming Land Co.	1941	Dr	228	225	4	Ss	Tw	C, W	S	45.62	Feb. 4, 1960	D12R, DD35R.
-7ad	Hepp Bros.	1955	Dr	525	502	4-2	Ss	Tw	C, G	S	48.74	Nov. 11, 1960	D10R, DD35R, L.
-17aa	Northern Wyoming Land Co.	1959	Dr	300	127	4	Ss	Tw	C, W	S	79.88	July 4, 1959	D7R, DD10R.
-17bc	do	1959	Dr	285	276	4	Ss	Tw	C, G	S	230.63	July 16, 1959	D6R, DD10R.

50-81-22dd	G. A. Hakert	1959	Dr	362	362	6	Ss	Tw	C, W	S	4.36	Feb. 4, 1960	Observation well.
-23cc	A. Curutchet	1959	Dr	496	496	4	Ss	Tw	C, G	S	284.58	do	D6R, DD70R.
-26ac	do	1960	Dr	215	209	4	Ss	Tw	C, G	S	15.40	Feb. 1, 1961	D15R, DD20R, T54; specific conductance 900.
-28ac	B. Hakert	1960	Dr	360	346	4	Ss	Tw	C, G	S	300.73	Sept. 12, 1960	
-32cb	G. A. Hakert	1954	Dr	220	194	4	Ss	Tw	C, W	S	.80	do	D10R, DD175R.
50-82-6ad	City of Buffalo	1958	Du	26			S, G	Qal	Gf	P	7	January 1958	Ca; D250R; infiltration gallery.
-11ad	J. W. Driskill	1957	Dr	308	308	4	Ss	Tw	C, G	S	20.32	Nov. 9, 1959	D16R, DD63R.
-11cb	S. K. McBride	1955	Dr	460	460	4	Ss	Tw	F	S	+	do	Ca, D1.8M, L.
-18cd	Northern Wyoming Land Co.	1954	Dr	300	210	4	Ss	Tw	C, W	S	9.52	Feb. 4, 1960	D5R, DD130R.
-23cd	do	1954	Dr	420	260	4-3	Ss	Tw	C, W	S	5.58	Mar. 2, 1960	D12R, DD69R.
-23dc	do	1942	Dr	243	148	4	Ss	Tw	N	N	105.91	do	D8R, DD35R.
-24cd	do	1955	Dr	310	268	4	Ss	Tw	C, W	S	6.34	Feb. 3, 1960	
-35bb	A. R. Shambaugh	1955	Dr	355	355	2	Ss	Tw	F	S	+	August 1955	D10R.
50-83-14dc	Northern Wyoming Land Co.	1956	Dr	290	280	4	Sh	Kc	C, W	S	27	August 1956	L; pumps dry.
-36aa	R. Stokey	1957	Dr	270	175	4	Sh	Kc	C, H	S	18.56	Apr. 21, 1961	Ca; unfit for livestock.
51-76-30dd	Cosden Petroleum Corp.	1958	Dr	7,270					N	N			L; oil test.
51-77-8ac	S. Michelena	1958	Dr	570	570	2	Ss	Tfu	F	S	+	Nov. 6, 1959	D1.3M, T55.
-17cc	T. Dixon		Dr	165	165	4	Ss	Tw	C, W	N	75.70	Nov. 17, 1959	Observation well.
-17dd	S. Michelena	1954	Dr	690	690	4-2	Ss	Tfu	F	S	+	December 1954	D60R, L.
-20ca	T. Dixon		Dr	580	580	2	Ss	Tfu	F	S	+	Nov. 17, 1959	Ca, D0.6M.
-20cc	do		Dr	758	758	2	Ss	Tfu	F	S	+	Nov. 17, 1959	Ca, D7.7M.
-20dc	do	1954	Dr	550	550	4-2	Ss	Tfu(?)	C, W	S	290	December 1954	
-22ba	do		Dr	935	935	2	Ss	Tfu	F	S	+	Nov. 17, 1959	D2.2M, T57.
-25ba	Dixon and Wagoner	1958	Dr	835	835	4-2	Ss	Tfu	F	S	+	Nov. 6, 1959	D5.0M.
-29aa	T. Dixon	1930	Dr	758	758	2	Ss	Tfu(?)	F	S	+	Nov. 17, 1959	D4.8M, T56.
-30da	do		Dr	400	400	2	Ss	Tw	F	S	+	do	D1.2M, T54.
-32cc	Kennedy-Brown		Dr	550	550	2	Ss	Tw, Tfu(?)	F	S	+	Dec. 3, 1959	D1.6M, L, T55.
51-78-32bb	U. M. Ranch	1948	Dr	344	278	4	Ss	Tw	C, W	S	200	September 1948	D7R, DD120R.
51-79-2ca	A. Wells	1957	Dr	285	285	4	Ss	Tw	C, G	S	70	December 1957	D14R, DD30R.
-11cd	do	1960	Dr	1,240	651	2	Ss	Tw, Tfu(?)	C, G	S	29.98	Dec. 13, 1960	D6R, DD132R.
-16ba	U. M. Ranch	1948	Dr	164	164	6-4	Ss	Tw	C, G	S	30	January 1948	Ca, L.
-23da	do	1948	Dr	130	130	4	Ss	Tw	C, W	S	80	January 1948	D8R, DD30R.
51-80-11bc	do	1951	Dr	215	203	4	Ss	Tw	C, W	S	33	March 1951	D6R, DD67R.
-15db	Northern Wyoming Land Co.	1955	Dr	270	270	4	Ss	Tw	C, W	S	132.14	May 19, 1960	D4.5R, DD32R.
-20ad	R. Hepp	1956	Dr	276	270	4	Ss	Tw	C, G	S	123.04	Nov. 11, 1960	D5R, DD67R.
-26dd	H. Moorhead	1947	Dr	166	166	4	Ss	Tw	C, W	S	133	May 1947	D12R, DD12R.
-32ab	R. Hepp	1958	Dr	220	220	4	Ss	Tw	C, W	S	80.90	Nov. 6, 1959	D10R, DD30R.
-32cb	do	1961	Dr	1,294		4	Ss	Tw	N	N	9.89	May 16, 1961	Abandoned.
51-81-7dc	J. Kumor		Du	10	10	3	S, G	Qal	Cf, E	S	5.95	May 15, 1961	Water is very hard and has a high concentration of iron.
-8da	Northern Wyoming Land Co.	1942	Dr	237	149	4	Ss	Tw	N	N	123.39	Mar. 8, 1960	Abandoned.
-18ba	J. Kumor	1948	Dr	92	92	6	Ss	Tw	C, W	S	27.44	May 15, 1961	
-19dd	B. Vannoy	1941	Dr	139	139	4	Ss	Tw	C, G	S	50	June 1941	3,400 ppm dissolved solids.
-27ad	Northern Wyoming Land Co.	1955	Dr	166	166	4	Ss	Tw	C, W	S	27.51	May 19, 1960	

TABLE 7.—*Records of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Well	Owner or tenant	Year constructed	Type	Depth (feet)	Casing		Principal water-bearing bed		Method of lift and type of power	Use of water	Distance to water level above (+) or below land surface (feet)	Date of measurement	Remarks
					Depth (feet)	Diameter (inches)	Character of material	Geologic source					
51-82-1bd	P. Belus	1940	Dr	150	86	6	Ss	Tw	C, W	S	24.30	May 4, 1960	L.
-6cd	Lower Johnson Creek School		Dr	100	100	4	Ss	Tw	C, H	P	17.84	Jan. 13, 1960	
-10db	Northern Wyoming Land Co.	1953	Dr	250	250	6	Ss	Tw	C, W	S	81.60	do	L.
-15dc	do	1940	Dr	135	92	5	Ss	Tw	N	N	18.17	Feb. 3, 1960	
-16cc	R. Robinson	1954	Dr	230	230	4	Ss	Tw	C, W	S	118	November 1954	D6R, DD32R.
-17ad	G. Limmer	1948	Dr	120	90	3	Ss	Tw	F	S	+	Jan. 23, 1960	D0.4M, T49.
-19ca	C. Dressler	1956	Dr	160	160	4	Ss	Tw	C, G	S	.75	Jan. 14, 1960	
-21cc	R. A. Fischer	1956	Dr	300	300	2	Ss	Tw	F	D, S	+	Nov. 13, 1959	D3R.
-33dd	L. Kinnison	1960	Dr	145		6	Ss	Tw	T, E	I	+4	Sept. 2, 1961	Ca, D (flow) 7.5M; D (pumping) 70M, DD46M.
-34ba	Powder River Golf and Country Club.	1960	Dr	280	180	4	Ss	Tw	T, E	I	22.34	do	
-36aa	H. Madsen	1954	Dr	30	22	12	S	Qal	C, W	S	12	March 1954	L.
51-83-3bc	C. Tarbet	1961	Dr	460	460	2	Ss	Tw	F	S	+	April 1961	
-3bd	N. Nielsen	1944	Dr	90	90	6-4	Ss	Twk(?)	C, W	S	1.36	Jan. 12, 1960	L.
-4bc	C. Tarbet	1961	Dr	205	205	4	Ss	Kl	C, E	D	2	April 1961	Ca.
-10ac	N. Nielsen	1944	Dr	275	206	6	Ss	Tw	C, W	N	31.22	Jan. 12, 1960	Observation well.
-10ca	C. Tarbet		Dr	505			Ss	Tw	F		+	April 1961	
-13cd	E. Hillard	1943	Dr	239	84	6	Ss	Tw	C, W	S	84.50	Mar. 1, 1960	
-14bd	Upper Johnson Creek School	1948	Dr	90	77	4	Ss	Tw	C, H	N	14.36	Jan. 13, 1960	L.
-27ad	J. Smith	1954	Dr	200	200	4	Ss	Tw	F	D	+	July 1954	D6.5R, DD75R; weak flow.
52-77-3ab	J. Otaegui	1947	Dr	828		4-2	Ss	Tfu	F	S	+	Nov. 17, 1959	Ca, D17.0M, L, T67.
-5aa	H. Baumgartner		Dr	460	460	2	Ss	Tw	F	S	+	Nov. 11, 1959	D1.0M.
-9ab	C. Knudson	1959	Dr	1,060	1,046	4-2	Ss	Tfu	F	S	+	do	D6.7M, L, T66.
-16bd	do	1955	Dr	605	605	2	Ss	Tfu(?)	F	S	+	do	D6.0M, T56; water contains gas.
-21ca	D and D Drilling Co.	1957	Dr	6,800					N	N			L; oil test.
-22ca	M. G. Ahern	1960	Dr	653	653	4	Ss	Tfu	F	S	+	Feb. 21, 1961	D8.5M, T58; water contains gas.
-30ba	E. I. Jewell	1960	Dr	210	210	6	Ss	Tw	C, W	S	149.90	June 10, 1960	
-32ad	H. Baumgartner		Dr	785	785	2	Ss	Tfu	F	D,S	+	Nov. 11, 1959	D1.2M, T56.
-36bb	T. Baumgartner	1960	Dr	1,179	1,158	4-2	Ss	Tfu(?)	F	S	+	July 9, 1960	D8.5M, T58; water contains gas.
52-78-1ba	J. Enochs	1958	Dr	1,085	1,085	4-2	Ss	Tfu(?)	C, W	S	48.54	Oct. 8, 1960	
-14aa	Clayton Oil Co.	1958	Dr	6,850					N	N			L; oil test.

52-78-15cd	S. Inchauspe	1960	Dr	905	905	2	Ss	Tfu(?)	F	S	+	Oct. 8, 1960	D4.8M, T57.
-16bc	F. Hepp	1958	Dr	725	185	4	Ss	Tw	C, G	S	77.89	Sept. 22, 1960	D12R, DD11R.
-16cb	do	1960	Dr	1,095	1,050	2	Ss	Tfu(?)	F	S	+	do	D8.9M, L, T64.
-22cb	S. Inchauspe	1959	Dr	245	245	4	Ss	Tw	C, W	S	81.77	Sept. 19, 1959	D10R, DD40R.
52-79-3ba	A. F. Betz	1954	Dr	260	260	4	Ss	Tw	C, G	S	96.72	Nov. 11, 1959	D6R, DD120R.
-10ab	do	1952	Dr	220	220	4	Ss	Tw	C, W	S	155.00	do	
-12cc	D. J. Watt	1947	Dr	160		4	Ss	Tw		D	28	1947	Ca.
-14bc	Hepp Bros	1952	Dr	270	270	4	Ss	Tw	C, G	S	65.78	1947	D4.5R, DD67R.
-24dd	F. Hepp	1957	Dr	246	246	4	Ss	Tw	C, G	S	105.15	Aug. 25, 1960	D6R, DD40R.
-35ad	Hepp Bros	1953	Dr	174	120	4	Ss	Tw	C, G	D	54.09	Nov. 11, 1960	
52-80-1ac	A. Fieldgrove	1950	Dr	312	312	4	Ss	Tw	C, W	S	27.38	Oct. 13, 1959	D4R, DD99R.
-2ac	do	1945	Dr	105	84	4	Ss	Tw	C, W	S	37.15	do	
-10ab	P. Schuman	1945	Dr	365	354	4	Ss	Tw	C, W	S	165	September 1945	
-18dc	K. Walters	1960	Dr	170	150	6-4	Ss	Tw	C, W	S	130.40	Nov. 10, 1960	D6R, DD19R; well gravel packed 150-170 ft.
-27bb	D. J. Watt	1945	Dr	363	124	4	Ss	Tw			60	October 1945	
52-81-18bd	do	1949	Dr	152	133	4	Ss	Tw	C, W	S	65	do	D8R, DD65R.
-27ad	C. Lawrence	1950	Dr	55	52	4	Ss	Qal, Tw(?)	C, W	S	20	September 1950	D4.5R, DD20R.
-29aa	do	1942	Dr	225	225	4	Ss	Tw	C, W	S	165	November 1942	
-33bd	S. K. Lawrence	1954	Dr	270	270	4	Ss	Tw	C, W	S	90	August 1954	D5R, DD85R.
52-82-6bc	Reynolds Mining Corp	1956	Dr	13+				Qal, Tw	N	N	11	May 14, 1956	Observation well.
-6cc	do	1956	Dr	130+				Qal, Tw	N	N	28	do	Do.
-13db	A. Belus	1956	Dr	246	246	6-4	Ss	Tw	C, W	S	12	April 1956	Ca, D10R, DD78R, L.
-19db	F. Lawrence	1942	Dr	306	89	4	Ss	Tw	C, W	S	12	January 1942	D12R, DD30R.
-25ab	Belus Bros	1956	Dr	240	240	6	Ss	Tw	C, W	S	55	October 1956	D8R, DD95R.
-33db	Northern Wyoming Land Co		Dr	312			Ss	Tw	N	N	67.94	Feb. 3, 1960	D10R, DD50R.
-35dc	do	1956	Dr	185	185	4	Ss	Tw	C, G	S	34.38	do	
52-83-1dc	Reynolds Mining Corp	1957	Dr	52+				Qal, Tw	N	N	52	May 16, 1957	Observation well.
-10dd	H. Buell		Du	16	16	36	S, G	Qal	Cf, E	S	12.25	Jan. 12, 1960	
-12aa	Reynolds Mining Corp	1957	Dr	70+				Qal, Tw	N	N	57	June 17, 1957	Do.
-22ba	C. Buell	1947	Dr	200	200	4-2	Ss	Tw	F	D, S	+	do	D1.0M.
-22ca	G. Stringer	1960	Dr	510	510	6-4	Ss	Tw, Twk	F	D, S	+	Oct. 20, 1961	Ca, D0.5M, L.
-23ab	K. Huey	1958	Du	18	12	12	S, G	Qal	Cf, E	D	6	May 8, 1961	
-30bc	C. Tarbet	1961	Dr	1,100	N	4	Sh	Kc	N	N	1,100+	May 1961	Dry hole, abandoned.
-35aa	C. Hepp	1945	Dr	305	138	4	Ss	Tw	C, W	S	58.68	Nov. 4, 1959	D15R, DD68R.
53-77-24cd	do	1954	Dr	780	756	2	Ss	Tfu	F	S	+	April 1954	D7R.
-24db	do	1959	Dr	981	981	4	Ss	Tfu	F	S	+	April 1959	D10R, L.
-26ba	S. Michelena	1955	Dr	265	265	2	Ss	Tw	F	S	+	December 1955	D40R.
-26cc	do	1942	Dr	428		2	Ss	Tfu(?)	F	S	+	1942	D30R.
-27ca	do	1952	Dr	900	900	2	Ss	Tfu	F	D, S	+	June 1952	D40R, L.
-34bd	J. Otaegui	1954	Dr	865	850	2	Ss	Tfu	F	S	+	Nov. 12, 1959	D12.0M, T60.
53-78-20cc	R. Hepp	1959	Dr	350	342	4	Ss	Tw	C, G	S	41.99	Nov. 11, 1960	D9R, DD80R.
53-79-25aa	Lion Oil Co	1957	Dr	7,315					N	N			L; oil test.
53-80-35ba	A. Landeck	1957	Dr	250	250	4	Ss	Tw	C, W	S	60	October 1957	D6R, DD100R.
53-81-23ad	C. Bolinger	1957	Dr	220	220	4	Ss	Tw	C, G	S	124	May 3, 1961	D5R, DD90R.
-34db	K. Leis	1955	Dr	420	420	4	Ss	Tw	C, G	S	112	October 1955	D4R, DD98R.
53-82-33bb	L. A. Wuthier	1956	Dr	60	60	6	Ss	Tw	J, E	D	6	Oct. 23, 1961	Ca, D20R, DD14R, L.
53-83-19bd	B. Stager	1959	Dr	130	112	6	Ss	Tw		D	20	August 1959	
-35aa	C. Hepp	1958	Dr	150	150	6	Ss	Tw	N	N	5.36	Nov. 4, 1959	

DRILLERS' LOGS OF WATER WELLS AND OIL-TEST HOLES

Table 8 contains logs of 72 water wells and oil-test holes drilled in the project area. The data were obtained principally from drillers' records, well owners, and files of the Johnson County Agricultural Stabilization and Conservation Office at Buffalo. The descriptive terminology used is mainly that of the driller. Stratigraphic interpretations in most logs, except those of oil-test holes, are by the authors. The location of the wells and oil-test holes listed is shown on the geologic map (pl. 1.).

TABLE 8.—*Drillers' logs of water wells and oil-test holes in northern and central Johnson County, Wyo.*

Material	*Thickness (feet)*	*Depth (feet)*
46-78-13bd		
Alluvium:		
Sand and gravel	47	47
Wasatch Formation:		
Blue shale with some sandstone and coal	193	240
Sandstone	60	300
Shale, blue	140	440
Sandstone (water)	46	486
46-81-18cd		
Alluvium:		
Silt and sand	40	40
Clay, yellow	30	70
Fort Union Formation:		
Shale, gray	80	150
Sandstone, gray (water, 1 gpm)	10	160
Shale, gray	110	270
Sandstone, gray (water)	13	283
Shale, gray	25	308
Sandstone, gray	15	323
Shale, gray, sandy (water)	42	365
Shale, gray	10	375
46-82-9ad		
Alluvium:		
Topsoil	4	4
Clay, yellow	11	15
Gravel	8	23
Parkman Sandstone:		
Shale, gray	69	92
46-82-9ad—Continued		
Parkman Sandstone—Continued		
Rock (sandstone?)	4	96
Shale, red	17	113
Shale, blue	20	133
Sandstone (water)	17	150
46-82-31ac		
Alluvium:		
Sandy soil	26	26
Cody Shale:		
Shale, gray	4	60
Shale, blue	110	170
Rock (sandstone?)	5	175
Shale, blue	99	274
Sandstone	11	285
Shale, blue	20	305
Shale; contains thin sandstone beds (water)	31	336
46-82-35bc		
Alluvium:		
Topsoil	5	5
Silt and sand	17	22
Lance Formation:		
Coal (carbonaceous shale?)	4	26
Shale, gray	64	90
Sandstone (water)	30	120
Shale, blue	60	180
Shale, blue; contains thin beds of sandstone (water)	22	202

TABLE 8.—*Drillers' logs of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Material	Thickness (feet)	Depth (feet)
46-83-22dd		
Alluvium:		
Topsoil	6	6
Gypsum and red-shale sequence:		
Red beds	182	188
Red beds and gypsum	25	203
Red beds	53	256
Tensleep(?) Sandstone:		
Sandstone (water)	2	258
47-77-24dc		
Wasatch Formation:		
Shale, brown, sandy	25	25
Shale, gray	105	130
Coal	2	132
Shale; contains stringers of coal	108	240
Sandstone (water)	9	249
Shale, blue	4	253
47-78-24db		
Alluvium:		
Soil, sand, and gravel	31	31
Wasatch Formation:		
Shale, blue	9	40
Shale, gray	35	75
Shale, brown	10	85
Coal	5	90
Shale, brown	30	120
Shale, gray	80	200
Sandstone, gray (water)	33	233
Shale, gray	2	235
47-78-28da		
Alluvium:		
Clay, brown	12	12
Wasatch Formation:		
Shale, blue	38	50
Sandstone	15	65
Shale, blue, hard; contains limy layers	275	340
Sandstone (water)	5	345
Shale, blue, hard	50	395
47-78-28da—Continued		
Wasatch Formation—Continued		
Sandstone (water)	8	403
Shale, blue, hard	47	450
47-79-15da		
Alluvium:		
Topsoil	8	8
Wasatch Formation:		
Sandstone	22	30
Shale, blue	40	70
Coal	6	76
Shale, blue	79	155
Rock (sandstone?)	1	156
Shale, blue; contains stringers of coal	54	210
Rock, hard (sandstone?)	2	212
Shale, blue	8	220
Rock (sandstone?)	3	223
Shale, blue	42	265
Rock, hard (sandstone?)	3	268
Shale, blue	23	291
Sandstone (water)	29	320
Shale, blue	60	380
Sandstone (water)	18	398
Shale	10	408
Rock (sandstone?)	2	410
Shale	10	420
Sandstone (water)	15	435
Shale	30	465
Rock (sandstone?)	5	470
Sandstone (water)	40	510
47-79-32bd		
Alluvium:		
Silt and fine sand	34	34
Wasatch Formation:		
Shale, blue	66	100
Sandstone	5	105
Shale, blue	69	174
Rock (sandstone?)	6	180
Shale, blue	86	266
Rock (sandstone?)	7	273
Shale, blue	171	444
Sandstone (water)	20	464

TABLE 8.—*Drillers' logs of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Material	*Thickness (feet)*	*Depth (feet)*
47-80-22dc		
Wasatch Formation:		
Shale, blue	140	140
Shale, brown	35	175
Shale, blue	15	190
Shale, gray, sandy (water)	95	285
Shale, blue	15	300
47-81-25cd		
Alluvium:		
Clay and silt	35	35
Wasatch Formation:		
Shale, blue; contains thin beds of sandstone (water, 0.5 gpm)	30	65
Shale, gray, hard; contains interbedded sandstone	50	115
Shale, blue	35	150
Coal	5	155
Shale, gray	5	160
Sandstone, gray, hard	5	165
Shale, gray	20	185
Coal	5	190
Shale, sandy (water)	10	200
Shale, gray	10	210
Coal	10	220
Shale, gray	25	245
Coal	5	250
Shale, gray	10	260
Shale, gray; contains stringers of coal	65	325
Coal	5	330
Shale, blue	20	350
Sandstone, gray, very fine grained (water)	10	360
Shale, blue	10	370
47-81-31ca		
Fort Union Formation:		
Shale, blue	30	30
Shale, gray and blue	40	70
Shale, blue	130	200
Shale, pink and light-blue	40	240
Shale, white, sandy (water)	45	285
47-82-13db		
Alluvium:		
Clay and silt	20	20
Fort Union Formation:		
Shale, red, sandy (water)	15	35
Shale, blue	257	292
Sandstone (water)	7	299
Shale, blue	24	323
47-82-18cc		
Alluvium	6	6
Cody Shale:		
Shale, yellow	24	30
Shale, blue	165	195
Rock (sandstone?)	5	200
Sandstone (water)	31	231
Shale, blue	179	410
Coal	7	417
Sandstone (water)	33	450
47-83-7bc		
Alluvium:		
Topsoil	8	8
Flathead(?) Sandstone:		
Sandstone, reddish-brown, hard	147	155
Sandstone, brown, soft (water)	34	189
47-83-15cd		
Alluvium:		
Soil	6	6

TABLE 8.—*Drillers' logs of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Material	Thickness (feet)	Depth (feet)
47-83-15cd—Continued		
Tensleep Sandstone:		
Sandstone, light-gray, moderately hard	44	50
As above, harder; contains interbedded soft gray shale (water at 286 ft)	250	300
48-76-16ab		
(Oil test about 0.5 mile east of project area; partial log)		
Wasatch Formation	850	850
Fort Union Formation:		
Shale and sandstone	530	1,380
Shale and coal	80	1,460
Shale and sandstone	2,600	4,060
48-76-20ba		
(Oil test, partial log)		
Wasatch Formation:		
Shale and sandstone	900	900
Fort Union(?) Formation:		
Shale and coal	25	925
Shale and sandstone	385	1,310
Shale and coal	70	1,380
48-77-25db		
Alluvium:		
Topsoil	2	2
Clay	6	8
Gravel	14	22
Wasatch and Fort Union Formations:		
Shale, gray	63	85
Sandstone	165	250
Shale, blue	310	560
Rock (sandstone?)	10	570
Sandstone (flow)	35	605
48-78-35db		
Alluvium:		
Soil and yellow clay	20	20
Wasatch Formation:		
Shale, brown	15	35
Shale, blue	15	50
Sandstone, gray	40	90
Shale, blue	7	97
Sandstone, gray (water)	8	105
Shale, gray	18	123
Shale, brown	7	130
Shale, gray	7	137
Sandstone, gray, hard	5	142
Shale, blue	10	152
Hard shell (limy layers?)	3	155
Sandstone, gray (water)	10	165
Shale, gray	5	170
Shale, brown	3	173
Shale, gray	20	193
Shale, brown	2	195
Sandstone, gray	22	217
Shale, brown	3	220
Sandstone, gray (water)	12	232
Shale, brown	8	240
Shale, gray	34	274
Shale, brown	6	280
Shale, gray	40	320
Shale, brown	6	326
Shale, gray	16	342
Shale, brown	13	355
Coal	5	360
Shale, gray	5	365
48-81-2ab		
Alluvium:		
Sandy soil	10	10
Sand, yellow, and gravel	5	15
Clay, brown	9	24
Gravel	6	30

TABLE 8.—*Drillers' logs of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Material	*Thickness (feet)*	*Depth (feet)*
48–81–2ab—Continued		
Wasatch Formation:		
Coal	10	40
Shale, blue	41	81
Rock (sandstone?)	4	85
Shale, blue	35	120
Sandstone	80	200
Shale, blue	60	260
Coal	10	270
Shale, blue	30	300
Coal	12	312
Shale, blue	165	477
Sandstone	48	525
Shale, blue	30	555
Sandstone (water)	19	574
48–81–5ac		
Alluvium:		
Topsoil	8	8
Sandy soil	22	30
Clay, yellow	10	40
Wasatch Formation:		
Sandstone	15	55
Shale, blue	5	60
Rock (sandstone?)	3	63
Shale, blue	137	200
Sandstone	50	250
Shale, blue	55	305
Sandstone (water)	30	335
48–81–12dd		
Alluvium:		
Sand and gravel	35	35
Wasatch Formation:		
Shale, blue	8	43
Coal	15	58
Shale, blue	82	140
Sandstone	60	200
Shale, blue	110	310
Coal	14	324
Shale, blue	38	362
Sandstone (water)	38	400
48–82–9ad		
Alluvium:		
Silt and fine sand	72	72
Lance Formation:		
Shale, blue	8	80
48–82–9ad—Continued		
Lance Formation—Continued		
Rock (probably limy layers)	4	84
Shale, blue	66	150
Sandstone (water)	4	154
Shale, blue	16	170
Sandstone (water)	16	186
48–82–10cb		
Alluvium:		
Silt and fine sand	31	31
Lance Formation:		
Rock (probably limy layers)	4	35
Shale, blue	35	70
Sandstone	18	88
Rock (probably limy layers)	7	95
Shale, blue	15	110
Sandstone (water 138–152 ft)	42	152
48–82–18ad		
Alluvium:		
Soil	8	8
Parkman Sandstone:		
Sandstone, brown	9	17
Shale, yellow	38	55
Sandstone, gray	5	60
Shale, gray	20	80
Sandstone, gray	2	82
Shale, gray, sandy (water)	40	122
Shale, blue	2	124
48–82–20bc		
Alluvium:		
Sand, brown	10	10
Parkman Sandstone:		
Sandstone, gray	15	25
Sandstone, brown	25	50
Sandstone, gray	15	65
Shale, brown	5	70
Shale, gray, sandy	10	80
Sandstone, gray (water)	20	100
Shale	5	105

TABLE 8.—*Drillers' logs of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Material	Thickness (feet)	Depth (feet)
49–75–29bc		
(Oil test about 5 miles east of project area; partial log)		
Wasatch Formation	926	926
Fort Union Formation	2,870	3,796
49–75–29ca		
(Oil test about 5 miles east of project area; partial log)		
Wasatch Formation	802	802
Fort Union Formation	2,893	3,695
49–76–13dd		
(Oil test about 4 miles east of project area; partial log)		
Wasatch Formation	833	833
Fort Union Formation	3,199	4,032
49–77–9ba		
Alluvium:		
Sand and gravel	30	30
Wasatch and Fort Union(?) Formations:		
Sandstone	7	37
Shale	3	40
Sandstone	5	45
Coal	5	50
Shale, blue	70	120
Sandstone	4	124
Shale, blue	174	298
Sandstone	9	307
Shale, blue	223	530
Sandstone	5	535
Shale, blue	31	566
Sandstone (water)	40	606
49–77–15cc		
Alluvium:		
Quicksand and gravel	34	34
Wasatch Formation:		
Shale, blue	6	40
Shale, brown	20	60
Shale, sandy; contains stringers of coal (water)	5	65
Shale, blue	25	90
Shale, brown	15	105
Shale, gray	11	116
Shale, gray, sandy	2	118
Shale, green	17	135
49–77–15cc—Continued		
Wasatch Formation—Continued		
Shale, blue	33	168
Shale, gray, sandy (water)	5	173
Shale, gray	12	185
Shale, green	15	200
Shale, gray	10	210
Sandstone (water)	20	230
49–77–20ba		
Alluvium:		
Sand (water at 7.6 ft)	8	8
Gravel	18	26
Wasatch Formation:		
Shale, blue	6	32
49–79–9cc		
Alluvium:		
Sand and gravel	22	22
Wasatch Formation:		
Shale, blue	33	55
Coal	5	60
Shale, blue	220	280
Coal	5	285
Sandstone	15	300
Rock (probably limy layers)	8	308
Shale, blue	112	420
Rock (sandstone?)	4	424
Shale, blue	63	487
Rock (probably limy layers)	5	492
Sandstone	31	523
Shale, blue	61	584
Sandstone	39	623
49–80–5dd		
Alluvium:		
Topsoil	3	3
Clay	5	8
Sand, red, coarse	9	17
Clay	5	22
Wasatch Formation:		
Coal	3	25
Shale, blue	15	40
Coal	6	46
Shale, brown	14	60
Sandstone	6	66

TABLE 8.—*Drillers' logs of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Material	*Thickness (feet)*	*Depth (feet)*
49-80-5dd—Continued		
Wasatch Formation—Continued		
Shale, blue	7	73
Rock, hard (probably limy layers)	5	78
Shale, blue	20	98
Sandstone (water, 1 gpm)	7	105
Shale, blue	45	150
Sandstone (water)	12	162
Shale	3	165
49-81-13cb		
Alluvium:		
Silt and fine sand	22	22
Clay, yellow	23	45
Wasatch Formation:		
Shale, blue	15	60
Coal	5	65
Shale, blue	45	110
Rock (sandstone?)	4	114
Shale, blue	66	180
Coal	8	188
Shale, blue	22	210
Rock (sandstone?)	6	216
Shale, blue	154	370
Coal	7	377
Shale, blue	99	476
Sandstone (water)	16	492
49-81-33bb		
Alluvium:		
Topsoil	4	4
Clay, yellow	36	40
Wasatch Formation:		
Shale, blue	34	74
Rock (probably limy layers)	3	77
Sandstone	9	86
Shale, blue	83	169
Coal	4	173
Shale, blue	75	248
Rock, hard (probably limy layers)	2	250
Sandstone (water)	5	255
49-82-24ad		
Alluvium:		
Clay, sandy	14	14
49-82-24ad—Continued		
Wasatch Formation:		
Shale, brown	26	40
Shale, blue	55	95
Sandstone	3	98
Shale, blue	58	156
Sandstone	1	157
Shale, blue	273	430
Sandstone (water)	30	460
Shale, blue	240	700
Sandstone	1	701
Shale, blue	164	865
49-83-27dc		
Alluvium:		
Soil	10	10
Gypsum and red-shale sequence:		
Red shale	120	130
Tensleep Sandstone:		
Sandstone (water at 200 ft)	115	245
50-76-8ad		
(Oil test; partial log)		
Wasatch Formation	1,129	1,129
Fort Union Formation	2,657	3,786
50-76-22bd		
(Oil test about 1.5 miles east of project area; partial log)		
Wasatch Formation	1,226	1,226
Fort Union Formation	1,130	2,356
50-76-23aa		
(Oil test about 3 miles east of project area; partial log)		
Wasatch Formation	718	718
Fort Union Formation	3,273	3,991
50-77-9bc		
Alluvium	27	27
Wasatch and Fort Union(?) Formations:		
Coal	24	51
Shale	20	71
Coal	3	74
Shale	68	142

TABLE 8.—*Drillers' logs of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Material	*Thickness (feet)*	*Depth (feet)*
50–77–9bc—Continued		
Wasatch and Fort Union(?) Formations—Continued		
Coal	3	145
Shale	29	174
Sandstone	5	179
Shale	12	191
Sandstone	10	201
Shale	63	264
Coal	2	266
Shale	85	351
Coal	6	357
Shale	7	364
Sandstone	8	372
Coal	4	376
Shale	2	378
Coal	8	385
Shale	102	487
Sandstone	58	545
Shale	15	560
50–77–12dc		
Alluvium:		
Topsoil	20	20
Gravel	10	30
Wasatch and Fort Union(?) Formations:		
Shale	50	80
Sandstone	20	100
Shale	140	240
Coal	20	260
Shale	30	290
Coal	20	310
Shale	100	410
Sandstone	50	460
Shale	130	590
Coal	20	610
Shale	80	690
Sandstone	20	710
Shale	10	720
Sandstone	20	740
Coal	30	770
Shale	30	800
Coal	20	820
Shale	50	870
Coal	10	880
Shale	50	930
Sandstone	40	970
Shale	30	1,000

Material	*Thickness (feet)*	*Depth (feet)*
50–77–29dc		
Alluvium:		
Sand and gravel	20	20
Wasatch and Fort Union(?) Formations:		
Shale, blue	180	200
Rock, hard	3	203
Shale, blue	327	530
Sandstone, hard	25	555
Sandstone, water	20	575
50–80–21bb (Oil test; partial log)		
Wasatch Formation	600	600
Fort Union Formation	821(?)	1,421
50–81–7ad		
Alluvium:		
Topsoil	5	5
Wasatch Formation:		
Red clinkers	25	30
Shale, blue	15	45
Coal	1	46
Shale, blue	9	55
Shale, carbonaceous	20	75
Sandstone	30	105
Shale, blue	85	190
Sandstone	30	220
Shale	35	255
Coal	5	260
Shale	85	345
Coal	2	347
Sandstone	53	400
Shale	30	430
Sandstone and coal (water)	70	500
Shale	25	525
50–82–11cb		
Alluvium:		
Sand	38	38
Wasatch Formation:		
Shale, brown	12	50
Shale, gray	62	112
Shale, blue	98	210
Sandstone	70	280
Shale, blue	152	432
Sandstone (water)	28	460

TABLE 8.—*Drillers' logs of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Material	Thickness (feet)	Depth (feet)
50-83-14dc		
Alluvium:		
Sand and boulders	30	30
Cody Shale:		
Shale, gray	20	50
Shale, blue	220	270
Sandstone (water)	10	280
Shale, blue	10	290
51-76-30dd		
(Oil test; partial log)		
Wasatch Formation	981	981
Fort Union Formation	3, 054	4, 035
51-77-17dd		
Alluvium:		
Topsoil	20	20
Wasatch and Fort Union(?) Formations:		
Shale	230	250
Sandstone	50	300
Shale	150	450
Coal	10	460
Shale	60	520
Coal	10	530
Shale	50	580
Coal	20	600
Shale	30	630
Sandstone (water, flow 60 gpm)	60	690
51-77-32cc		
Alluvium:		
Sand and clay	19	19
Sand and gravel	13	32
Wasatch and Fort Union(?) Formations:		
Shale, carbonaceous	23	55
Shale, gray	20	75
Sandstone, hard (water)	30	105
Shale, carbonaceous	20	125
Sandstone, hard	72	197
Shale, bluish-gray	88	285
Shale, dark-gray	15	300
Shale, gray, sandy	10	310
Shale, gray	60	370
51-77-32cc—Continued		
Wasatch and Fort Union(?) Formations—Continued		
Shale, carbonaceous	24	394
Hard shell (limy layer?)	1	395
Sandstone (water)	20	415
Shale, carbonaceous	35	450
Hard shell (limy layer?)	1	451
Shale, carbonaceous	47	498
Shale, hard, limy	5	503
Sandstone, hard	8	511
Hard shell (limy layer?)	1	512
Sandstone, soft (water, flows)	30	542
Sandstone, hard	1	543
Coal	1	544
Sandstone and coal	4	548
Shale	2	550
51-79-16ba		
Alluvium:		
Sand and gravel (water)	30	30
Wasatch Formation:		
Shale, gray, sandy	20	50
Sandstone, gray	5	55
Shale, gray	25	80
Coal	7	87
Shale, brown	7	94
Shale, gray, sandy (water)	6	100
Shale, brown and gray, interbedded	55	155
Shale, gray, sandy (water)	7	162
Shale, brown	2	164
51-82-1bd		
Wasatch Formation:		
Shale, carbonaceous	15	15

TABLE 8.—*Drillers' logs of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Material	Thickness (feet)	Depth (feet)
51-82-1bd—Continued		
Wasatch Formation—Continued		
Shale, gray	30	45
Sandstone (water)	25	70
Shale, gray	14	84
Sandstone (water)	64	148
Shale	2	150
51-82-10db		
Alluvium:		
Sand and gravel	47	47
Wasatch Formation:		
Shale, gray	8	55
Shale, brown	15	70
Sandstone, gray (water)	15	85
Shale, brown; contains thin stringers of coal	52	137
Sandstone, gray	33	170
Shale, gray	1	171
Shale, blue	33	204
Sandstone (water)	43	247
Shale	3	250
51-82-36aa		
Alluvium:		
Topsoil	4	4
Silt and sand	13	17
Sand (water)	13	30
51-83-3bd		
Alluvium:		
Soil and gravel	10	10
Wasatch Formation:		
Kingsbury Conglomerate(?) Member:		
Sand and gravel (water)	46	56
Shale, blue	9	65
Sandstone, blue (water)	16	81
Sandstone, gray	6	87
Shale, blue	3	90
51-83-14bd		
Alluvium:		
Sand and gravel	27	27
Wasatch Formation:		
Sandstone	16	43
Shale, blue	27	70
51-83-14bd—Continued		
Wasatch Formation—Continued		
Sandstone (water)	4	74
Shale, blue	16	90
52-77-3ab		
Alluvium:		
Sand and gravel	55	55
Wasatch and Fort Union Formations:		
Shale	242	297
Sandstone	9	306
Shale	169	475
Sandstone (water)	11	486
Shale	179	665
Coal	10	675
Shale	60	735
Sandstone (water)	70	805
Coal	19	824
Shale	4	828
52-77-9ab		
Wasatch and Fort Union Formations:		
Shale, red (clinkers), and gravel (?)	45	45
Shale	85	130
Sandstone	10	140
Shale	146	286
Sandstone	16	302
Shale	233	535
Sandstone	10	545
Shale	40	585
Coal	20	605
Shale	25	630
Sandstone (water)	10	640
Shale	244	884
Sandstone	8	892
Shale	88	980
Coal	43	1,023
Sandstone (water, flow 10 gpm)	27	1,050
Shale	10	1,060
52-77-21ca		
(Oil test; partial log)		
Wasatch Formation	740	740
Fort Union Formation	1,160(?)	1,900

TABLE 8.—*Drillers' logs of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Material	*Thickness (feet)*	*Depth (feet)*
52-78-14aa		
(Oil test; partial log)		
Wasatch Formation	1,374	1,374
Fort Union Formation	2,073	3,447
52-78-16cb		
Alluvium:		
Sand and gravel	54	54
Wasatch and Fort Union(?) Formations:		
Shale	21	75
Sandstone	45	120
Shale	25	145
Coal	15	160
Shale	84	244
Sandstone	12	256
Shale	104	360
Sandstone	10	370
Shale	76	446
Sandstone	59	505
Shale	15	520
Sandstone	30	550
Shale	140	690
Coal	28	718
Shale	12	730
Sandstone	20	750
Shale	43	793
Coal	24	817
Shale	123	940
Coal	20	960
Shale	75	1,035
Sandstone	60	1,095
52-82-13db		
Alluvium:		
Silt and sand	7	7
Gravel	13	20
Clay, yellow	35	55
Wasatch Formation:		
Coal	13	68
Shale, blue	22	90
Rock (sandstone?)	4	94
Shale, blue	16	110
Sandstone	16	126
Shale, blue	22	148
Rock (sandstone?)	5	153
Shale, blue	7	160
Rock (sandstone?)	5	165

Material	*Thickness (feet)*	*Depth (feet)*
52-82-13db—Continued		
Wasatch Formation—Continued		
Sandstone	15	180
Shale, blue	20	200
Rock (sandstone?)	5	205
Shale, blue	23	228
Sandstone	16	244
Shale, blue	2	246
52-83-22ca		
Alluvium:		
Silt, sand, and gravel	55	55
Wasatch Formation:		
Shale, gray, hard	12	67
Shale, sandy (water)	18	85
Shale, brown; contains some stringers of coal	12	97
Shale, blue, hard	13	110
Sandstone, gray (water at 118 ft)	20	130
Shale, blue	40	170
Sandstone, bluish-gray (water)	10	180
Shale, blue	95	275
Coal	105	380
Shale containing stringers of coal	80	460
Sandstone (water)	3	463
Shale and coal	39	502
Sandstone (flow 1 gpm)	6	508
Shale	2	510
53-77-24db		
Alluvium(?):		
Sand and gravel	102	102
Wasatch and Fort Union Formations:		
Shale	128	230
Coal	16	246
Shale	84	330
Sandstone	20	350
Shale	128	478
Coal	12	490

TABLE 8.—*Drillers' logs of water wells and oil-test holes in northern and central Johnson County, Wyo.*—Continued

Material	Thickness (feet)	Depth (feet)
53-77-24db—Continued		
Wasatch etc.—Continued		
Shale	222	712
Sandstone (flow 1 gpm)	28	740
Shale	70	810
Coal	20	830
Shale	55	885
Sandstone	25	910
Shale	30	940
Sandstone (water)	41	981
53-77-27ca		
Alluvium:		
Sand and gravel	60	60
Wasatch and Fort Union Formations:		
Shale	240	300
Sandstone	10	310
Shale	170	480
Sandstone (water)	10	490
Shale	180	670
53-77-27ca—Continued		
Wasatch and Fort Union Formations—Continued		
Coal	10	680
Shale	60	740
Sandstone (flow)	70	810
Coal	10	820
Shale	80	900
53-79-25aa (Oil test; partial log)		
Wasatch Formation	990	990
Fort Union Formation	2, 964	3, 954
53-82-33bb		
Alluvium:		
Clay	5	5
Gravel	13	18
Wasatch Formation:		
Shale, blue	12	30
Sandstone (water)	2	32
Shale, blue	9	41
Sandstone (water)	19	60

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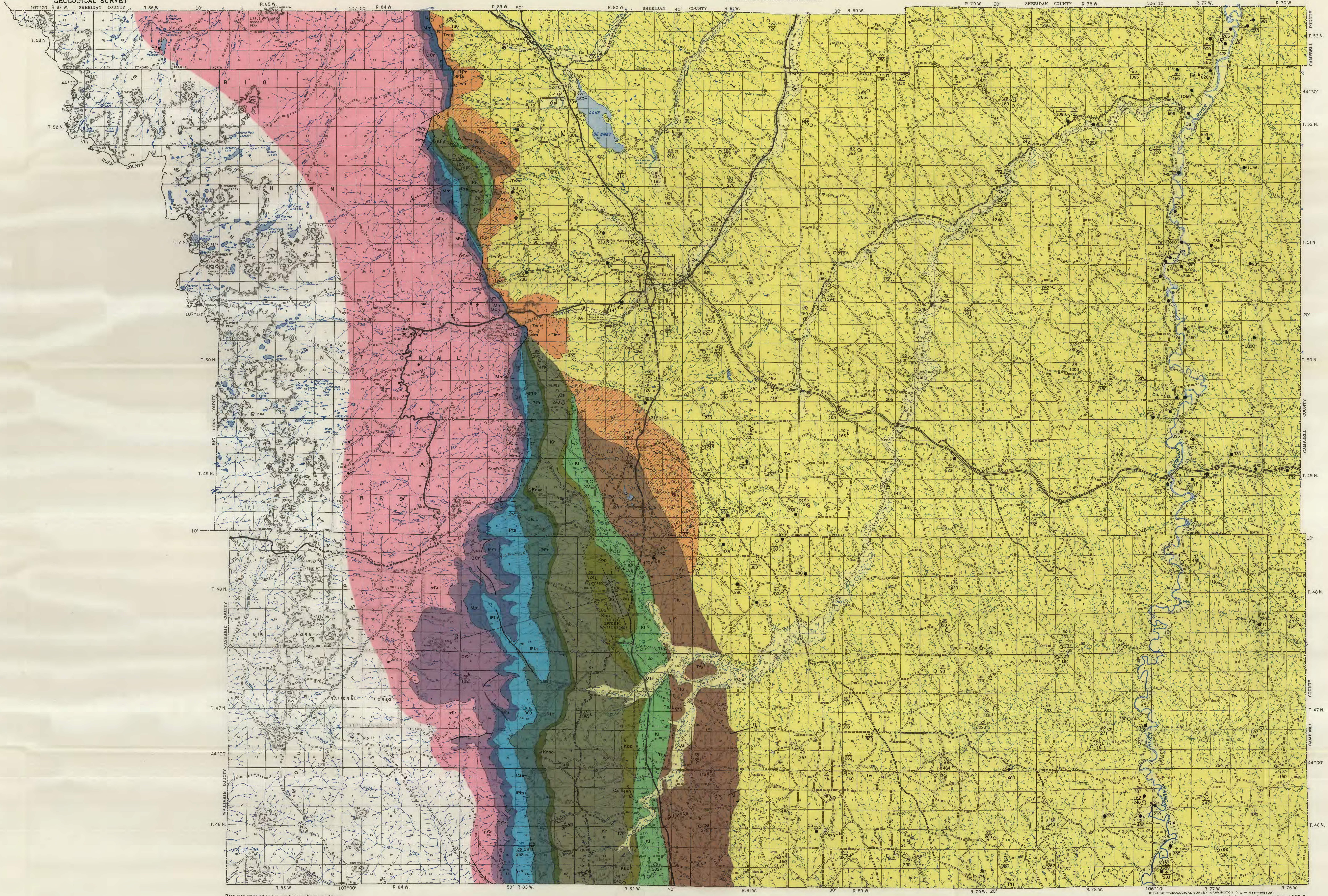
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
WYOMING STATE ENGINEER



INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1966—W65091

Geology adapted from U.S. Geological Survey Bulletin 1027–B, Plate 6 (Hose, 1955), and U.S. Geological Survey Bulletin 1078, Plate 1 (Mapel, 1959). Hydrology by H. A. Whitcomb and R. A. McCullough, 1960–62

GEOLOGIC MAP OF NORTHERN AND CENTRAL JOHNSON COUNTY, WYOMING, SHOWING LOCATION OF WELLS, SPRINGS, AND OIL-TEST HOLES

SCALE 1:125 000

2 0 2 4 6 8 10 MILES

2 0 2 4 6 8 10 KILOMETERS

EXPLANATION

QUATERNARY — *Pleistocene and Recent*

Qal

Alluvium

Flood-plain and terrace deposits of major stream valleys. Clay, silt, and fine sand containing lenses of coarser sand and gravel that differ locally in thickness and extent

TERTIARY — *Eocene*

Twm, Twk, Tw

Wasatch Formation

Principally a sequence of alternating light-gray fine-grained sandstone and dark-gray to brown shale containing thin beds of coal and carbonaceous shale

Twm, *Moncrief Member, and*

Twk, *Kingsbury Conglomerate Member, consists of conglomerate lenses interbedded with light-gray medium- to coarse-grained sandstone and greenish-gray siltstone and shale*

Paleocene

Tfu

Fort Union Formation

Interbedded light-gray and light-brown fine-grained sandstone and darker gray shale; contains beds of carbonaceous shale and, in southern part of area, thin beds of coal

CRETACEOUS — *Upper Cretaceous*

Kl

Lance Formation

Interbedded light-gray fine- to medium-grained sandstone and darker gray shale; contains some thin beds of carbonaceous shale

Kbp

Bearpaw Shale and Parkman Sandstone

Bearpaw Shale is principally a dark-greenish-gray shale containing some light-gray fine-grained sandstone in upper part. Parkman Sandstone is light gray and fine to medium grained; contains some interbedded dark-gray sandy shale in upper and lower parts

Kr

Sedimentary rocks

A thick sequence of preponderantly dark-gray to black shale containing some thin to relatively thick beds of light-gray fine-grained sandstone and siltstone

Lower Cretaceous

Knsc

Newcastle Sandstone, Skull Creek Shale, and Cloverly Formation

Newcastle Sandstone is light gray, fine to medium grained, and generally friable. Skull Creek Shale is grayish black, and contains thin beds of brown siltstone in lower part. Cloverly Formation consists principally of interbedded dark-gray shale and brown siltstone; a light-gray fine- to coarse-grained well-sorted sandstone occurs at base

PERMIAN, TRIASSIC, AND JURASSIC

J₸Pr

Sedimentary rocks

Upper part consists of light- to greenish-gray and red claystone and shale containing light-gray fine-grained friable sandstone, and thin beds of gray limestone. Lower part is principally reddish-brown shale, siltstone, and fine- to medium-grained poorly sorted sandstone containing thick beds of gypsum near the base

CARBONIFEROUS — **PENNSYLVANIAN**

IPta

Tensleep Sandstone and Amsden Formation

Tensleep Sandstone is light yellowish gray to white, fine to medium grained, thick bedded, and cross laminated; locally contains thin beds of dolomite. Amsden Formation consists of interbedded light-gray dolomite and red and purple shale; some sandstone and limestone occur near top and base

MISSISSIPPIAN

Mm

Madison Limestone

Light-yellowish-brown to white limestone, dolomitic limestone, and dolomite

CAMBRIAN AND ORDOVICIAN

O€r

Sedimentary rocks

Consist of an upper unit that is principally yellowish-gray massive dolomite, a middle unit of soft green shale, and a lower unit of yellowish-gray to brown medium- to coarse-grained sandstone

PRECAMBRIAN

p€r

Red and gray granite and gneiss

Contact
Dashed where approximately located

Contact of surficial deposits

U / D

Fault
Dashed where approximately located. U, *upthrown side;* D, *downthrown side*

Anticline
Showing trace of axial plane. Dashed where approximately located

9

Strike and dip of beds

Strike of vertical beds

Strike and dip of overturned beds

Water wells

$O\frac{55}{186}$ Ca, L

Domestic or stock well
55, *depth to water, in feet*
186, *depth of well, in feet*
Ca, *water sample taken for chemical analysis*
L, *log in table of well logs*

Flowing domestic or stock well

Public-supply well

Irrigation well

Flowing irrigation well

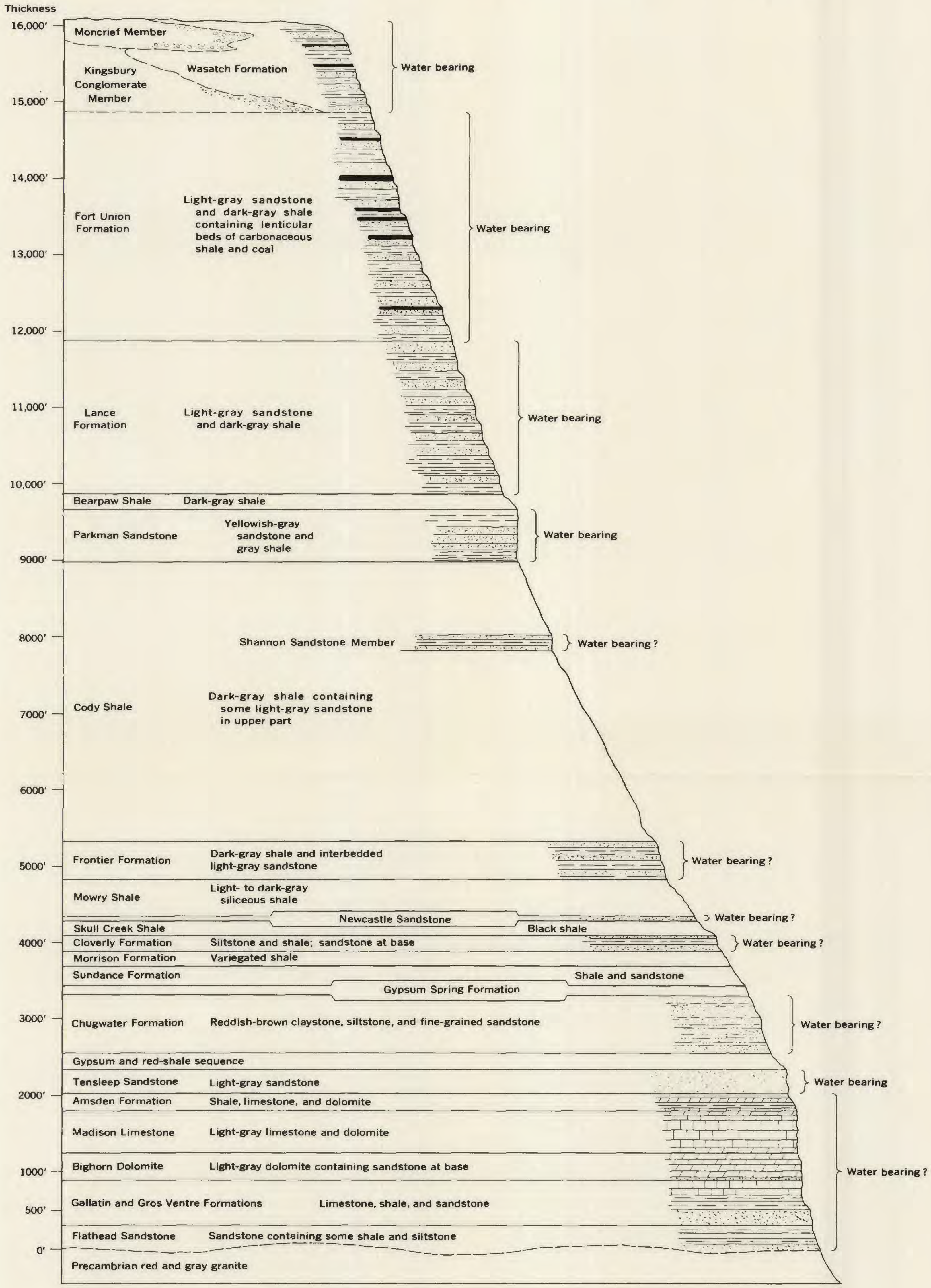
L

Oil-test hole
L, *log in table of well logs*

Spring

A—A'
Geologic section

PREPARED IN COOPERATION WITH THE
WYOMING STATE ENGINEER



GENERALIZED COLUMNAR SECTION SHOWING ROCKS OF NORTHERN AND CENTRAL JOHNSON COUNTY, WYOMING

795-830 O - 66 (In pocket)