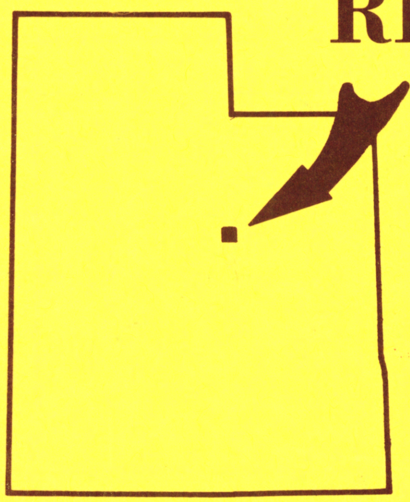
WATER-RESOURCES BULLETIN 4
1963

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY
affiliated with
THE COLLEGE OF MINES AND MINERAL INDUSTRIES
University of Utah, Salt Lake City, Utah

HYDROGEOLOGIC RECONNAISSANCE



of part of
the Headwaters Area of
the Price River,
Utah

Prepared by
The United States Geological Survey
in cooperation with
The State Engineer of Utah and the
Price River Water Improvement District

Price $1.75

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

103 Civil Engineering Building
University of Utah
Salt Lake City, Utah 84112

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DIRECTORS:

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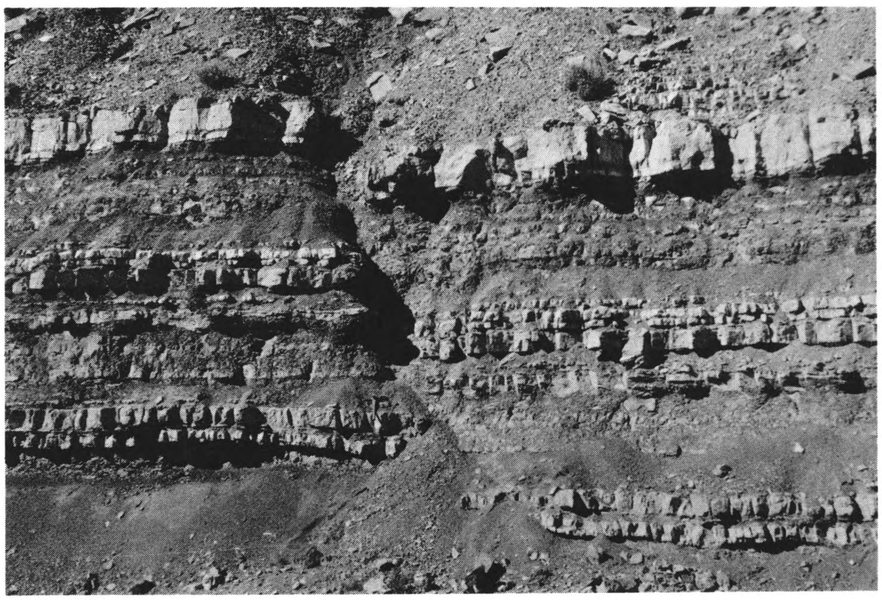
WATER-RESOURCES BULLETIN 4

HYDROGEOLOGIC RECONNAISSANCE OF PART OF THE HEADWATERS AREA OF THE PRICE RIVER, UTAH

by Robert M. Cordova
Geologist, U. S. Geological Survey



Fault in the Flagstaff Limestone in T. 11 S., R. 8 E., Sec. 26. Such a fault may be a barrier to ground-water movement or serve as a conduit to carry ground water to the land surface. (Photograph by H. D. Goode)

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UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

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HYDROGEOLOGIC RECONNAISSANCE OF PART OF THE HEADWATERS AREA OF THE PRICE RIVER, UTAH

by Robert M. Cordova
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ABSTRACT

The area investigated comprises 33 square miles in the Price River drainage basin and is in the High Plateaus section of Utah. Precipitation on most of the area ranges from about 20 to 23 inches per year, and the average annual precipitation for the entire area was assumed to be 22 inches, of which approximately 65 per cent is lost by evapotranspiration. The geologic formations underlying the area are the Blackhawk and Price River Formations of Cretaceous age, the North Horn Formation of Cretaceous and Tertiary ages, the Flagstaff Limestone and Colton Formation of Tertiary age, and unconsolidated deposits of probable Quaternary age.

Some ground water issues from springs and seeps and is used by stock and the cities of Price and Helper. The annual discharge from springs and seeps in the area averages about 3,000 acre-feet. Two deep wells supply about 500 acre-feet per year for use at a steam-generating plant. The aquifers penetrated by the wells are in the Flagstaff Limestone and the North Horn Formation, the deepest aquifer being about 1,500 feet below the land surface. Most of the ground water in the area is suitable for municipal and industrial use.

The surface discharge from the area is approximately 6,000 acre-feet per year. By means of a water budget, it is calculated that approximately 4,000 acre-feet per year leaves the area by subsurface flow. Further development of ground water on a large scale can be accomplished only by the use of wells. It is possible, however, that part of any newly developed supply from wells may be drawn from existing spring discharge or streamflow.

INTRODUCTION

Purpose and Scope of the Investigation

The State Engineer of Utah and the Price River Water Improvement District in 1960 requested the U.S. Geological Survey to make an investigation of part of the headwaters area of the Price River (Figs. 1 and 2). The purpose of the investigation was to determine the amount of ground water available and the most efficient way, or ways, to develop the water.

The area was chosen because it is now the source of part of the municipal supplies for the cities of Helper and Price, and it would be convenient for the development of additional needed supplies.

Methods of Study

The following methods of study were used: (1) Reconnaissance of the structure and stratigraphy of the rocks with the aid of aerial photographs (Fig. 5); (2) laboratory analysis of the hydrologic properties of rocks of formations considered to be or to include aquifers (Table 1); (3) chemical analysis of surface and ground waters (Table 6); (4) mapping of seepage areas (Fig. 2); (5) measurement of spring flows with a portable weir and measurement of Colton Spring using an automatic water-stage recorder; (6) measurement of the discharge of the Price River to study the gains and losses in streamflow; and (7) pumping tests at two wells (referred to in this report as the Colton wells or individually as Colton well 1 and Colton well 2) to determine the characteristics of the ground-water reservoir.

In addition, use was made of data collected by the U.S. Weather Bureau at Scofield, Scofield Dam, and Soldier Summit, of metered-flow records of water piped from seepage areas by the cities of Helper and Price and of varied data for the Colton wells collected by the Utah Power and Light Co.

Acknowledgments

Grateful acknowledgment is made to landowners Mrs. Phyllis Nelson, Mr. George Jackson, Mr. Oren Jackson, and Mr. Neil Johnson for allowing access to their property; to the cities of Price and Helper for allowing use of their water records; and to the Utah Power and Light Co. for use of their data on the Colton wells and for permitting the writer to make pumping tests at these wells. The Utah State Department of Health made available an analysis of the water from Colton well 2. Dr. H. D. Goode, of the University of Utah, began this study in 1960 while employed by the Geological Survey. Thanks are expressed to Dr. Goode for his assistance in the field and his helpful criticism of the report.

Well-Numbering and Location-Numbering System

The well numbers used in this report indicate the well location by land subdivision according to a numbering system that was devised cooperatively by the Utah State Engineer and G. H. Taylor of the Geological Survey about 1935. The system is illustrated in Figure 3. In this report, places where water samples or rock samples were collected are also designated using this system. The complete well number comprises letters and numbers that designate consecutively the quadrant and township (shown together in parentheses by a capital letter designating the quadrant in relation to the base point of the Salt Lake Base and Meridian, and numbers designating the township and range); the number of the section; the quarter section (designated by a letter); the quarter of the quarter section; the quarter of the quarter-quarter section; and, finally, the particular well within the 10-acre tract (designated by a number). By this system the letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quadrants of the standard base and meridian system of the Bureau of Land Management, and the letters a, b, c, and d designate, respectively, the northeast, northwest, southwest, and southeast quarters of the section, of the quarter section, and of the quarter-quarter section. Thus, the number (B-2-2)12dcd-2 designates well 2 in the SE1/4 SW1/4 SE1/4, sec. 12, T. 2 N., R. 2 W., the letter B showing that the township is north of the Salt Lake Base Line and the range is west of the Salt Lake Meridian; and the number (D-3-2)34bca-1 designates well 1 in the NE1/4 SW1/4 NW1/4, sec. 34, T. 3 S., R. 2 E.

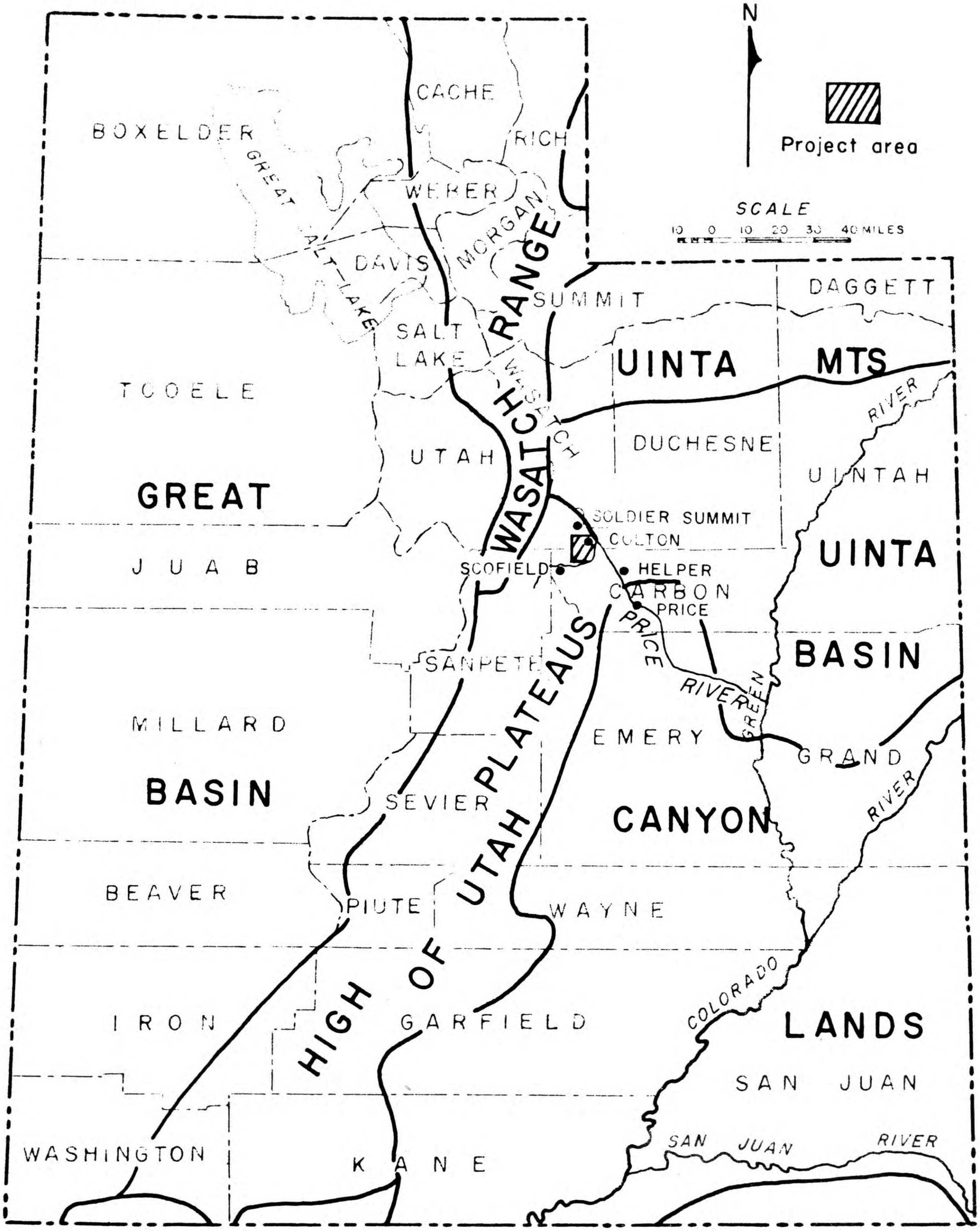

Figure 1. Index map of Utah showing Physiographic subdivisions and location of project area.

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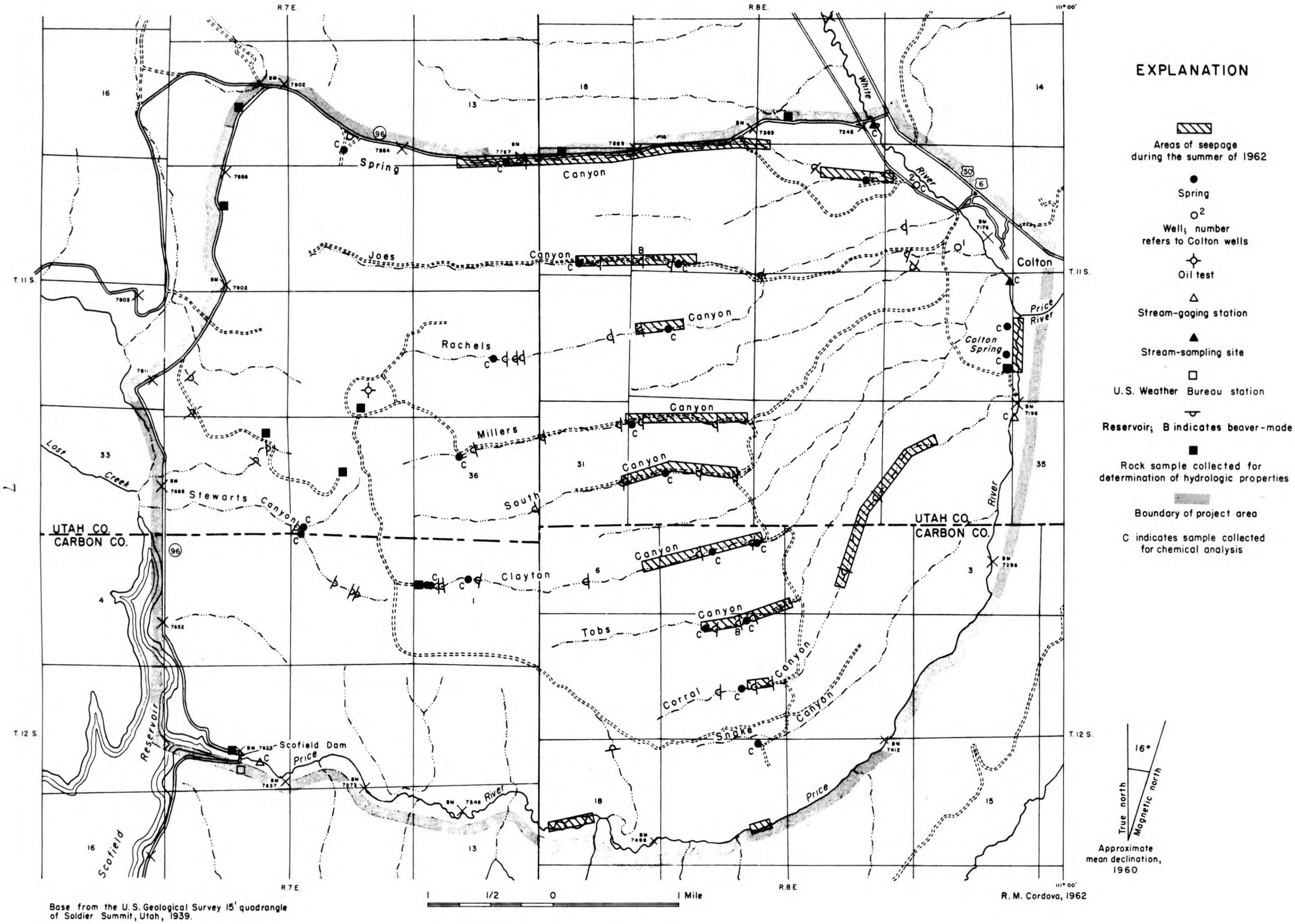

Figure 2.- Map of the project area showing selected springs, seepage areas, wells, data-collection points, and reservoirs.

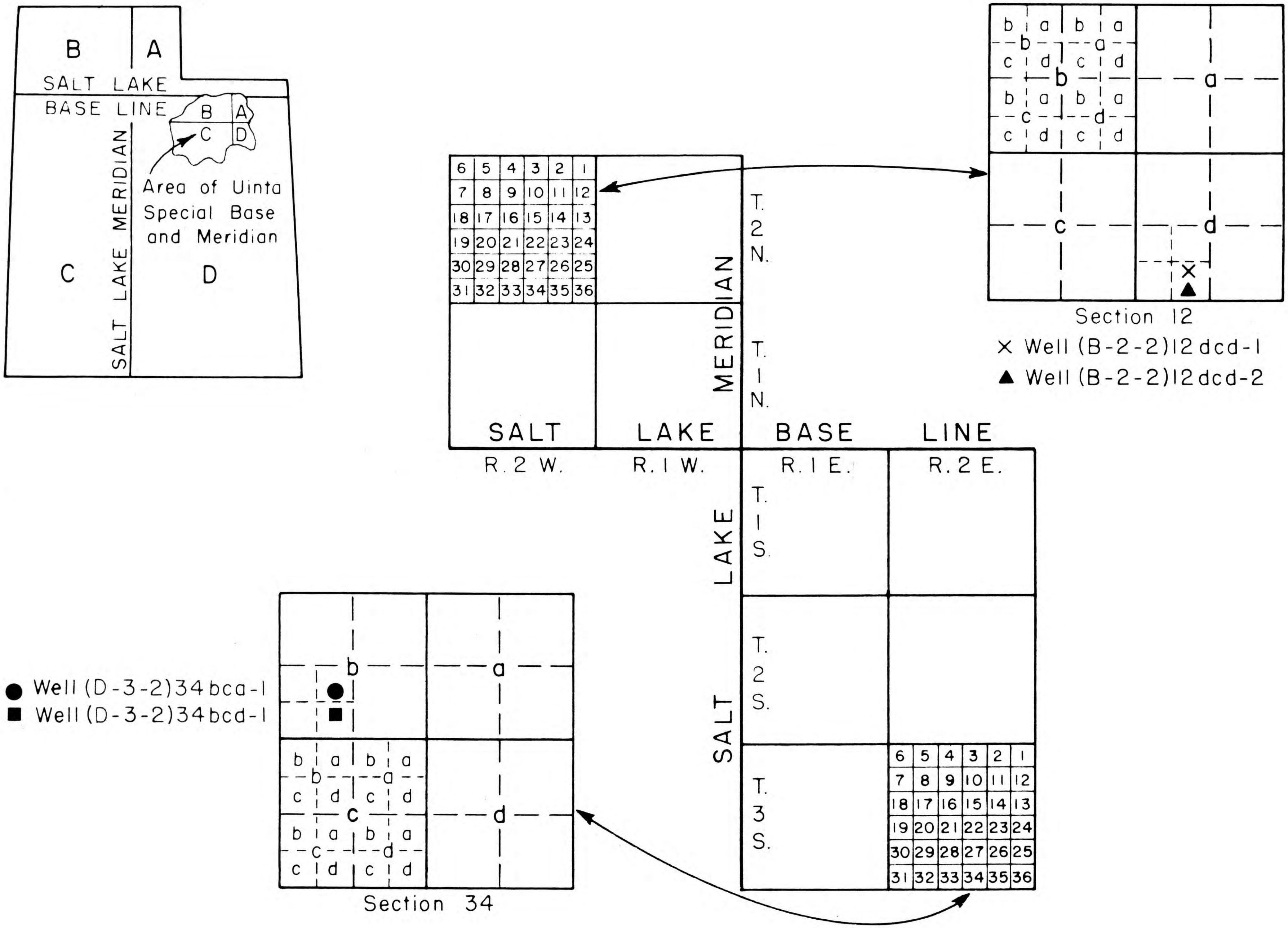

Figure 3. Well-numbering system used in Utah.

GEOGRAPHIC SETTING

The project area (Fig. 1), which is in the High Plateaus of the Utah section of the Colorado Plateaus province as defined by Fenneman (1931, p. 294), has an area of 33 square miles. It is bounded (Fig. 2) on the west and north by State Highway 96, on the northeast by the White River, on the east and south by the Price River. The area as delineated includes several springs and ephemeral streams which flow out of the area toward the west. The total flow of these springs is about 10 gallons per minute, which is insignificant compared to the total spring flow in the project area. The streams are thought to lose water to the ground-water reservoir of the project area because of the high porosity and structure of the bedrock.

Altitudes of the project area range from about 7,000 feet in the northeastern part to about 9,000 feet in the southwestern part. The Price and White Rivers, which join near Colton, are the major drainageways (Fig.2).

The names of the canyons that contain tributaries to the White and Price Rivers as used in this report are those known to the local landowners and water users. Joes Canyon, so known, is called Woods Canyon on published topographic maps. Snake Canyon, previously unnamed, was named by the author.

The normal annual precipitation in the project area ranges from about 18 inches in the eastern part to about 23 inches in the western part (U.S. Weather Bureau, 1963). Most of the area (the high southern and eastern parts and the lower central part) has a normal annual precipitation that ranges from about 20 to 23 inches. For the general calculations of this report, 22 inches is assumed to be the normal annual precipitation on the project area.

According to precipitation records collected at the U.S. Weather Bureau station at Scofield Dam, 1956 was an extremely dry year, but 1957 was one of the wettest years recorded. The period 1958-61 was relatively dry, and 1961 was reported by local landowners to be the driest since 1935.

Precipitation generally is greatest during the winter (Fig. 4), although in some years, such as 1957, it may be fairly evenly distributed throughout the year. In infrequent years, such as 1961, the greatest precipitation may fall during the summer. Precipitation during the period October-April falls chiefly as snow, and small amounts of precipitation during this period are characteristic of "dry" years. Precipitation records at Scofield Dam show that the "dry" years of 1959, 1960, and 1961 were preceded by winter snowfalls of 67, 101, and 58 inches, respectively. The "wet" year of 1962, in contrast, was preceded by a snowfall of 179 inches. The average annual snowfall at Scofield (15-year record between 1894 and 1931) and Soldier Summit (20-year record between 1894 and 1931) are respectively 124.0 and 102.1 inches. On the water-snow ratio of 1:10 as used by the U.S. Weather Bureau, these average snowfalls are equivalent to an average of about 11 inches of water.

A significant percentage of the total annual precipitation that falls on the project area is lost by evapotranspiration. Croft and Monninger (1953, p. 571) found that evapotranspiration consumed as much as 44 per cent of the annual precipitation (about 53 inches) on aspen forests of the Wasatch Range. The percentage is probably greater than 44 per cent in the project area because of its drier climate. A crude estimate was made by adding precipitation for the April-October period to snow evaporation. The evaporation from snow in the project area probably exceeds the maximum value used by Crofts and Monninger (1953, p. 565-566) because total precipitation in the project area is less than that in the area studied by them. For purposes of this report, therefore, the evapotranspiration in the project area is assumed to be 65 per cent of the total precipitation.

GEOLOGIC SETTING

Stratigraphy

Five geologic formations of pre-Quaternary age are distinguishable in the project area (Fig. 5). The formations include, from oldest to youngest, the Blackhawk and Price River Formations of Upper Cretaceous age, the North Horn Formation of Upper Cretaceous and Paleocene ages, the Flagstaff Limestone of late Paleocene and early Eocene (?) age, and the Colton Formation of Eocene age. Overlying these formations in places are unconsolidated deposits of probable Quaternary age.

Blackhawk Formation: The Blackhawk Formation is the name given by Spieker and Reeside (1925) to the coal-bearing rocks of the northern part of the High Plateaus (Fig. 1). In the project area, a maximum of about 500 feet of the Blackhawk Formation crops out in the canyon of the Price River (Fig. 5). The formation generally consists of gray very fine grained, silty sandstone, gray siltstone, dark carbonaceous shale, and coal. Many of the beds are lenticular and range in thickness from about 1 to 4 feet.

Price River Formation: The Price River Formation, named by Spieker and Reeside (1925), conformably overlies the Blackhawk Formation and crops out in the canyon of the Price River and in the western part of the project area (Fig. 5). The formation consists mainly of very fine to coarse-grained sandstone with interbedded pebbly sandstone, siltstone, limestone, and shale. The sandstone is characterized by grains that are generally coarser than those of sandstones in the immediately overlying and underlying formations, by its yellowish-tan color (although gray in places), by being loosely cemented, by its low content of dark minerals, and by crossbedding. In places, the sandstone contains iron oxide concretions and irregularly shaped light-red areas. The siltstone is gray or yellowish-tan and in some places limy; the shale is yellowish, gray, red, or green; and the limestone is gray, gray-tan, or whitish. The thickness of the Price River Formation in the canyon of the Price River is about 600 feet, but an oil test penetrated about 2,000 feet of the formation in sec. 26, T. 11 S., R. 7 E. (Fig. 2). Faulting or thickening may account for this disparity in thickness. Spieker (1931, p. 41) found the Price River Formation to range in thickness from 700 to 1,000 feet in the northern part of the High Plateaus (Fig.1).

North Horn Formation: The North Horn Formation (Fig. 5), named by Spieker (1946), comprises interbedded limestone, sandstone, siltstone, and shale, and overlies the Price River Formation. The limestone is hard, dense, and generally sandy or silty and is either gray, grayish-tan, or tan. The sandstone is gray, very fine to fine grained, hard, compact, generally calcareous, crossbedded, and contains a high

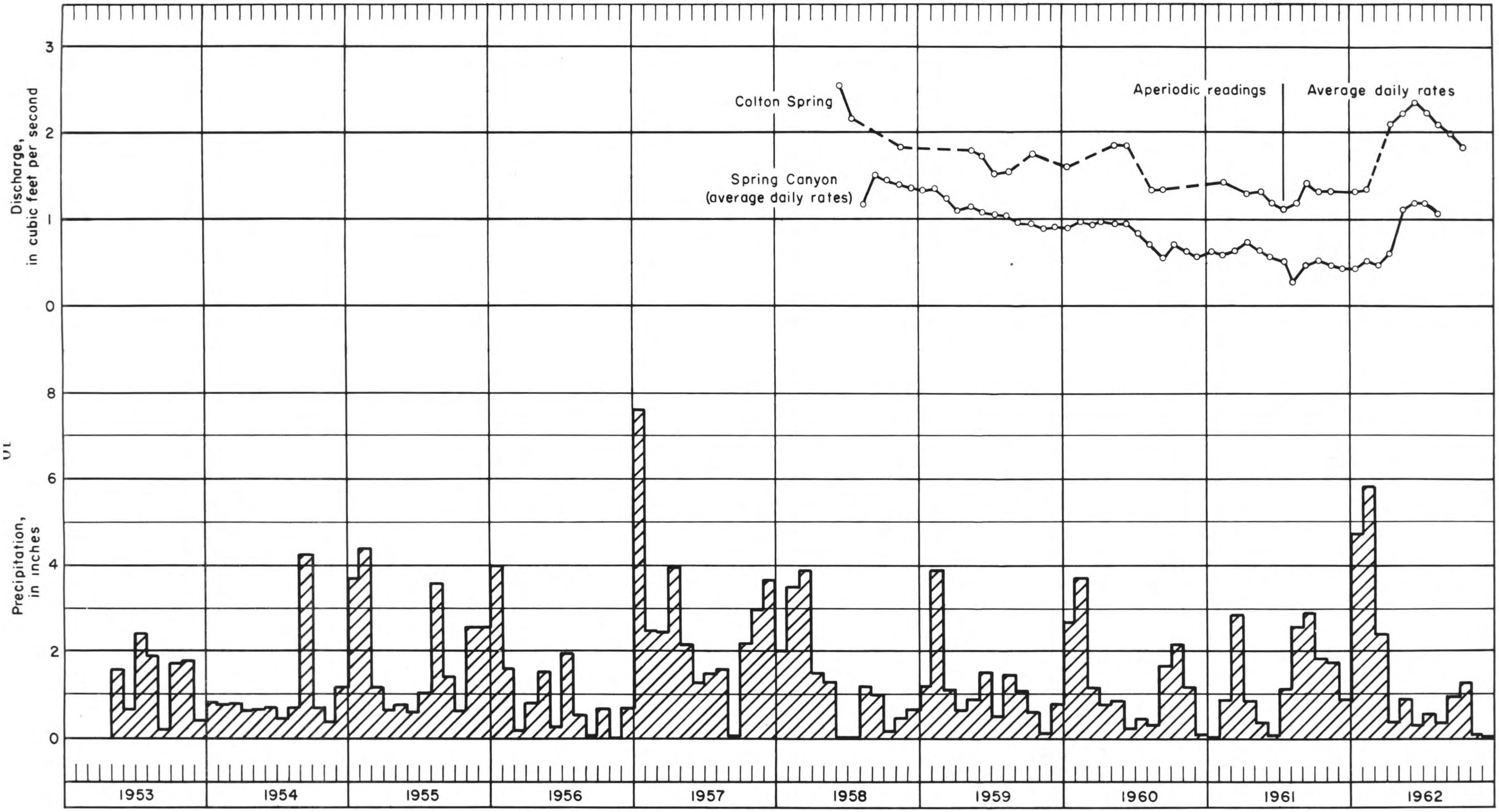

Figure 4. Precipitation at Scofield Dam (1953-62), and discharge of the Colton Spring locale (1953-62) and the Spring Canyon seepage area (1958-62).

percentage of dark minerals and feldspars. In places the sandstone contains iron oxide concretions and irregularly shaped light-red areas of various sizes. The siltstone is gray, hard, and dense. The shale is red, green, brown, gray, and black, and some is pyritic and some limy.

The thickness of the North Horn Formation must be arbitrarily assigned because it grades into the overlying Flagstaff Limestone and perhaps locally into the underlying Price River Formation. A thickness of 1,260 feet was estimated from the log of the Colton well 2 (Table 8).

Flagstaff Limestone: The Flagstaff Limestone, named by Spieker and Reeside (1925), consists mainly of light- to dark-reddish-brown, light-brown to tan, and dark-gray to black dense limestone and some sandstone and shale. The dark-gray to black limestone is not abundant and is so fossiliferous in places that the rock appears to be coquina. Minor amounts of tufaceous limestone are included in the limestone sequence as is a yellowish-tan dense limestone, which is apparently a fracture filling. Individual beds range in thickness from about 4 inches to 3 feet. The sandstone is in zones which have a maximum thickness of 6 feet, and it is gray, very fine to fine grained and contains a large amount of dark minerals. Of five zones of sandstone that crop out in the section along State Highway 96, only one was calcareous and friable; the rest were very hard and quartzitic. Outcroppings of shale were not observed, but the logs of the Colton wells (Tables 7 and 8) indicate that some gray and red shale are interbedded with the limestone and sandstone.

The thickness of the Flagstaff Limestone depends on where the bottom of the formation is placed. A thickness of 450 feet was estimated by correlating data obtained from fieldwork and from the logs of the Colton wells. This thickness includes limestone beds that represent transitional zones between the Flagstaff and the underlying North Horn Formation and the overlying Colton Formation.

Colton Formation: The Colton Formation, named by Spieker (1946), consists of a sequence of interbedded red, gray, green, and purple shales and gray, reddish-weathering, very fine to fine-grained sandstone. The shales are clayey to sandy, and the sandstone is friable to hard and contains a high percentage of dark minerals. The formation crops out (Fig. 5) in the northeastern part of the project area. It conformably overlies the Flagstaff Limestone and only the lower 200 feet crops out in the project area. The remaining 1,300 feet of the formation is exposed north of the project area.

Unconsolidated deposits: Unconsolidated deposits, mainly composed of silt and fine-grained quartz sand, overlie bedrock in the small canyons in the western part of the project area. These deposits apparently are thickest in the middle and upper reaches of the canyons, but total thicknesses could not be measured. A maximum thickness of 10 feet was measured in Clayton Canyon. The material that forms these deposits probably was transported from the outcrop area of the Price River Formation by the prevailing westerly winds, by running water, or by both. They do not appear to be typical alluvial deposits.

Talus and landslide deposits are obscured by vegetation and soil and were not delineated on the geologic map. Individual boulders, especially of sandstone from the Price River Formation, are numerous in the upper reaches of the canyons. A large unconsolidated deposit at the head of Millers Canyon is thought to be talus or landslide debris.

Pediment debris, generally less than 5 feet thick, covers the Colton Formation and the Flagstaff Limestone where they crop out at lower altitudes. The debris consists mainly of limestone, and individual fragments range in size from pebbles to boulders and show little or no erosional effects. Some of the supposed pediment material may have resulted from frost heaving.

The alluvium shown on the geologic map (Fig. 5) includes flood-plain and terrace deposits. The flood-plain deposits are in the channels of the White and Price Rivers and their tributaries. A partial thickness of 5 feet was measured in the White River channel, where the material consists of a lower zone of disc-shaped gravel, with individual fragments having a maximum diameter of 4 inches imbedded in a silt or clay matrix, and an upper zone about 4 feet thick consisting of gray silt. A deposit measured in Spring Canyon was about 2 1/2 feet thick. This deposit has a lower zone, 1/2 to 1 foot thick, consisting of limestone pebbles in a clay matrix, and an upper zone of dark silt about 15 inches thick. The thickness of the flood-plain deposits may vary considerably but probably is greatest in the channels of the two main streams.

Terrace deposits lie along the edges of the main stream channels (Fig. 5). They consist of pebbles, disc-shaped cobbles, and boulders which range in diameter from about 1 inch to 3 feet but generally are less than 6 inches. Most of the large fragments are composed of limestone. The thickness of the terrace deposits, where they are detached from the flood-plain deposits, is at least 5 feet and may possibly be 10 feet. The total thickness of the terrace deposits and the flood-plain deposits probably does not exceed 20 feet (Tables 7 and 8).

Structure

The rocks in the project area are folded into a shallow syncline (Fig. 5), named the Beaver Creek syncline by Walton (1959, p. 150). The axis of the syncline trends from north to northeast. The rocks dip toward the axis and down the plunge of the syncline, which is toward the Colton Spring. The magnitude of the dip generally increases from east to west and locally where faulting and minor folding have affected the rocks. For example, near Colton Spring the dip is about 5°, but in the western part of the project area the dip is about 10°. Faulting has produced dips as great as 18°, and minor folding, dips up to 45°.

Faulting is common in the project area, and normal faults are the most common type (Fig. 5). Reverse faults were mapped in the central part of the area and are thought to exist in the western part. They may be more numerous than could be determined from a reconnaissance. The Forge Mountain fault (Walton, 1959, pl. 1) is a normal fault which trends down the north-flowing reach of the Price River and apparently has the largest displacement and longest lateral extent of any fault in the project area. It can be traced northward and southward out of the project area and has an estimated vertical displacement of 300 feet.

The Flagstaff Limestone contains minor folds and fractures. The folding or crumpling is in a discontinuous belt which

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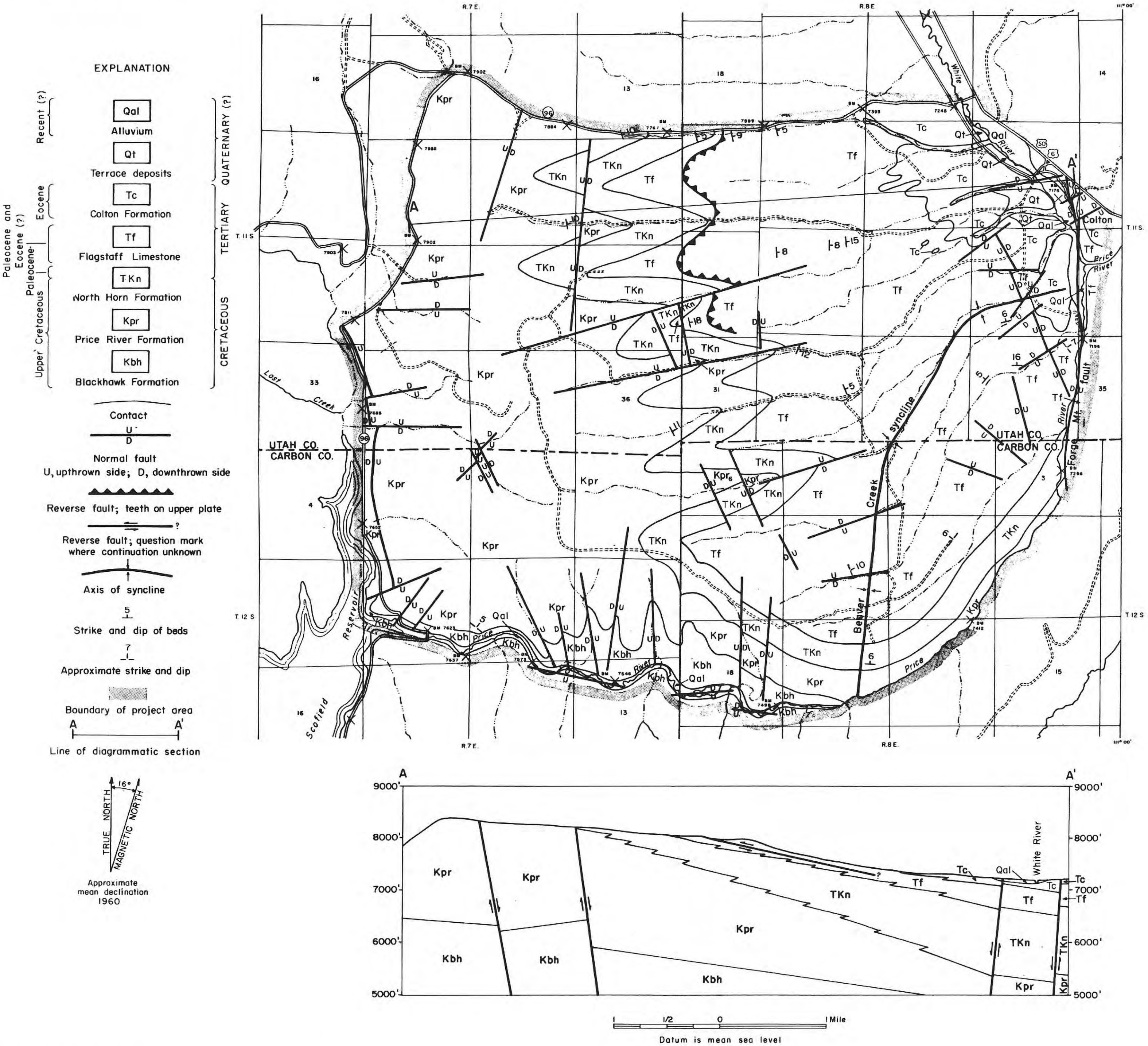

Base from the U.S. Geological Survey 15' quadrangle of Soldier Summit, Utah, 1939.

Geology by R. M. Cordova, 1962

Figure 5.- Geologic map and diagrammatic section of the project area based on reconnaissance.

extends from north to south through the middle of the project area. Minor fracturing has broken at least some of the beds into polygonal blocks. Both the folds and fractures probably resulted from stresses produced by the synclinal folding or thrusting.

Jointing is well developed in all the formations in the project area. The geologic reconnaissance did not show any systematic distribution of joint sets, and they may strike at any angle. The dips of the joints are steep to vertical.

HYDROLOGY

Ground Water

Present Use

Ground water in the project area is used for three purposes. Sheepmen use the water from many springs, and they have built many earthfill dams to collect the spring water (Fig. 2). The cities of Price and Helper collect water from seepage areas along the Price River canyon and Spring Canyon and pipe the water down Price River canyon. The Utah Power and Light Co. has drilled two deep wells, (D-11-8)22dcb-1 and (D-11-8)22bca-1 (the Colton wells in Fig. 2), to obtain supplemental water for a steam-generating plant near Helper.

A maximum of about 9,000 sheep graze the project area during the periods May 1 to July 1 and September 15 to October 15; a minimum of about 3,600 sheep graze the area during the period July 1 to September 15. On the basis of data from C. W. Cook (Utah State University, written communication, 1962), it is calculated that the sheep consume about 2.2 million gallons (6.7 acre-feet) of water annually.

The city of Helper obtains water from springs and seeps in Spring Canyon (Table 5) and in the Price River canyon. The water collected from Price River canyon does not originate in the project area and is not considered in this report. The city of Price obtains water from Colton Spring (Fig. 2) which is close to the confluence of the White and Price Rivers. The city also obtains water from a drainage system that was constructed in a seepage area adjacent to the spring to collect additional water. The total withdrawal of ground water from the project area by Price during 1958-62 is shown in Table 4.

The deep wells drilled by the Utah Power and Light Company have supplied water to Price and Helper during dry periods as well as supplemented the needs of the power company for steam generation. Both wells have been pumped at rates exceeding 1,000 gpm (gallons per minute) or 2.2 cfs (cubic feet per second) for extended periods of time. It is estimated that during the period 1957-61 total pumpage averaged 500 acre-feet annually.

Aquifers

Vertical Distribution of Aquifers

Logs of the Colton wells (Tables 7 and 8) suggest that most of the aquifers in the project area are sandstone and limestone zones. The aquifers range in thickness from about 5 to 200 feet. Sandstones in the Flagstaff Limestone and the North Horn Formation are friable and calcareous, and they undoubtedly contain water in intergranular openings and open fractures. The Flagstaff Limestone also contains limestones through which water probably moves in fractures that have been enlarged by solution. Drilling data, together with geologic and topographic evidence, indicate the existence of solution cavities: Colton well 2 penetrated an aquifer in the middle of the Flagstaff Limestone whereas Colton well 1 penetrated none; the limestone strata are highly fractured; and at least one small surface stream terminates in the limestone area of outcrop.

The deepest aquifer penetrated by the Colton wells is in the North Horn Formation at a depth of about 1,500 feet, but most of the aquifers are within 1,400 feet of the surface in the Flagstaff Limestone and the North Horn Formation. Colton well 2 penetrated 300 feet of the Price River Formation (the thickness of this formation probably is 600 feet at this site) without encountering aquifers. The Price River Formation has intergranular porosity both at the surface and in the subsurface, however, and an average porosity of 21 percent was determined by laboratory tests of five samples (Table 1). Although the formation has high porosity, it apparently has a low permeability.

Hydrologic Properties of Aquifers

Laboratory tests: Ten samples were collected from sandstones that crop out in the project area. The samples represent the materials that are most likely to have relatively high intergranular porosity and permeability and therefore likely to be aquifers where saturated. The samples were analyzed in the laboratory to determine particle-size distribution, specific yield, porosity, and specific retention, and the results are summarized in Tables 1 and 2.

The particle sizes of the consolidated-rock samples range from clay to coarse sand, but most range from very fine to medium sand (Table 2).

The porosity of a rock is the ratio of the volume of pore space to the total volume of the rock. In consolidated rocks, the number and size of open fractures and the amount of interstitial cement are the chief factors determining porosity, whereas in unconsolidated rocks, the chief factors are sorting and degree of compaction. The average porosity of five samples from the Price River Formation is 21 per cent. This is greater than the porosity of any of the other consolidated rocks, but it is considerably less than the porosity of about 48 per cent that was determined for an unconsolidated deposit. The high porosity of the unconsolidated deposit is largely attributable to its loose compaction.

The specific retention of a water-bearing material is the ratio, expressed as a percentage, of the total volume of water retained in a sample after saturating and then draining it to the total volume of the sample. Porosity minus specific retention equals specific yield or effective porosity. Specific yield is the term used to express the quantity of water that a saturated water-bearing material will lose by gravity draining. It is the ratio of the volume of the water drained to the total volume of the material, expressed as a percentage. The specific yield of the five samples of sandstone from the Price River Formation ranges from 1.3 to 18.7 per cent and averages about 10 per cent. Two of the five samples have specific yields that are in the same low range as specific yields determined for sandstones from other formations.

Table 1. — Results of laboratory tests on probable aquifer material of the project area.

Location	Geologic source	Rock type and dominant particle size, where determined	Porosity (percent)	Specific retention (percent)	Specific yield (percent)
(D-11-7)15dbb	Price River Formation	Sandstone, fine	20.8	9.9	10.9
22dba	" " "	Sandstone	26.5	9.4	17.1
26dcc	" " "	"	28.4	9.7	18.7
34aab	" " "	"	17.6	14.3	3.3
35bdd	" " "	"	11.5	10.2	1.3
(D-11-8)16cca	Colton Formation	"	11.4	8.4	3.0
19bba	North Horn Formation	Sandstone, fine	16.8	15.6	1.2
27dda	Colton Formation	" "	13.8	-	-
(D-12-7)1bcb	Unconsolidated deposit	Sand, fine	48.3	18.4	29.9
10dbc	Blackhawk Formation	Sandstone, very fine	15.8	14.8	1.0

Table 2. — Particle-size distribution of samples from five formations in the project area.

Particle size (diameter in millimeters)	North Horn Formation (D-11-8)19bba	Price River Formation (D-11-7)15dbb	Colton Formation (D-11-8)27dda	Blackhawk Formation (D-12-7)10dbc	Unconsolidated deposit (D-12-7)1bcb
	Percentage of particle size				
Gravel (greater than 2.0)	-	-	-	-	0.6
Very coarse sand (1.0-2.0)	-	-	-	-	.4
Coarse sand (0.5-1.0)	0.2	-	-	-	3.0
Medium sand (0.25-0.5	21.6	21.4	12.4	2.6	18.1
Fine sand (0.125-0.25)	38.6	63.6	36.8	39.0	23.8
Very fine sand (0.0625-0.125)	19.0	5.2	24.0	41.2	12.6
Silt (0.004-0.0625)	16.4		18.9		29.0
		9.8		17.2	
Clay (less than 0.004)	4.2		7.9		12.5

The wide range in specific yields of samples from the Price River Formation suggests that the aquifer characteristics vary from place to place. This may also be true of the other consolidated formations. Interpretations of aquifer characteristics that are based on only a few surface samples obviously are limited in their applicability. More samples collected at depth as well as at the surface are desirable for an adequate understanding of aquifer characteristics.

Field tests: Field tests of the aquifers were made by pumping the Colton wells for different lengths of time. Several long tests were conducted by the Utah Power and Light Co., and two short tests were supervised by the Geological Survey during the fall of 1962.

Colton well 1 was pumped at an average rate of about 1,100 gpm for 126 days, and the maximum drawdown measured was 230 feet. Colton well 2 was pumped at an average rate of 1,600 gpm for 8 hours, and the maximum recorded drawdown was 180 feet. The specific capacities of the two wells are thus 5 and 9 gpm per foot of drawdown. By contrast, the specific capacities of the Colton wells were determined also under conditions of free artesian flow. The flow of Colton well 1 for the period 1953-62 averaged 170 gpm, and the head averaged 12 feet above the land surface. The average specific capacity of this well, therefore, is 14 gallons per foot. The flow of Colton well 2 in 1962 was 270 gpm and the head was 14 feet above the land surface. The specific capacity of Colton well 2, therefore, is 19 gallons per foot. The lower specific capacities observed when wells were pumped are thought to be due to well losses.

The results of these tests indicate that the composite field coefficient of transmissibility 1/ of the aquifers in the Flagstaff Limestone and the North Horn Formation is in the magnitude of 50,000 gpd/ft. The results of the pumping tests were not entirely satisfactory, but the information obtained can be correlated with other data to provide some understanding of the hydrologic properties of the aquifers.

Springs and Seeps

Discharge

Some of the natural discharge from the ground-water reservoir in the project area is from springs and seeps (Fig. 2), many of which are in the channels of the Price River and the streams tributary to the Price and White Rivers. The largest spring in the project area, the Colton Spring, is part of an area of ground-water discharge in the channel of the Price River which is called the "Colton Spring locale" in this report. Smaller springs and seeps in the tributary channels discharge from the main ground-water reservoir, whereas springs and seeps outside the channels may drain small ground-water bodies that are separate from the main reservoir. The springs in the western parts of Spring, Rachels, and Clayton Canyons and those in Stewarts and Snake Canyons may be of the latter type. All these springs dried up during 1961.

1/ The field coefficient of transmissibility expresses the rate of movement of ground water in gallons per day at the prevailing water temperature through a saturated vertical strip of the aquifer 1 mile wide when the hydraulic gradient is 1 foot per mile.

The areas of ground-water discharge along the east-flowing reach of the Price River are perennial, but the source of the water probably is the area to the south.

The discharge from the Colton Spring locale is perennial, and it is the largest discharge of all the seepage areas in the project area. The discharge from the Colton Spring locale during the "wet" year 1957 was about 690 million gallons (2,100 acre-feet) and in the "dry" year 1961 about 390 million gallons (1,200 acre-feet) (see Table 3).

The second largest area of ground-water discharge in the project area is the seepage area of Spring Canyon (Fig. 2). The discharge of this area in 1957 was estimated from the rate of decline of the following years to be 370 million gallons (1,100 acre-feet). This discharge diminished to about 130 million gallons (400 acre-feet) in 1961. (See Table 4.)

The aggregate discharge in 1961 of other seepage areas in the channels of the tributaries to the Price and White Rivers probably did not exceed a maximum of 250 gpm (about 400 acre-feet per year), and it probably diminished to about 170 gpm (about 270 acre-feet per year) at summer's end. The seepage areas mapped in the summer of 1962 are perennial (Fig. 2), but they diminished in size through the year. The discharge from all the seeps and springs, except the Colton Spring locale and the Spring Canyon area, is included in the calculation of surface discharge in the section on "Streamflow."

Considering that 1957 was one of the wettest and 1961 one of the driest years of record, the rates of ground-water discharge from springs and seeps during these years probably approximate the maximum and minimum rates that may generally be expected. The maximum discharge of the springs and seepage areas discussed above, therefore, probably will be about 3,600 acre-feet per year and the minimum about 1,900 acre-feet per year. The average annual measured discharge during the period 1957-62 from the Colton Spring locale and the Spring Canyon area was about 2,400 acre-feet. Considering the unmeasured discharge from springs and seeps and the possibility of some discharge from the Flagstaff Limestone along the north-flowing reach of the Price River (Fig. 5), a total of 3,000 acre-feet may be assumed as the annual discharge from seeps and springs in the project area.

The rate of ground-water discharge is affected by annual and long-term variations of precipitation. Where ground water is unconfined and the water table intersects the land surface, changes in discharge rates result from changes in the altitude of the water table. A rise of the water table causes an increase in discharge, and a decline of the water tables causes a decrease of discharge. The water table rises in response to additions of water from snowmelt and rainfall and declines in response to discharge. Water-table conditions apparently prevail in the seepage areas in the channels of the tributaries to the Price and White Rivers.

Ground water that discharges from Colton Spring is under artesian pressure, and changes in the rate of flow are a direct reflection of changes in the pressure gradient. During the spring and early summer, when snowmelt recharges the ground-water reservoir, the pressure gradient increases because water is added to the reservoir faster than it is discharged. The increased gradient produces increased flow from the spring until a maximum gradient is reached. When the amount of

Table 3. — Estimated monthly flow from the Colton Spring locale used by Price 1957-62.

	Flow in millions of gallons					
	1957	1958	1959	1960	1961	1962
January	1/42	2/40	2/37	38	49	2/27
February	1/40	2/38	2/34	2/29	42	2/25
March	1/45	2/43	30	2/34	2/27	2/30
April	55	2/44	46	2/34	54	65
May	58	55	42	2/37	43	70
June	92	65	37	52	2/22	74
July	80	43	25	49	2/24	2/46
August	80	43	24	41	2/25	2/43
September	68	60	39	37	2/28	2/39
October	54	3/60	44	36	2/27	2/38
November	2/37	3/60	52	42	2/26	2/34
December	2/40	57	51	2/28	2/27	2/33
Total (millions of gallons)	691	608	461	457	394	524
Total (acre-feet, rounded)	2,100	1,900	1,400	1,400	1,200	1,600

1/ Estimate based on the flow of the same month in the following year.
2/ Flow of Colton Spring only.
3/ Estimate based on previous month's flow.

Table 4. — Estimated monthly flow from the Spring Canyon seepage area used by Helper, 1958-62.

	Flow in millions of gallons				
	1958	1959	1960	1961	1962
January	1/29	27	18	13	9
February	1/27	25	18	11	9
March	1/27	25	19	13	10
April	1/23	21	19	15	12
May	1/25	23	19	13	22
June	1/23	21	18	11	23
July	1/24	22	17	10	24
August	23	21	14	6	22
September	29	19	11	9	22
October	29	19	15	11	20
November	27	18	13	10	20
December	27	18	12	9	20
Total (millions of gallons)	313	259	193	131	213
Total (acre-feet, rounded)	960	790	590	400	650

1/ Estimates for 1958 are based on amounts for 1959.

Table 5. Losses and gains in discharge of the Price River between Scofield Dam and Colton during the 1962 water year.

Month	Total monthly discharge near Scofield Dam (acre-feet)	Total monthly discharge near Colton (acre-feet)	Gain (+) or loss (-) in discharge (acre-feet)
October 1961	462	625	+163
November	640	766	+126
December	474	566	+92
January 1962	301	413	+112
February	199	301	+102
March	375	493	+118
April	62	451	+389
May	1,200	1,340	+140
June	8,950	8,970	+20
July	11,230	11,500	+270
August	10,040	8,990	-1,050
September	5,520	5,310	-210

recharge decreases and it cannot maintain the maximum gradient, the gradient decreases and consequently flow decreases. Snowmelt percolating to the ground-water reservoir results in the most marked increase in gradient; but as seen in Figure 4, recharge from rainfall during the summer and fall may also increase the gradient, although to a lesser extent than does recharge from snowmelt.

Superposed on the annual change in discharge of springs and seeps are long-term changes. These changes result from variations of precipitation during a span of years. The long-term change is often more significant than the annual change because of its effects on the long-range availability of water.

The effect of long-term variations of precipitation on ground-water conditions can be seen by comparing the precipitation pattern at Scofield Dam with the available discharge records of the Colton Spring locale and the Spring Canyon seepage area (Fig. 4 and Tables 3 and 4). The "wet" winters of 1956-57 and 1957-58 (October-April period) had about 18 and 20 inches of precipitation, respectively, and were followed by three "dry" winters having precipitation that ranged from about 8 to about 10 inches. The three relatively dry winters were followed by the "wet" winter of 1961-62 which had about 18 inches of precipitation. Discharge from the springs and seepage areas was at a maximum during the years that followed the winters of 1957-58 and 1961-62 and generally declined during the intervening years. The discharge rates during the period of declining discharge always were less than the maximum rates reached before and after this period.

Structural Control of the Colton Spring Locale and Several Seepage Areas

Faults may have caused the localization of the Colton Spring locale and several other seepage areas. Fault zones in the project area were identified at several outcrops of the Flagstaff Limestone. Where faulted, the formation is a hard, firmly cemented breccia, and such rock may form impermeable barriers to the movement of ground water. Faults are the most obvious explanation of the comparatively large and apparently persistent flows in the seepage areas of the lower parts of Millers, Tobs, and Corral Canyons.

The Forge Mountain fault passes through the Colton Spring locale (Figs. 2 and 5). If the fault zone is impermeable, ground water in the Flagstaff Limestone may be shunted upward to discharge at the surface. The aquifer that was penetrated in the middle of the Flagstaff Limestone by Colton well 2, however, was not penetrated by Colton well 1. This indicates that ground water in the Flagstaff Limestone moves in solution channels that may not be connected. Because the Colton Spring discharges close to the contact of the Flagstaff Limestone and the overlying, relatively impermeable Colton Formation, the ground water reaching the Colton Spring locale may be forced to the surface at the formation contact. A third possibility is that the water may be flowing in a solution channel that is near the top of the Flagstaff Limestone and consequently has been breached by the erosional processes that formed the river valley.

Effect of Pumping Wells

Although no concrete evidence on the effects of pumping the Colton wells was available for this report, it is conceivable that long-term continuous pumping could decrease discharge from local seeps and springs.

Pumping from wells upsets the natural equilibrium of the ground-water reservoir. Pumping from the reservoir may result in a decrease in natural discharge, an increase in recharge, a decrease in storage, or a combination of all. Because the aquifers in the project area are artesian, and because the distances between points of recharge and discharge are relatively small, pumping could affect the quantities of water recharged and discharged in a relatively short time. Pumping wells that are in or near discharge areas would affect the discharge before it affected the recharge in more distant areas.

Streamflow

Streamflow is the water from precipitation that appears in surface streams. Water may reach a stream as overland flow, storm seepage, or discharge from the ground-water reservoir. Overland flow and storm seepage are the main sources of streamflow during the spring and early summer when the winter snowfall is melting, and also during summer rainstorms of high intensity. Ground-water discharge is the chief source of streamflow during the summer and fall.

Measurements of streamflow from part of the project area drained directly by the Price River were made during the 1962 water year (October 1961-September 1962) by comparing discharges at two stream-gaging stations on the Price River (Fig. 2). Table 5 shows the monthly losses and gains in discharge along the gaged reach of the river. From October to July the reach gained 1,532 acre-feet, but during August and September it lost 1,260 acre-feet. Thus, the net gain during the entire period was 270 acre-feet. The gain during the October-July period from the 17 square miles of drainage area (about 7 square miles of which are in the project area) contributing to the reach represents a streamflow of about 90 acre-feet per square mile. This streamflow is very small when compared with similar figures for nearby streams. For example, during the same October-July period the average streamflow from the areas drained by the White River above the gage at Soldier Summit and by the Price River above the gage at Scofield Dam was 375 and 734 acre-feet per square mile, respectively. Long-term records for the White River at Soldier Summit (22-year record, 1939-61) and the Price River above Scofield Dam (23-year record, 1938-61) show an average streamflow of 260 and 520 acre-feet per square mile, respectively.

Although the general range in altitude of the three drainage areas, the altitudes of the gaging stations, and the meteorological conditions in the areas are similar, the geologic formations underlying most of the project area are different from those underlying the other two areas. The Price River and North Horn Formations underlie most of the area that contributes to the gaged reach of the Price River in the project area. The Colton Formation underlies most of the White River drainage basin, and the Blackhawk Formation underlies most of the Price River drainage basin above Scofield Dam. The Colton and Blackhawk Formations generally have low porosity and permeability, whereas the Price River and the North Horn Formations have relatively high porosity and permeability. Thus, the large difference in the value of streamflow per square mile may be caused by different geologic conditions. It is possible that much of the precipitation in the project area is literally soaked up by the rocks. This water may be held until lost by evapotranspiration or it may percolate rapidly to the part of the ground-water reservoir that discharges outside the project area.

It is necessary to estimate the streamflow from the remaining 26 square miles of the project area for which measurements were not made. Most of the remaining area is underlain by relatively porous and permeable rocks of the Price River, North Horn, and Flagstaff formations. The streamflow from this area undoubtedly is less than that from nearby areas which are underlain by the Colton and Blackhawk Formations, but it probably is more than the streamflow from the 7 square miles of the project area discussed above. A usable compromise figure can be obtained by considering the entire drainage basin of the Price River above Helper. This area is similar to the project area in geology, altitude, and climate; therefore, the streamflow from the two areas should be similar. The streamflow from the Price River drainage basin above Helper for the period 1934-61 averaged about 170 acre-feet per square mile. Applying this figure to the remaining 26 square miles of the project area gives a streamflow of about 4,400 acre-feet. The total streamflow from the 33 square miles of the project area thus may be in the order of 6,000 acre-feet annually.

Chemical Quality and Temperature of Water

The chemical quality of ground and surface waters in the project area, which was evaluated by studying 28 analyses (Table 6), is chiefly determined by the chemical content and solubility of the rocks in the area. Water percolating through limestone and calcareous sandstone and shale can be expected to have a high content of calcium and bicarbonate; water percolating through ferruginous sandstone and shale can be expected to have a high iron content; and water percolating through sandstones containing considerable feldspar and ferromagnesian silicates can be expected to have a relatively high content of calcium, magnesium, sodium, potassium, and silica. By contrast, water flowing in surface streams generally contains less dissolved solids than does ground water. For example, the two samples of water from the Price River (Table 6) contain 197 and 205 ppm of dissolved solids, as compared to an average of 312 ppm for ground water in the project area. The two samples from the White River, however, contain 328 and 337 ppm of dissolved solids, suggesting that the contribution of ground water to the White River exceeded that to the Price River at the time of sampling.

Ground water from the calcareous rocks of the Flagstaff Limestone and North Horn Formation are similar, and they contain more dissolved solids than does water from the other formations in the project area. Water from the North Horn has the widest range of mineral concentration, which probably is a reflection of the varied lithology of the formation. The North Horn contains an abundance of limestone, sandstone, and shale, some of which are ferruginous and some of which contain considerable feldspar and ferromagnesian silicates.

Water from the Price River Formation generally contains less dissolved solids than do other waters in the project area. The Price River Formation, in contrast to the North Horn Formation and Flagstaff Limestone, comprises a thick section of clean quartzose sandstone; therefore, ground water passing through the formation comes in contact with relatively little soluble material.

Evaluation of the chemical quality of water from the Blackhawk and Colton Formations and the unconsolidated deposits is not practicable because of lack of sufficient data. However, such an evaluation is not necessary because these formations are not known to yield water in the project area.

The maximum, minimum, and mode of the concentration of each chemical constituent in the ground water of the project area are compared below:

Chemical constituent	Maximum (ppm)	Minimum (ppm)	Mode (ppm)
Silica (SiO_2)	12	6.5	7.1
Iron (Fe)	7.3	.00	.05
Calcium (Ca)	106	27	78.2
Magnesium (Mg)	39	8.3	29
Sodium + potassium (Na + K)	54	2.5	6.3
Bicarbonate (HCO)	539	202	347
Sulfate (SO_4)	53	7.0	15
Chloride (Cl)	26	4.5	8.0
Nitrate (NO_3)	8.8	.1	.5
Dissolved solids	562	191	318
Hardness as $CaCO_3$	394	194	307

The total range in concentration of each constituent, as indicated by the maximum and minimum concentrations, includes anomalous concentrations and therefore has little or no relation to the general range. The mode (the value around which the other values tend to be centralized) is an expression of the general range, and it indicates the magnitude of concentration that is most likely to be expected in the project area.

The U. S. Public Health Service (1962) recommends the following standards for drinking water:

1. Dissolved solids not to exceed 500 ppm.
2. Chloride not to exceed 250 ppm.
3. Sulfate not to exceed 250 ppm.
4. Iron not to exceed 0.3 ppm.
5. Nitrate not to exceed 45 ppm.

The maximum dissolved solids concentration of the analyses in Table 6 slightly exceeds the recommended limit of the Public Health Service, but the mode is well below it. The maximum concentration of 562 ppm is anomalous and is probably the result of deep circulation in a highly fractured zone. The sulfate, chloride, and nitrate concentrations are well below the limits recommended by the Public Health Service. The mode of the iron concentration is also below the recommended limit. The maximum iron concentration of 7.3 ppm was observed in a sample from Colton well 2 which taps the

North Horn Formation. Three other samples from the North Horn contained no iron. This suggests that the iron content of the sample from the Colton well is anomalously high and may be a result of contamination by the casing. It is possible, however, that the North Horn Formation, at depth, contains ferruginous sandstone which is a source of iron. Water sampled in the project area is very hard and softening of the waters is desirable for most uses.

The temperature of water is particularly important if the water is to be used for cooling. The temperature of ground water from springs and seeps in the project area ranges from 41° to 58° F and generally is less than 50° F (Table 6). The water of the Colton Spring locale is about 48° F throughout the year.

CONCLUSIONS

Estimation of the Ground-Water Supply

The lack of detailed information about the amount of water entering, leaving, and being stored in the project area makes it impossible to determine accurately the amount of ground water that is available in the area. It is possible, however, to make a crude estimation of the ground-water supply in the project area by means of a water-budget technique using the the following equation:

$$P = E + S + G \pm \Delta S$$

where P is precipitation, E is evapotranspiration, S is streamflow, G is ground-water discharge, and ΔS is change in storage.

The normal annual precipitation on the project area is assumed to be about 22 inches, or 38,000 acre-feet per year. Evapotranspiration is assumed to be about 65 per cent of the normal annual precipitation, or 25,000 acre-feet per year. Streamflow is estimated to be about 6,000 acre-feet per year. Storage is assumed to be constant. The ground-water discharge from the project area (exclusive of the amount that contributes to streamflow) is therefore estimated to be about 7,000 acre-feet per year. Of this, about 500 acre-feet per year was pumped from the Colton wells, and an average of about 2,400 acre-feet per year was obtained from springs and seeps by the cities of Price and Helper. The remaining ground-water discharge, therefore, which leaves the project area by subsurface flow, is approximately 4,000 acre-feet per year.

Future Development of the Ground-Water Supply

The only feasible way to develop additional ground water in the project area is by means of wells. Although wells could not intercept all the water now leaving the area in subsurface flow, they probably could tap at least half of it. In addition, wells would provide a relatively stable supply which is not subject to the fluctuations that affect the flow of springs.

In order to have the greatest opportunity for obtaining large yields, wells should penetrate as many of the water-bearing formations as possible. A well that obtains water in the Flagstaff Limestone is likely to obtain additional water if drilled deeper into the underlying North Horn Formation, and in places it may also obtain water from the Price River Formation. It is possible that the relatively impermeable Blackhawk Formation acts as a barrier to the downward percolation of water, and a considerable quantity of ground water may be moving out of the project area in the subsurface on the top of the Blackhawk.

The water percolating through the ground and the water flowing in the streams in the project area are all part of a single hydrologic system. Withdrawal from one source may affect flow from another source. It is possible, therefore, that part of any newly developed supply from wells in the project area may be drawn from existing spring discharge or streamflow. Such possible effects are unavoidable, however, if the ground-water resources of the project area are to be fully developed.

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Table 6. — Chemical quality of ground and surface waters in the project area (Analyses by U. S. Geological Survey unless indicated otherwise)

Location	Source	Owner	Geologic source	Date of collection	Temperature (°F.)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids [1]	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Percent sodium	Specific conductance (micromhos/cm at 25°C.)	pH
						Parts per million														
(D-11-7)13ddc-1	Spring	G. Jackson	North Horn Formation	8-24-62	44	6.5	0.00	67	27	2.5	316	14	5.5	2.7	256	278	19	2	495	7.7
14cda-1	do.	O. Jackson	Price River Formation	9-12-62	44	7.4	-	78	21	7.4	330	14	5.0	8.8	290	283	12	5	523	7.6
25dba-1	do.	N. Johnson	North Horn Formation	9-11-62	58	7.7	-	83	39	54	539	7.0	26	1.7	562	370	0	24	869	7.8
35ccc-1	do.	do.	Price River Formation	9-12-62	44	10	-	59	15	15	202	44	19	.8	270	207	41	13	407	7.2
35ccc-2	do.	do.	do.	9-13-62	44	10	-	70	8.3	7.6	222	25	10	4.4	238	209	27	7	441	7.7
36bdb-1	do.	do.	do.	7-11-62	42	6.8	-	67	23	3.9	307	7.4	5.0	2.8	264	260	8	3	484	7.7
(D-11-8)16dda-1	White River			8-28-62	58	11	.04	63	24	34	345	36	6.5	.1	328	254	0	23	574	8.1
19dcc-1	Spring	G. Jackson	North Horn Formation	7-13-62	44	6.9	-	71	34	6.4	373	12	8.5	.2	323	316	10	4	583	7.7
20cdc-1	do.	do.	Flagstaff Limestone	7-12-62	52	8.6	-	83	33	8.5	406	15	9.0	.2	358	342	9	5	631	7.9
21adb-1	do.	do.	do.	8-28-62	48	7.5	-	82	29	5.8	365	22	10	.6	326	324	25	4	593	8.0
22bca-1 [2]	Well	Utah Power and Light Co.	North Horn Formation	2- 9-54	-	11	7.3	55	26	11	301	53	15	7.2	310	246	22	9	-	7.6
27aaa-1	White River			8-28-62	52	10	.03	54	30	38	349	40	8.0	.1	337	256	0	24	589	8.2
27add-1	Colton seepage area	City of Price	Alluvium	7-11-61	48	7.9	.00	33	33	13	3/238	36	11	.5	236	220	25	11	430	8.2
27dad-1	Colton Spring	do.	Colton Formation	7-11-62	48	7.3	.00	27	31	7.6	214	24	7.0	.4	191	194	19	8	369	8.1
27dad-1	do.	do.	do.	8-10-62	48	6.8	.00	72	27	5.5	314	30	9.0	1.2	282	290	33	4	528	8.1
29bdc-1	Spring	N. Johnson	Flagstaff Limestone	7-12-62	42	7.0	-	73	31	7.6	366	14	10	.1	323	312	12	5	581	7.8
32bbc-1	do.	do.	North Horn Formation	7-31-62	45	7.8	.00	88	26	9.0	376	26	8.5	.4	326	328	20	6	600	7.7
32cab-1	do.	do.	Flagstaff Limestone	7-20-62	48	7.9	-	80	34	4.8	382	22	9.5	.1	349	339	26	3	618	7.8
35bbb-1	Price River			8-28-62	61	2.0	.23	55	3.6	21	213	17	3.0	.2	197	151	0	23	356	8.1
(D-12-7)1acb-1	Spring	P. Nelson	Price River Formation	7-10-62	41	7.0	-	72	19	3.4	303	7.8	4.5	1.9	274	257	9	3	471	7.9
1acb-1	do.	do.	do.	9-13-62	44	7.0	-	77	17	4.6	302	14	4.5	1.9	276	260	12	4	475	7.6
1bcc-1	do.	do.	do.	7-10-62	43	7.1	-	81	19	4.6	334	8.0	5.5	.3	303	280	6	3	512	7.8
10ddb-1	Price River			8-31-62	62	2.1	.18	56	14	1.9	219	15	3.5	.1	205	196	16	2	368	7.9
(D-12-8)5bda-1	Spring	P. Nelson	North Horn Formation	8- 9-62	50	7.8	.00	96	23	7.6	371	29	11	1.1	345	334	30	5	615	7.6
8aba-1	do.	do.	Flagstaff Limestone	8- 9-62	44	8.0	-	82	29	6.0	372	16	10	1.8	345	324	19	4	603	7.6
8bac-1	do.	do.	do.	8-10-62	43	6.5	.00	83	20	6.0	318	21	9.5	6.5	290	288	27	4	531	7.7
8dba-1	do.	do.	do.	7-19-62	44	8.1	-	89	28	6.9	392	15	9.5	1.3	348	336	15	4	622	7.8
17aab-1	do.	do.	do.	7-19-62	50	11	-	106	32	14	458	25	16	.1	428	394	18	7	754	7.7

1/ Dissolved solids calculated from determined constituents.

2/ Analysis by Utah State Department of Health.

3/ Includes equivalent of trace of carbonate (CO_3).

Table 7. — Log of Colton well 1

Well number: (D-11-8)22dcb-1.

Altitude of derrick platform: 7,208 feet.

Driller: J.S. Lee & Sons.

Completed: March 1953.

Total depth below land surface: 1,523 feet.

Casing: Steel, 16-inch to 628 feet, 12-inch from 628 to 1,138 feet.

Log by: Driller. Formational designations by R. M. Cordova.

	Thickness (feet)	Depth (feet)
Quaternary:		
Terrace deposits:		
Gravel, dry	18	18
Tertiary:		
Eocene.		
Colton Formation:		
Shale, red	115	133
Shale, gray	20	153
Shale, brown	70	223
Eocene (?) and Paleocene.		
Flagstaff Limestone:		
Shale, brown, and limestone	150	373
Shale, gray	40	413
Shale, brown, and limestone	40	453
Shale, sticky, and limestone	155	608
Tertiary and Cretaceous:		
Paleocene and Upper Cretaceous.		
North Horn Formation:		
Sand; water	3	611
Shale, sticky, and limestone	165	776
Sand and limestone	17	793
Limestone and shale	570	1,363
Sandstone; water flowing	10	1,373
Limestone, shale, and sandstone	140	1,513
Bentonite	10	1,523

Table 8. — Log of Colton well 2

Well number: (D-11-8)22bca-1.

Altitude of derrick platform: 7,198 feet.

Driller: Roscoe Moss Drilling Co.

Completed: June 1954.

Total depth below land surface: 2,103 feet.

Casing: Steel, 20 inch to 280 feet, 17 inch from 280 to 1,290 feet, 14 inch (perforated) from 1,290 to 1,948 feet.

Log: Modified from a log by D. J. Jones, University of Utah, with formational designations added by R. M. Cordova.

	Thickness (feet)	Depth (feet)
Quaternary:		
Terrace deposits.		
Gravel, water at 13 feet	18	18
Tertiary:		
Eocene.		
Colton Formation:		
Sandstone, reddish-tan, fine- to medium-grained, dense, hard, tightly cemented, abundant dark grains resembling phyllite	2	20
Sandstone, reddish-gray, fine- to medium-grained, well-cemented, "salt and pepper" type, and red silty shale	10	30
Shale, red-brown to maroon, fine-grained	20	50
Shale, maroon and gray-green to purple, fine-grained	20	70
Shale, gray to gray-green and purple, fine-grained; contains a streak of lime	20	90
Shale, reddish-brown, fine-grained, silty	20	110
Eocene (?) and Paleocene.		
Flagstaff Limestone:		
Sandstone, reddish-gray, fine-grained, subangular grains, loosely cemented, probably porous; gray-tan limestone; artesian water from this zone to bottom	10	120
Sandstone, as above, darker color; dark-red-brown shale	20	140
Shale, gray-green and reddish, limy; gray finely crystalline dense limestone	10	150
Sandstone, gray-tan, fine-grained, lime-cemented, dense; abundant phlogopite mica and rose-yellow quartz grains	5	155
Shale, dark-gray, fine-grained, silty, hard	20	175
Limestone, dark-gray-brown, very finely crystalline, lithographic, hard, dense; contains calcite veinlets	5	180
Shale, red, fine-grained, clayey, soft	20	200
Limestone, dark-gray-brown, finely crystalline, dense; increase in water	12	212
Shale, dark-gray, slightly carbonaceous, and a thin streak of limestone	20	232
Limestone, gray-brown to tan, very finely crystalline, dense, lithographic	18	250
Shale, dark-gray, calcareous, and thin limestone streaks	10	260
Limestone, gray-brown, finely crystalline; fine-grained gray and tan sandstone	10	270

Table 8. — Log of Colton well 2 — Continued

	Thickness (feet)	Depth (feet)
Tertiary--Continued		
Eocene (?) and Paleocene--Continued		
Flagstaff Limestone--Continued		
Limestone, light-tan, medium to finely crystalline, dense; medium-grained subangular gray sandstone	10	280
Limestone, as above, and small amount of sandstone	10	290
Limestone, light-tan to gray-tan, slightly sandy, finely crystalline, dense	10	300
Limestone, as above, and a few sandy stringers	20	320
Limestone, gray-brown, finely crystalline, dense, hard, veined with calcite	20	340
Limestone, gray-brown to gray-tan, slightly sandy, medium-fine crystalline, dense, hard, fossiliferous	20	360
Limestone, gray, very finely crystalline, lithographic, dense, hard, and a few pieces of gray-brown limestone	20	380
Limestone, as above, darker in color	20	400
Sandstone, light-gray, medium-fine grained, micaceous, "salt and pepper" type, phyllitic, tightly cemented	20	420
Limestone, gray, very finely crystalline, lithographic, dense, hard	20	440
Limestone, light-tan to gray-tan, very finely crystalline, dense	20	460
Shale, red, silty, sandy, fine-grained; dense, medium-fine crystalline gray-brown limestone	20	480
Limestone, gray to gray-brown, very finely crystalline, dense, lithographic	20	500
Shale, red and gray-green variegated; some very finely crystalline dense gray limestone	20	520
Siltstone and fine sandstone, red, fine-grained, subangular, tightly cemented, dense	20	540
Limestone, dark-gray, very finely crystalline, dense, lithographic	20	560
Tertiary and Cretaceous:		
Paleocene and Upper Cretaceous.		
North Horn Formation:		
Sandstone, gray, very fine grained, "salt and pepper" type, subangular, tightly cemented, hard	20	580
Tertiary and Cretaceous--Continued		
Paleocene and Upper Cretaceous--Continued		
North Horn Formation--Continued		
Shale, red, fine-grained; sandy reddish shale	20	600
Shale, yellow-brown, brown-gray variegated, fine-grained, slightly calcareous	20	620
Shale, red, some red and green variegated, fine-grained	20	640
Limestone, dark-gray to gray-brown, very finely crystalline, dense; some argillaceous pieces	20	660
Siltstone, gray, very fine grained, limy, dense	20	680
Sandstone, light-gray, fine-grained, subangular grains, dense, tightly cemented with lime; and sandy, finely crystalline gray limestone	20	700
Limestone, light-gray, sandy, dense, finely crystalline	20	720
Sandstone, gray-tan, very coarse grained, subangular, poorly cemented, micaceous; has intergranular porosity	20	740
Sandstone, white-gray, medium-grained, subangular, dense, tightly cemented	10	750
Limestone, gray, finely crystalline, sandy, dense	10	760
Siltstone, gray, very fine grained, hard, dense	10	770
Sandstone, gray, medium-grained, tightly cemented, limy, subangular grains	10	780
Sandstone, as above; fine-grained limy dark-gray shale	10	790
Siltstone, light-gray, fine-grained, hard, dense, limy	10	800
Limestone, gray-brown, dense, finely crystalline	10	810
Sandstone, gray, medium-grained, tightly cemented, dense	10	820
Shale, gray-brown, fine-grained, limy	10	830
Sandstone, white to gray, medium-grained, pyritic, dense	10	840
Limestone, dark-gray-tan, dense, finely crystalline	10	850
Limestone, as above, somewhat darker, pyritic	10	860
Limestone, light-gray, sandy, medium-fine crystalline, dense; limy fine-grained gray sandstone	10	870

Table 8. — Log of Colton well 2 — Continued

	Thickness (feet)	Depth (feet)
Tertiary and Cretaceous--Continued		
Paleocene and Upper Cretaceous--Continued		
North Horn Formation--Continued		
Limestone, dark-gray-brown, shaly, finely crystalline	10	880
Shale, dark-gray, fine-grained, limy, dense	10	890
Limestone, gray, sandy, finely crystalline, dense	10	900
Sandstone, gray, fine-grained, hard, almost a siltstone	10	910
Sandstone, gray, medium-grained, limy, hard, dense	10	920
Shale, dark-gray, fine-grained, limy; and shaly finely crystalline gray limestone	10	930
Sandstone, gray, medium-fine-grained, dense, limy	10	940
Limestone, gray, finely crystalline, sandy, dense, pyritic	10	950
Shale, dark-gray to black, coaly, clusters of pyrite	10	960
Limestone, medium-gray, finely crystalline, dense, slightly sandy	10	970
Sandstone, gray, coarse-grained, subangular grains, micaceous, "salt and pepper" type, limy cement	10	980
Sandstone, as above, slightly smaller grains, micaceous, phyllitic	10	990
Siltstone, gray, limy; and limy fine-grained gray shale	10	1,000
Shale, dark-gray to black, fine-grained, pyritic, coaly	10	1,010
Siltstone, gray, fine-grained, hard, dense, limy	10	1,020
Sandstone, white to gray, medium-grained, slightly limy, "salt and pepper" type	10	1,030
Shale, black, fine-grained, coaly, pyritic; and gray fine-grained sandstone	10	1,040
Limestone, gray, silty, dense, finely crystalline	10	1,050
Siltstone, dark-gray, fine-grained, coaly, limy, dense	10	1,060
Shale, black, carbonaceous, coaly; and coal	10	1,070
Sandstone, white to gray, very coarse grained, subrounded porous	10	1,080
Siltstone, gray, fine-grained, very limy	10	1,090
Sandstone, white to gray, medium-grained, loosely cemented, porous, calcareous cement	10	1,100
Sandstone, white-gray, fine-grained, dense, slight porosity	10	1,110
No sample	10	1,120
Siltstone, gray, fine-grained, calcareous	10	1,130
Tertiary and Cretaceous--Continued		
Paleocene and Upper Cretaceous--Continued		
North Horn Formation--Continued		
Sandstone, white-tan, medium-grained, subrounded, loosely cemented	20	1,150
No sample	20	1,170
Sandstone, gray-tan, medium-fine-grained, loosely cemented; dense finely crystalline tan limestone	10	1,180
Sandstone, as above	10	1,190
Limestone, gray, very finely crystalline, dense	10	1,200
Limestone, as above, but sandy	20	1,220
Shale, yellow, clayey, bentonitic	5	1,225
Shale, as above; slightly sandy gray limestone	5	1,230
Limestone, gray-tan, finely crystalline, sandy	10	1,240
Limestone, grayish-tan, medium-crystalline, sandy	5	1,245
Limestone, gray, very finely crystalline, and medium-fine-grained loosely cemented sandstone	5	1,250
Sandstone, fine-grained, loosely cemented; and micaceous fine-grained gray sandstone	5	1,255
Limestone, gray-tan, finely crystalline, sandy	5	1,260
Limestone, as above; contains gray shale partings	5	1,265
Limestone, gray-tan, finely crystalline, dense, sandy	5	1,270
Limestone, as above, sandy, much loose sand in sample	10	1,280
Limestone, as above, but not as sandy	5	1,285
No sample	10	1,295
Limestone, pale-gray-tan, finely crystalline, sandy, dense	5	1,300
Limestone, as above; contains many calcite veinlets	10	1,310
Limestone, as above, slightly darker, less sandy, hard, dense, pyritic	10	1,320
Sandstone, gray, medium-grained, subrounded, very limy	10	1,330
Sandstone, as above, very limy, hard, dense	10	1,340
Limestone, gray-tan, very finely crystalline, dense, hard	10	1,350
Shale, red, fine-grained, clayey limonitic	10	1,360
Limestone, gray-tan, very finely crystalline, very silty, dense	10	1,370
Limestone, as above, very sandy	10	1,380
Limestone, gray-tan, finely crystalline, very sandy, dense	10	1,390
Limestone, as above; some dark coaly shale	10	1,400
Limestone, dark-gray-tan, very finely crystalline, lithographic, hard, dense	10	1,410

Table 8. — Log of Colton well 2 — Continued

	Thickness (feet)	Depth (feet)
Tertiary and Cretaceous--Continued		
Paleocene and Upper Cretaceous--Continued		
North Horn Formation--Continued		
Limestone, as above, but sandier	10	1,420
Sandstone, light-gray, medium-fine-grained, poorly cemented, limy; has some porosity	10	1,430
Limestone, light-gray-tan, finely crystalline, dense, sandy and silty	10	1,440
Limestone, light-gray, finely crystalline, dense, silty	10	1,450
Limestone, as above, less silt and sand in the lime	10	1,460
Limestone, tan, very finely crystalline, dense, almost lithographic	10	1,470
Limestone, gray-tan, finely crystalline, sandy; some red and gray variegated shale	10	1,480
Limestone, yellowish-tan, finely crystalline; and some reddish-gray variegated shale	10	1,490
Shale, red and gray variegated; grades into gray-brown finely crystalline,dense limestone	10	1,500
Limestone, light-tan, finely crystalline, very sandy and silty; contains loose sand and silt grains; probably has some porosity	10	1,510
Limestone, light-gray, very sandy, coarse grains, loose; some porosity	10	1,520
Sandstone, limy, as above; some red shale	10	1,530
Limestone, tan, medium-fine crystalline, sandy; some red shale	10	1,540
Sandstone, light-gray, medium-coarse grains; some finely crystalline limestone	10	1,550
Limestone, reddish-brown and tan, medium-fine crystalline, sandy and clayey	10	1,560
Siltstone, light-gray-tan, fine-grained, dense, limy	10	1,570
Limestone, reddish-gray-tan, finely crystalline, dense, slightly silty; may be oolitic in part	10	1,580
Limestone, as above; fossiliferous	10	1,590
Shale and gray fine-grained sandy siltstone	10	1,600
Siltstone, light-tan-gray, sandy, limy	10	1,610
Limestone, buff, finely crystalline, sandy, hard	10	1,620
Limestone, tan to brown, finely crystalline, very silty	10	1,630
Shale, gray-tan, very fine grained, dense, very limy	10	1,640

	Thickness (feet)	Depth (feet
Tertiary and Cretaceous--Continued		
Paleocene and Upper Cretacous--Continued		
North Horn Formation--Continued		
Sandstone, gray, very fine grained, dense, limy	10	1,650
Shale, red and gray variegated, silty, fine-grained, clayey	20	1,670
Shale, red and gray-tan variegated, fine-grained	10	1,680
Limestone, gray-tan, very fine grained, dense, sandy	10	1,690
Sandstone, gray, very fine grained, dense; has a limy cement	10	1,700
Sandstone, as above; some loose grains	10	1,710
Sandstone, gray-white, fine-grained, loosely cemented, porous	10	1,720
Shale, red and gray variegated, silty; some sandstone	10	1,730
Shale, gray-buff, very fine grained, silty	10	1,740
Siltstone, gray, very fine grained, limy	10	1,750
Limestone, gray-tan, very finely crystalline, dense	10	1,760
Shale, silty, red and gray variegated, fine-grained, limy	10	1,770
Sandstone, gray, fine-grained, loosely cemented, porous	10	1,780
Sandstone, white to gray, fine-grained, loosely cemented; red and gray variegated shale	10	1,790
Shale, gray, fine-grained	10	1,800
Sandstone, gray, very fine grained, limy, porous	10	1,810
Limestone, gray-tan, fine-grained, sandy, dense, hard	10	1,820
Sandstone, white-gray, fine-grained, dense, tightly cemented; some limestone, as above	5	1,825
Cretaceous:		
Upper Cretaceous.		
Price River Formation:		
Sandstone, medium-coarse-grained, subrounded loose grains, abundant grains of rose quartz; probably is porous	15	1,840
Sandstone, medium-to medium-fine-grained, subrounded loose grains, porous; rose quartz grains common	10	1,850
Sandstone, as above; probably porous	5	1,855
Siltstone, gray, very fine grained, hard, dense, limy	5	1,860
Siltstone, as above; contains some loose sand grains from above	5	1,865

Table 8. — Log of Colton well 2 — Continued

	Thickness (feet)	Depth (feet)
Cretaceous--Continued		
Upper Cretaceous--Continued		
Price River Formation--Continued		
Siltstone, yellowish-tan, sandy, fragmental, dense	5	1,870
Limestone, gray-tan; fine-grained sandstone	5	1,875
Sandstone, white, medium-coarse, loose grains; some siltstone	5	1,880
Siltstone, yellow-tan, fine-grained; contains loose grains of sand	10	1,890
Sandstone, medium-fine-grained, loose grains, subrounded	10	1,900
Sandstone, as above; and some gray-tan, fine-grained shale	5	1,905
Sandstone, medium-fine-grained, loose grains, subrounded	10	1,915
Sandstone, as above; some gray thin shale	5	1,920
Sandstone, as above; some pieces of white-gray fine-grained limestone	10	1,930
Sandstone, gray-tan, medium-grained; contains a few fragments of white limestone	5	1,935
Limestone, gray-tan, finely crystalline; and white to gray medium-fine-grained sandstone	5	1,940
Sandstone, white to gray, medium-fine-grained, hard, limy	5	1,945
Sandstone, as above, subangular grains, loosely cemented	5	1,950
Limestone, white-gray, medium-fine crystalline, very sandy	5	1,955
Sandstone, white to tan, medium-coarse-grained, loosely cemented	5	1,960
Sandstone, gray-tan, medium-coarse-grained, loosely cemented	5	1,965
Sandstone, as above, slightly limy	5	1,970
Sandstone, white to gray-tan, medium-grained, somewhat dense, limy	5	1,975
Sandstone, as above; has a limy cement	5	1,980
Sandstone, gray-tan, medium-fine-grained, partially cemented, somewhat dense	10	1,990
Sandstone, as above; contains a few thin limy seams	5	1,995
Sandstone, gray, medium-fine-grained, loose grains; has some porosity	5	2,000
Cretaceous--Continued		
Upper Cretaceous--Continued		
Price River Formation--Continued		
Sandstone, gray, medium-coarse-grained, loose grains; some grains are cemented	5	2,005
Sandstone, medium-fine-grained, loose grains, porous	5	2,010
Sandstone, white to gray, medium-grained; blue-gray and tan limy shale	5	2,015
Sandstone, white to gray, medium-coarse-grained, loose grains; some shale and gray limestone	5	2,020
Sandstone, as above; more yellow-tan fine-grained shale	5	2,025
Shale, red, yellow-tan, and gray variegated, limy	10	2,035
Shale, as above; contains a few pieces of gray fine-grained limestone	5	2,040
Shale, as above	5	2,045
Shale, as above, but sandier	5	2,050
Shale, as above, variegated	5	2,055
Sandstone, medium-fine-grained, loosely cemented, porous	5	2,060
Shale, gray and green variegated; contains some fine loose sand	5	2,065
Shale, as above; and tan fine-grained loosely cemented sandstone	5	2,070
Sandstone, tan, fine-grained, loosely cemented; some variegated shale	5	2,075
Sandstone, as above	5	2,080
Sandstone, tan, medium-grained, loose grains; shale	5	2,085
Sandstone, as above; some gray-green variegated shale	5	2,090
Sandstone, white and tan, medium-grained tightly cemented; gray-green and red shale	5	2,095
Shale, gray, red, and green variegated; gray, finely crystalline limestone	5	2,100
No sample	3	2,103

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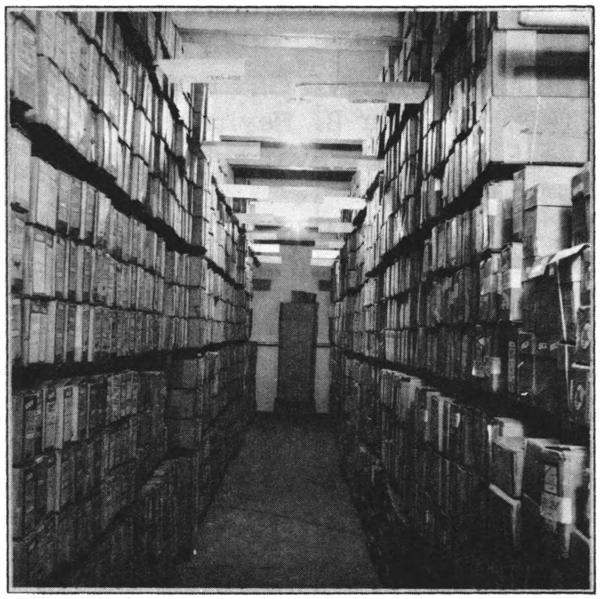

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