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Water resources of Grand Teton National Park, Wyoming

by

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Abstract

The study described in this report is an appraisal of water resources in Grand Teton National Park where hydrologic data are needed for planning water supplies for public use. Water is used in the park for public-water supplies at National Park Service facilities, for commercial and domestic use at guest ranches and private residences, and for irrigation. Public-water supplies in the park utilize both surface and ground water. Some of the surface-water sources are in areas of heavy use by park visitors. Public-health requirements are that only ground water, if adequate in quantity and quality, should be used for public-water supplies in such areas.

Ground water in alluvium and glacial deposits in Jackson Hole moves toward the Snake River and the lower reaches of Pacific Creek and Buffalo Fork, indicating gaining reaches of streams, but moves parallel to or away from several other streams, indicating losing reaches in some streams. Measured gains in flow of the Snake River from ground-water inflow in Jackson Hole were 5.7 ft^3/s (cubic feet per second) per mile or 0.10 m^3/s (cubic meters per second) per kilometer in a 17.5-mile (28.2-kilometer) reach and 49.3 ft^3/s per mile (0.87 m^3/s per kilometer) in a 7.0-mile (11.3-kilometer) reach. The largest measured loss from a stream was 11.7 ft^3/s per mile (0.20 m^3/s per kilometer) in a 4.2-mile (6.8-kilometer) reach of Cottonwood Creek. The estimated average transmissivity is 30,000 cubic feet per day per foot (2,800 cubic meters per day per meter) for the alluvium and glacial deposits in Jackson Hole between Jackson Lake Dam and Moose.

All ground and surface waters in the park that were sampled and analyzed during this study are potable and would be satisfactory, as far as chemical quality is concerned, for public, domestic, or commercial supplies. The Snake River upstream from the park contains fluoride greater than the limit recommended by the U.S. Public Health Service for drinking water but less than the concentration that constitutes grounds for rejection of such a supply.

Ground-water supplies could be developed in places in and near the park. Yields of as much as 1,000 gpm (gallons per minute) (3,800 l/m) (liters per minute) of water per well could be obtained from alluvium and glacial-outwash deposits of Quaternary age in Jackson Hole and some nearby stream valleys. Each well in glacial-moraine deposits would yield from a few gallons per minute of water from clay and silt to as much as 100 gpm (380 l/m) of water from sand and gravel. The Madison Limestone of Mississippian age may yield several hundred gallons per minute per well, and the Teewinot Formation of Tertiary age may yield as much as 100 gpm (380 l/m) of water per well. Other geologic units would yield less than 100 gpm (380 l/m) of water per well; the probable yields from other geologic units are given in this report.

Introduction

Because the number of tourists visiting Grand Teton National Park increased markedly during the 1960's, the U.S. National Park Service requires hydrologic information for use in planning water supplies for public facilities. Most of the points of tourist interest in the park are near the lakes and streams east of the Teton Range where tourists enjoy mountain and water scenery. Water supplies that are sufficient in quantity, suitable in quality, and safe for human consumption are needed but are not always available near some of these points of interest. Water supplies are also needed in the park at centers of accommodation for tourists and employees. The National Park Service requires information on hydrologic conditions in the park for its mission of protecting the ecological system.

Water supplies in the park utilize both surface and ground water. Some of the surface-water sources, although adequate in quantity and quality, are in areas of heavy use by park visitors. Public-health requirements in the park are that only ground water, if adequate in quantity and quality, should be used for water supplies in areas of heavy use by park visitors.

The U.S. Geological Survey made a study of hydrologic conditions in Grand Teton National Park in cooperation with the National Park Service. The study started in October 1967 as an investigation of water problems at specific sites in the park where new or additional water supplies were needed for public use. The study was expanded early in 1969, and the main purpose of the study was changed to an overall appraisal of water resources in Grand Teton National Park. Field investigations were concluded in October 1972.

Use of metric units

Because use of the metric system is increasing in the United States, values for units of measure are given in metric as well as in English units in the text of this report. Metric equivalents of English units are given in parentheses following the English units. Metric equivalents of English units used elsewhere in this report may be determined by the following conversion factors:

From	Multiply by	To obtain
Inches	2.54	Centimeters
Feet	.3048	Meters
Miles	1.609	Kilometers
Square miles	2.590	Square kilometers
Acres	.4047	Hectares
Gallons per minute	3.7854	Liters per minute
Cubic feet per second	.0283	Cubic meters per second
Cubic feet per day per foot	.0929 [redacted]	Cubic meters per day per meter

Water temperatures were measured by the U.S. Geological Survey in degrees Fahrenheit (°F) prior to October 1, 1967 and in degrees Celsius (°C) since that date. The following conversion table will help to clarify the relation between °F and °C:

Temperature-conversion table

Temperatures in °C are rounded to nearest 0.5 degree. Underscored temperatures are exact equivalents. To convert from °F to °C where two lines have the same value for °F, use the line marked with an asterisk (*) to obtain equivalent °C.

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
-20.0	-4	-10.0	14	0.0	32	10.0	50	20.0	68	30.0	86	40.0	104
-19.5	-3	-9.5	15	+0.5	33	10.5	51	20.5	69	30.5	87	40.5	105
-19.0	-2	-9.0	16	1.0	34	11.0	52	21.0	70	31.0	88	41.0	106
-18.5	-1	-8.5	17	1.5	35	11.5	53	21.5	71	31.5	89	41.5	107
-18.0 *	0	-8.0 *	18	2.0 *	36	12.0 *	54	22.0 *	72	32.0 *	90	42.0 *	108
-17.5	0	-7.5	18	2.5	36	12.5	54	22.5	72	32.5	90	42.5	108
-17.0	1	-7.0	19	3.0	37	13.0	55	23.0	73	33.0	91	43.0	109
-16.5	2	-6.5	20	3.5	38	13.5	56	23.5	74	33.5	92	43.5	110
-16.0	3	-6.0	21	4.0	39	14.0	57	24.0	75	34.0	93	44.0	111
-15.5	4	-5.5	22	4.5	40	14.5	58	24.5	76	34.5	94	44.5	112
-15.0	5	-5.0	23	5.0	41	15.0	59	25.0	77	35.0	95	45.0	113
-14.5	6	-4.5	24	5.5	42	15.5	60	25.5	78	35.5	96	45.5	114
-14.0	7	-4.0	25	6.0	43	16.0	61	26.0	79	36.0	97	46.0	115
-13.5	8	-3.5	26	6.5	44	16.5	62	26.5	80	36.5	98	46.5	116
-13.0	9	-3.0	27	7.0	45	17.0	63	27.0	81	37.0	99	47.0	117
-12.5	10	-2.5	28	7.5	46	17.5	64	27.5	82	37.5	100	47.5	118
-12.0 *	10	-2.0 *	28	8.0 *	46	18.0 *	64	28.0 *	82	38.0*	100	48.0 *	118
-11.5	11	-1.5	29	8.5	47	18.5	65	28.5	83	38.5	101	48.5	119
-11.0	12	-1.0	30	9.0	48	19.0	66	29.0	84	39.0	102	49.0	120
-10.5	13	-0.5	31	9.5	49	19.5	67	29.5	85	39.5	103	49.5	121

For temperature conversions beyond the limits of the table, use the equations °C = 0.5556 (°F - 32) and °F = 1.8(°C) + 32. The formulae say, in effect, that from the freezing point of water (0°C, 32°F) the temperature in °C rises (or falls) 5° for every rise (or fall) of 9°F.

Location and extent of the area

Grand Teton National Park is in Teton County in the northwestern part of Wyoming. The park is about 38 miles (61 kilometers) long (north-south) at its longest part and about 22 miles (35 kilometers) wide (east-west) at its widest part. The park contains about 500 square miles (1,300 square kilometers).

The north and east boundaries of the park are generally the edges of upland areas that extend westward from the Absaroka, Washakie, and Wind River Ranges. The west boundary is the crest of the Teton Range. The south boundary is the Gros Ventre and Snake Rivers and a line across Jackson Hole and part of the Teton Range (fig. 1).

Topography and drainage

Most of Grand Teton National Park is in Jackson Hole and the Teton Range. Jackson Hole is part of the Snake River valley. It is surrounded by mountains or upland areas, extending from Jackson Lake to about 6 miles (10 kilometers) south of Jackson. The valley is bordered on the west by the Teton Range, which rises abruptly above the floor of Jackson Hole to form the famous scenic mountain views in the park, and on the east by less prominent uplands. Jackson Hole slopes from an altitude of about 7,000 feet (2,100 meters) near Jackson Lake to about 6,000 feet (1,800 meters) at the south end of the valley. The regularity of the valley floor is broken by stream channels, terraces, ridges, and depressions.

The lowest point in Grand Teton National Park is at about altitude 6,320 feet (1,930 meters) in Jackson Hole near the Snake River on the south boundary; the highest point is Grand Teton at altitude 13,770 feet (4,197 meters) in the Teton Range.

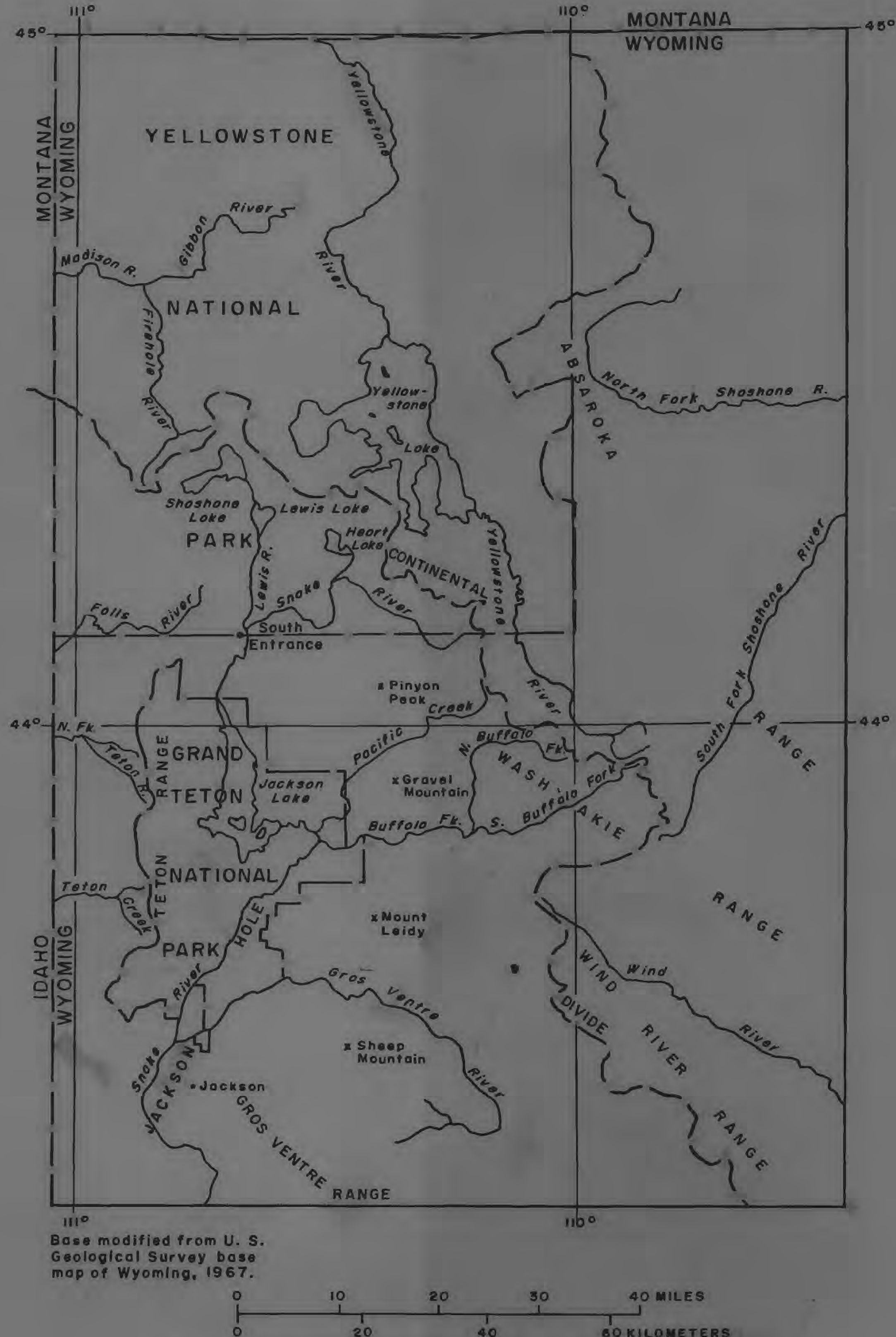

Figure 1.--Location of geographic features in the northwestern part of Wyoming.

Grand Teton National Park lies a few miles west of the Continental Divide in the Snake River drainage. The Snake River heads northeast of Grand Teton National Park near the Continental Divide and near the south boundary of Yellowstone National Park. The Snake River enters Grand Teton National Park near the upper end of Jackson Lake. The river flows eastward from Jackson Lake, then turns to flow generally southwestward through Jackson Hole. Many perennial streams flow from nearby mountains across Jackson Hole to the Snake River. Principal tributaries of the Snake River in Grand Teton National Park are Arizona, Pilgrim, Pacific, and Spread Creeks, Buffalo Fork, and the Gros Ventre River from the east and Cottonwood Creek from the west (fig. 2).

Climate

Annual precipitation in Grand Teton National Park ranges from about 16 inches (41 centimeters) in Jackson Hole near the south boundary to as much as 70 inches (178 centimeters) in the southern part of the Teton Range (Thomas and others, 1963, pl. 2). Records of the U.S. National Oceanic and Atmospheric Administration show the average annual precipitation through 1971 was 14.83 inches (37.67 centimeters) at Jackson and 21.30 inches (54.10 centimeters) near Moran. These are the only weather stations in and near the park with records long enough to have established averages. Other weather stations are operated at Moose and at the South Entrance of Yellowstone National Park. The weather station near Moran is located at Jackson Lake Dam.

Figure 2.--Location of selected wells and surface-water data collection sites in and near Grand Teton National Park.

Although mountains and valleys locally influence precipitation amounts, precipitation generally increases with altitude. Precipitation occurs as snow during the winter, as rain and snow during the spring and fall, and generally as rain during the summer. Brief snow storms, however, occasionally occur in summer at higher altitudes. Snow begins to accumulate in October in the higher parts of the park and in December in the lower parts. The snowpack commonly reaches depths of 5 feet (1.5 meters) by spring. Precipitation is greatest in winter and spring. The average monthly precipitation through 1971 at Jackson and near Moran are shown in the following table:

	Average precipitation (inches)	
	Jackson	near Moran
January	1.43	2.35
February	1.32	2.28
March	1.20	2.08
April	1.20	1.73
May	1.50	1.85
June	1.51	1.77
July	.75	.97
August	1.12	1.30
September	1.04	1.28
October	1.11	1.45
November	1.11	1.88
December	1.54	2.36
Total	14.83	21.30

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The average annual air temperature through 1971 was 34.7°F (1.5°C) at the weather station near Moran and 38.0°F (3.3°C) at Jackson according to records of the National Oceanic and Atmospheric Administration. The average monthly temperatures near Moran ranged from 10.6°F (-11.9°C) for January to 57.9°F (14.4°C) for July. During most years, maximum temperatures are near 90°F (32°C) and minimum temperatures are less than -30°F (-34°C).

Previous investigations

Geologic investigations in Grand Teton National Park began in the 19th Century when observations were made of the glacial features in Jackson Hole. Bradley (1873) recognized that the lakes east of the Teton Range were formed by the deposition of morainal material. Blackwelder (1915) studied the glacial features in northwestern Wyoming and recognized three ice advances. Fryxell (1930) made detailed studies of glacial features in Grand Teton National Park. J. D. Love of the U.S. Geological Survey has made many contributions to the knowledge of the geology of the park and nearby areas. Wyoming Geological Association (1956) contains articles by individual authors on the physiography, stratigraphy, and structure of the park and nearby areas, including a geologic map of Teton County compiled by J. D. Love. Behrendt and others (1968) made a geophysical study in the park and vicinity. Love and Reed (1968) summarize the geology of Grand Teton National Park.

McGreevy and Gordon (1964) made a study of ground-water conditions in the north half of Grand Teton National Park. Streamflow data have been collected at gaging stations and at miscellaneous sites in the park for many years and are published in the annual reports of water-resources data by the Geological Survey.

Methods of investigation

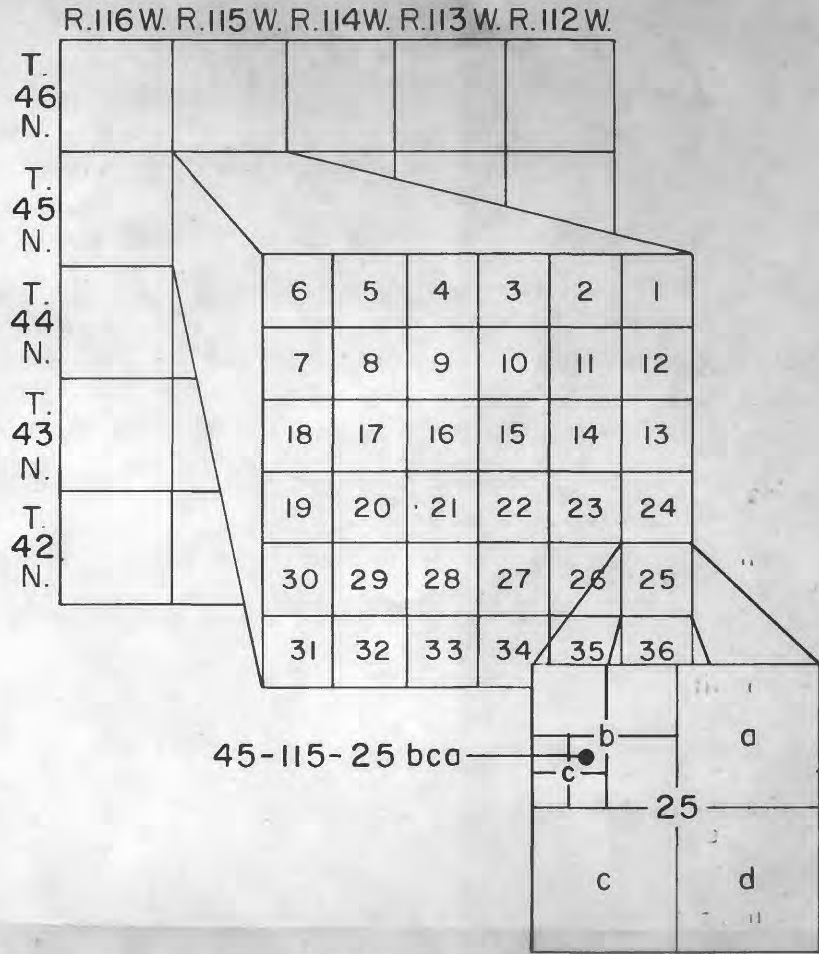
Reconnaissance of surface geology, topography, and hydrologic features were made in the park. Locations were selected for test holes to study subsurface features. Most wells in and a few wells adjacent to the park were inventoried to collect ground-water data. Most information was collected in Jackson Hole and nearby stream valleys where the need for hydrologic data is greatest.

Test holes were drilled with a power-driven auger to study the occurrence of ground water and the nature of the water-bearing materials in areas where no wells had been drilled. Drilling of test holes in the park with a power-driven auger was limited, however, because the auger bit could not penetrate beds of gravel and cobbles.

Water levels were measured in observation wells at intermittent intervals to determine the range of fluctuations of ground-water levels. Discharge measurements were made at some sites on streams and springs in and near the park to determine magnitude and range of flow. Water samples were collected from selected wells, streams, and springs and were analyzed for chemical character.

Well and station numbers

Wells are numbered in this report according to their location within the Federal system of land subdivision. Part of the area of this report has not been surveyed for inclusion in the system of land subdivision. Wells in the unsurveyed part are numbered as if the area had been surveyed. Each well number shows the location by township, range, section, and location within the section. The first numeral of the number denotes the township; the second numeral, the range; and the third numeral, the section in which the well is located. The lowercase letters after the section number indicate the location within the section. The first letter denotes the quarter section; the second letter, the quarter-quarter section; and the third letter, the quarter-quarter-quarter section (10-acre tract) (4-hectare tract). The subdivisions of a section are lettered a, b, c, and d in a counterclockwise direction, beginning with "a" in the northeast quarter. If more than one well is listed in the same 10-acre (4-hectare) tract, consecutive numerals starting with 1 are added to the well number. The location of well 45-115-25bca in the NE$\frac{1}{4}$SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 25, T. 45 N., R. 115 W. is shown in the following diagram:



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As a means of identification, an eight-digit station number (such as 13012800) is assigned to each site where surface-water data are collected. Springs have been assigned surface-water station numbers in this report. The station numbers increase in downstream order. Stations on tributaries are assigned numbers between upstream and downstream stations on main stems. Gaps are left in the numbering system to allow for new stations that may be established. The first two digits of the station number denote the drainage basin. Station numbers beginning with "13" are in Snake River drainage.

Acknowledgments

Acknowledgment is given personnel of the National Park Service at Grand Teton National Park for their excellent cooperation during this investigation. Also, acknowledgment is given owners of wells on private and leased land for supplying information and for allowing access to their property.

Geology

The Teton Range is an uplifted block bounded on the east by the Teton fault and bounded on the west by an obscure fault along the Wyoming-Idaho State line. Jackson Hole is a folded and faulted downwarp east of the Teton fault. The uplands east of Jackson Hole are anticlinal uplifts of the Gros Ventre and Washakie Ranges (Love, in Behrendt and others, 1968, p. E9).

Rocks ranging in age from Precambrian to Quaternary crop out in and near Grand Teton National Park. The Teton Range consists of a core of igneous and metamorphic Precambrian rocks overlain in most of the range by westward dipping sedimentary Paleozoic rocks. Jackson Hole contains mostly Quaternary glacial, lacustrine, and alluvial deposits underlain by Tertiary and older rocks. The uplands east of Jackson Hole are underlain by Precambrian, Paleozoic, Mesozoic, and Cenozoic rocks.

Faults have greatly altered the continuity of rock units in and near the park. Vertical displacement along the Teton fault is as much as 7 kilometers (about 23,000 feet) (Love, in Behrendt and others, 1968, p. E11). Other faults occur in the uplands east and south of Jackson Hole. Faults are obscured by glacial and alluvial deposits in Jackson Hole.

Jackson Hole has been glaciated at least three times. The oldest glaciation was the most widespread, and the ice in many places was 2,000 feet (600 meters) thick (Love and Reed, 1968, p. 106). Later glaciations eroded or covered parts of the deposits of earlier ones.

The geologic units used in this report are those most convenient for discussing the occurrence of ground water in the park. Other studies may divide the geology into different units. Most data from wells are limited to Tertiary and Quaternary rocks. Records of selected wells in and near the park are shown in table 1. Logs of wells are shown in table 2. Because ground-water data are not available from most Precambrian, Paleozoic, and Mesozoic rock units, the interpretations of the water-bearing properties are based on the lithology of the rocks and the water-bearing properties of similar rocks in other areas. A generalized section of rocks exposed in and near the park is given in table 3. Thickness, lithology, and water-bearing properties in table 3 are from reported values and the author's interpretations. A geologic map of the park and nearby areas is shown in figure 3.

Precambrian rocks

Precambrian rocks are exposed in the Teton, Washakie, and Gros Ventre Ranges. The Precambrian rocks are predominantly gneiss, schist, granitic gneiss, and granite. Dikes of diabase and basalt occur in the Precambrian rocks in the Teton Range.

Figure 3.--Geologic map of Grand Teton National Park and vicinity.

The Precambrian rocks are hard and dense and have little, if any, permeability except in fractures. In the Teton Range, the topographically high areas of Precambrian rocks are drained of ground water. However, springs and seeps occur in valleys and along canyon walls where fractures are exposed. Developed springs yielding an estimated 200 gpm (gallons per minute) or 757 l/m (liters per minute) from Precambrian rocks provide the water supply for Teton Village.

Paleozoic rocks

Paleozoic rocks in and near Grand Teton National Park are marine limestone, dolomite, sandstone, siltstone, and shale. Rocks of all systems in the Paleozoic, except the Silurian, occur in or near the park. Paleozoic rocks crop out in the Teton, Gros Ventre, and Washakie Ranges, and in Blacktail Butte.

In the topographically high areas, the Paleozoic rocks may be drained of ground water. Where the rocks are saturated, ground water occurs in interstices in sandstone, siltstone, and shale, and in fractures and solution channels in limestone and dolomite. Springs issue from Paleozoic rocks in and near Grand Teton National Park. Paleozoic rocks that would yield the most water to wells are the Madison Limestone of Mississippian age, the Gallatin Limestone and the Flathead Sandstone of Cambrian age, the Bighorn Dolomite of Ordovician age, and the Tensleep Sandstone of Pennsylvanian age.

Factors controlling the occurrence of ground water in limestone and in dolomite probably are similar. Because limestone and, to a lesser degree, dolomite are soluble in water, solution openings have developed along bedding planes, joints, faults, and in brecciated zones. The degree of solution development depends on the present and former topographic position of the rocks. As water moves through the rocks, solution openings are enlarged and connected to other openings to form channels and conduits through which the movement of water is relatively rapid from recharge to discharge areas. Thick deposits of limestone, such as the Madison Limestone, may have extensive development of solution channels; however, thin beds of limestone in other Paleozoic units may also have solution channels. Faults form avenues for the deep percolation of water as well as avenues for water to rise to the surface from deep-seated rocks. Warm springs issuing near fault zones indicate connection between near-surface and deep-seated rocks.

The Madison Limestone is an important aquifer in places in Wyoming, and large yielding wells have been drilled that tap solution channels in the Madison. In and near Grand Teton National Park, the Madison has been faulted, tilted, and overturned in places, and solution-channel development may not be widespread.

The Madison Limestone is the source of water discharging from many springs in and near the park. The Madison is the source of water discharging at warm springs near Teton Valley Ranch. The Madison probably is the source of water discharging at Kelly Warm Spring and may be the source of water discharging at the warm spring at Warm Spring Ranch. The Flathead and Tensleep Sandstones probably are the sources of water discharging from several springs in the Teton and Gros Ventre Ranges and the upland area east of Grand Teton National Park.

Love and Reed (1968, inside fold) show Paleozoic rocks in a geologic section from more than 5,000 to 15,000 feet (1,500 to 4,500 meters) below land surface in Jackson Hole. Paleozoic rocks probably contain water at shallower depth on the west slope of the Teton Range, in the northwestern part of Grand Teton National Park, in the Gros Ventre Range, and in the uplands east of the park.

Mesozoic rocks

Mesozoic rocks in and near Grand Teton National Park are marine, transitional, and nonmarine sedimentary rocks. Mesozoic rocks crop out in upland areas east and northeast of Jackson Hole and at the north end of the Teton Range. Mesozoic rocks underlie younger rocks in Jackson Hole.

Triassic and Jurassic rocks are mostly nonmarine sandstones and siltstones, but they do contain thin beds of marine limestone and shale. Cretaceous rocks are mostly marine shale and sandstone units overlain by nonmarine sandstone, siltstone, and conglomerate units. Beds of coal are present in some of the Cretaceous rocks.

Mesozoic rocks that would yield the most water to wells are sandstone beds in the Nugget Sandstone; sandstone and limestone beds in the Sundance Formation; sandstone beds in the Thermopolis Shale, Frontier Formation, Bacon Ridge Sandstone, Mesaverde Formation, and Meeteetse Formation; and sandstone and conglomerate beds in the Harebell Formation.

Cenozoic rocks

Tertiary rocks in and near Grand Teton National Park are nonmarine sedimentary rocks deposited mainly in basins and shallow lakes and volcanic rocks. Part of the sedimentary rocks are composed of volcanic-rock fragments. Most of the Quaternary rocks are glacial, alluvial, and lacustrine deposits; however, some of the volcanic rocks in and near the park are of Quaternary age.

Tertiary rocks

Tertiary rocks crop out in the upland areas east and north of Jackson Hole. Love and Reed (1968, p. 88) state that maximum thicknesses of Tertiary formations in these areas total over 30,000 feet (9,000 meters) and that no other region in the United States has a thicker or more complete section of nonmarine Tertiary sedimentary rocks. The thickest accumulation of Tertiary rocks probably is along the Continental Divide east of Grand Teton National Park. Tertiary rocks are thinner in or near the park.

The Pinyon Conglomerate of uppermost Cretaceous and Paleocene age crops out in the upland area near the eastern boundary of the park and at the north end of the Teton Range. The Pinyon is exposed in topographically high areas near Pinyon Peak and Mount Leidy where it is mostly drained of ground water. However, in stream valleys, such as the upper reaches of Pilgrim and Pacific Creeks, the Pinyon may contain ground water.

The Colter Formation of Miocene age crops out along the eastern boundary of the park near Pilgrim Creek and Two Ocean Lake and between Spread and Ditch Creeks. Claystone and clayey sandstone of the Colter were penetrated in the bottom 27 feet (8 meters) of test well 46-114-29adc in the Pilgrim Creek valley, but this part of the well did not yield measurable amounts of water (McGreevy and Gordon, 1964, fig. 5). Some of the beds of conglomerate and sandstone may yield measurable amounts of ground water.

The Teewinot Formation of Pliocene age crops out along the eastern boundary of the park and in Blacktail Butte. The Teewinot was deposited in a large freshwater lake (Love and Reed, 1968, p. 92). Most outcrops of limestone and tuff of the Teewinot are conspicuously white.

Well 43-115-26cad yields water from about 80 feet (24 meters) of mostly limestone, presumably of the Teewinot Formation. Well 43-115-26cad yielded 120 gpm (454 l/m) during a test shortly after the well was completed; the drawdown is not known. Well 42-115-11acc yields water from 76 feet (23 meters) of mostly sandstone of the Teewinot. During a one-hour test, well 42-115-11acc yielded 15 gpm (57 l/m) with a drawdown of 10 feet (3 meters). Beds of limestone probably would yield the largest quantities of ground water from the Teewinot.

Extensive deposits of the Absaroka Volcanic Supergroup of Eocene age occur in the Absaroka Range northeast of Grand Teton National Park (Smedes and Prostka, 1972, p. C1-C2). These rocks crop out in small areas near the park, where they are mostly drained of ground water. They probably contributed much material to younger Tertiary sedimentary rocks that crop out in and near the park.

Tertiary or Quaternary rocks

The Bivouac Formation of Pleistocene or Pliocene age crops out at Signal Mountain. Conglomerate in the Bivouac is tapped by well 45-114-19baa at Jackson Lake Dam; yield of the well is not known.

Quaternary rocks

Yellowstone Group

Rhyolitic lava flows and tuffs extend from the plateau area of Yellowstone National Park to the north, northeast, and west flanks of the Teton Range and have been included in the Yellowstone Group (Christiansen and Blank, 1972, p. B3). Earlier geologic maps show the rhyolitic rocks as Tertiary in age, but stratigraphic work and potassium-argon dating indicate these rocks are Quaternary in age (Christiansen and Blank, 1972, p. B2).

Some of the rhyolite is hard and dense, and some is soft and weathered. Hard rhyolite is commonly jointed and fractured. Ground water occurs in porous or fractured zones in rhyolite except in those areas that are topographically high and drained of ground water.

Glacial deposits

Most of Grand Teton National Park has been covered by glaciers that originated in mountainous areas northeast, east, and west of Jackson Hole. The earlier ice masses flowed south across nearby uplands and through Jackson Hole, covering all but the highest peaks. At least three stages of glaciation have been recognized in the park, and each successive stage was less extensive than earlier ones. During the latest glacial stage, ice flowed down canyons in the Teton Range onto the floor of Jackson Hole and built the moraines that dam Jackson, Leigh, Jenny, Bradley, Taggart, and Phelps Lakes.

The glacial deposits in and near Grand Teton National Park generally are either morainal or outwash deposits. Morainal deposits are commonly ridges or hills that were formed by material deposited directly by glaciers as the ice melted. Outwash deposits are commonly plains formed by material carried by streams that flowed from melting glaciers. Outwash deposits are more permeable and yield water more easily to wells than morainal deposits.

Morainal deposits contain more clay and silt than outwash deposits, resulting in more soil moisture and nutrients in the moraines than in the outwash plains. Consequently, moraines are heavily forested, and outwash plains are covered only by sagebrush in Grand Teton National Park.

Wells have been drilled in Jackson Hole that tap glacial deposits. Most of the wells in Jackson Hole were drilled only deep enough to obtain water for domestic use, usually about 10 gpm (38 l/m). A few wells were drilled to obtain water for public supply and most were tested to determine potential yields. Tests suggest that wells yielding as much as 1,000 gpm (3,800 l/m) each could be drilled in outwash deposits in Jackson Hole.

Because of the abundance of clay and silt, most wells in morainal deposits yield only a few gallons per minute. Well 45-114-19bdc2, drilled to a depth of 145 feet (44 meters) in morainal deposits near Jackson Lake, yielded only 4 gpm (15 l/m) with a drawdown of 120 feet (37 meters) during a 41 hour test. However, well 45-115-25bca, drilled to a depth of 205 feet (62 meters), taps sandy zones in presumably morainal deposits near Jackson Lake and yielded 115 gpm (435 l/m) with a drawdown of 11 feet (3.3 meters) during a 24-hour test (McGreevy and Gordon, 1964, p. 24).

Lacustrine deposits

Lacustrine deposits in and near the park occur where lakes existed before, during, or after glaciation. Love and Reed (1968, p. 104) describe two sets of lake deposits that occurred during downdroppings of Jackson Hole in Quaternary time prior to glaciation. Most of these lake deposits may have been removed by erosion, particularly during the early glaciation. McGreevy and Gordon (1964, p. 14-15) describe lacustrine deposits overlying bedrock in test holes and wells near Moran. Logs of some wells in Jackson Hole report fine-grained deposits that are probably of lacustrine origin underlying sand and gravel. Lakes probably existed during periods of glaciation where ice temporarily blocked streams. Remnants of ice covered by debris and left by retreating glaciers melted to form kettles that contained ponds and that are at least partly filled by lake sediments. Lacustrine deposits crop out in and near the park but have not been delineated on geologic maps and are not shown in figure 3.

Landslide deposits

Landslides have occurred in some of the valleys in and near Grand Teton National Park. The most extensive landslide deposits are in upland areas east and northeast of Jackson Hole. The topographically higher parts of landslide deposits are drained of ground water, but the lower parts may be saturated.

Alluvium

Alluvium occurs as flood-plain deposits and alluvial fans in valleys in Grand Teton National Park. Alluvium commonly consists of well sorted beds of silt, sand, and gravel. Much of the alluvium in Jackson Hole is glacial-outwash material that has been reworked by modern streams. The alluvium closely resembles the glacial-outwash deposits, and alluvium and glacial-outwash deposits are combined into one unit on the geologic map in this report (fig. 3). Alluvial fans have formed along the margins of Jackson Hole where streams enter the valley from surrounding uplands.

Relatively large quantities of ground water occur in alluvium in the park. Sand and gravel of alluvial or glacial-outwash origin yield as much as 800 gpm (3,000 l/m) per well. Several wells that penetrate at least 100 feet (30 meters) of saturated sand and gravel each yield a few hundred gallons per minute of water. Where saturated thicknesses are less, yields of wells are less. The largest yielding wells in the park tap alluvium or glacial-outwash deposits along the Gros Ventre River and Pilgrim Creek. Wells yielding as much as 1,000 gpm (3,800 l/m) each could be drilled in alluvium near many streams in Jackson Hole.

Hydrology

Water is used in the park for irrigation and for public, domestic, and commercial supplies. Most of the irrigated lands in the park lie east of the Snake River between Buffalo Fork and the Gros Ventre River. Water is diverted through numerous ditches from Spread and Ditch Creeks and the Gros Ventre River to hay and pasture lands. Water is pumped for irrigation from one well in the park (table 1).

The National Park Service pipes water from springs to Colter Bay Village and Jackson Lake Lodge for public use. Water is pumped from the outlet of String Lake to Jenny Lake Lodge and from Jenny Lake to the Jenny Lake campground. Water is diverted from Taggart Creek below Taggart Lake to the Beaver Creek residential area and to the park headquarters and residential area at Moose.

At the time of this study (1967-73), water was pumped from wells for public-water supplies at Gros Ventre and Lizard Creek campgrounds, Signal Mountain Lodge and nearby campground, and Jackson Hole Airport. Ground water was pumped to supplement spring flow at Colter Bay Village and Jackson Lake Lodge. Guest ranches and private residences use water diverted from springs and small streams and water pumped from wells for commercial and domestic supplies.

Most of the water used in the park is not measured. Water flows in many of the diversion ditches most of the year and flows in some throughout the year. Much of the diverted surface water probably either seeps into the ground or returns directly to streams. Consequently, data are not available on the amount of surface water used in the park. The amount of ground-water pumpage was not determined, but it is small compared to other ground-water discharge such as evapotranspiration and discharge to streams.

Surface water

Many streams originate in the uplands surrounding Jackson Hole and flow to the Snake River. The streams contain runoff from melting snow and rainfall. The park has several large natural lakes and many small ones. One large natural lake, Jackson Lake, has been enlarged by a dam. Numerous springs occur in the park where ground water discharges at the land surface by gravity flow.

Streamflow data have been collected for many years at gaging stations in and near the park. Nearly continuous record of streamflow is obtained during the time a gaging station is in operation. Streamflow records are available from gaging stations presently being operated and from stations that were operated temporarily and have been discontinued. In addition, streamflow has been measured at miscellaneous sites in and near the park.

Streamflow is greatest during May-July as a result of melting snow. Streamflow declines during the summer and fall and is lowest in the winter. The streamflow varies from year to year owing to weather conditions affecting snowmelt and local precipitation, but the pattern of high flows in late spring and early summer and low flows in fall and winter occurs each year. Yearly and monthly mean streamflow at three gaging stations in the park for January 1968-September 1972 are shown in figure 4. No other gaging stations were operated in the park during that period. Flow of the Snake River near Moran, station 13011000, represents releases of water from Jackson Lake, and data from this station represent regulated flow in the stream. Flows of Pacific Creek at Moran, station 13011500, and Buffalo Fork above Lava Creek near Moran, station 13011900, are unregulated. Other data, including daily flow at gaging stations, are listed in State reports and water-supply papers on surface-water records by the U.S. Geological Survey. Locations of gaging stations are shown in figure 2.

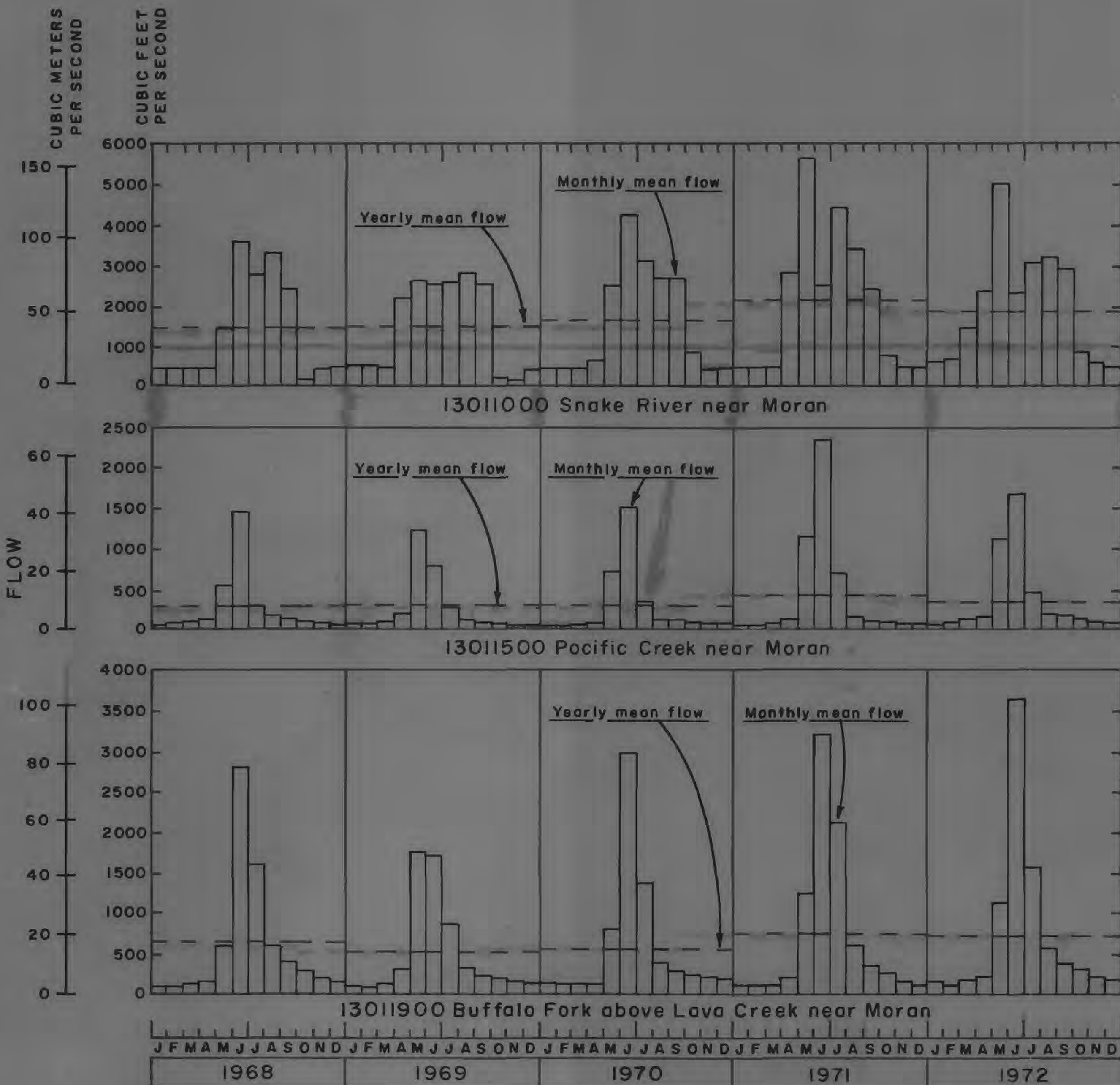

Figure 4.--Yearly and monthly mean flow at gaging stations in Grand Teton National Park.

The distribution of streamflow at a gaging station can be shown by a flow-duration curve. The flow-duration curve shows the percentage of time a specified discharge was equaled or exceeded during the period of record. The longer the period of record the more accurately the curve shows the past distribution of streamflow. Flow-duration curves for gaging station 13011500, Pacific Creek at Moran, for water years 1945-68, and station 13012000, Buffalo Fork near Moran, for water years 1945-60, are shown in figure 5. Water year is the 12-month period ending September 30 of the specified year. These are the only stations that were operated for periods long enough to be useful for indicating past distribution of unregulated streamflow in the park. The gaging station on Buffalo Fork was located 0.5 mile (0.8 kilometer) from its mouth, station 13012000, until September 1960 and about 4 miles (6 kilometers) upstream at a site above Lava Creek, station 13011900, from September 1965 to the present (1973).

Streamflow measurements were made at miscellaneous sites in the park. Measurements made during this study (1967-73) are listed in table 4, and their locations are shown in figure 2. Only one measurement was made at several of these sites. Measurements were made to determine the variation in flow of selected ungaged streams and to determine gains or losses in flow in selected channel reaches.

Measurements were made of the flow of several streams June 4-9, 1971 during a period of relatively high streamflow and later in 1971 when streamflow was relatively low. These streamflow measurements and comparable data from gaging stations give an indication of the range in streamflow during 1971 and are shown in the following table:

Station no.	Stream	Streamflow, in cubic feet per second, 1971			
		June 4-9	Aug. 13-18	Sept. 19-21	Oct. 13
13010360	Lizard Creek	37.5	0.61	-----	----
13010380	Arizona Creek	319	7.09	-----	----
13010440	Pilgrim Creek	504	24.8	15.9	----
13011500	Pacific Creek	1/ 2,260	1/ 126	1/ 78	1/ 78
13011900	Buffalo Fork	1/ 2,140	1/ 588	1/ 314	1/ 280
13012500	Spread Creek	469	11.4	-----	----
13012800	Cottonwood Creek	441	271	72.0	----
13013530	Ditch Creek	221	8.09	-----	----
13014400	Gros Ventre River	2,380	------	-----	266
13016250	Lake Creek	234	------	12.5	----
13016320	Granite Creek	207	------	15.5	----

1/ Average of daily discharge for dates shown. Determined from stage-discharge relationship at gaging station.

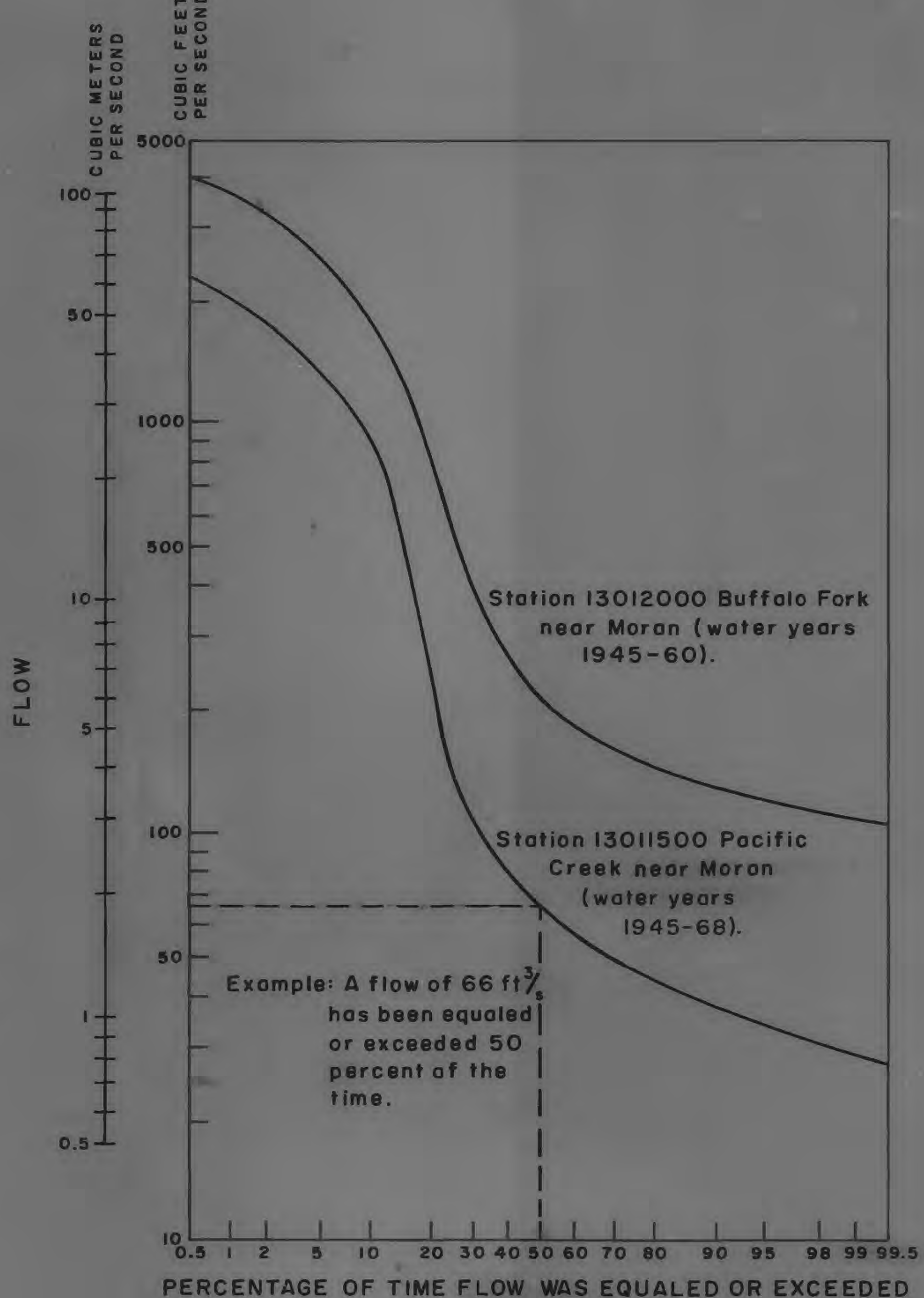

Figure 5.--Flow-duration curves at gaging stations in Grand Teton National Park.

Streamflow at the time of measurements in June was below the maximum for the year. Maximum daily discharge for 1971 was 3,390 ft^3/s (96 m^3/s) for Pacific Creek, station 13011500, and 4,810 ft^3/s (136 m^3/s) for Buffalo Fork, station 13011900. Both maximum discharges occurred June 23. Minimum daily discharges during the following winter were 40 ft^3/s (1.1 m^3/s) for Pacific Creek and 100 ft^3/s (2.8 m^3/s) for Buffalo Fork. Minimum discharges for both stations occurred during several days in January and February 1972.

Streamflow measurements were made at two or more locations on Pilgrim and Cottonwood Creeks to determine losses in flow of selected reaches of the streams. Measurements in each set were made the same day during periods of uniform flow, generally during low flow. Measurements of Pilgrim and Cottonwood Creeks and computed losses are shown in the following tables. Losses were determined by subtracting flow at downstream station from flow at upstream station after accounting for tributary inflow (if any) between the stations. Locations of the sites are shown in figure 2.

Selected streamflow measurements of Pilgrim Creek

Station no.	Stream	Streamflow, in cubic feet per second									
		Sept.25, 1969		Aug. 17, 1971		Sept.20, 1971		July 26, 1972		Sept.21, 1972	
		Flow	Loss	Flow	Loss	Flow	Loss	Flow	Loss	Flow	Loss
13010390	Pilgrim Creek above East Fork									9.7	
13010420	East Fork Pilgrim Creek									11.9	
	TOTAL									21.6	7.5
13010440	Pilgrim Creek at abandoned ford	17.2	2.6	24.8	4.3	15.9	2.3	48.1	8.8	14.1	4.0
13010445	Pilgrim Creek below abandoned ford	14.6		20.5		13.6	2.9	39.3		10.1	
13010455	Pilgrim Creek below new highway bridge					10.7	4.8				
13010465	Pilgrim Creek below old highway bridge					5.9					

Selected streamflow measurements of Cottonwood Creek

Station no.	Stream	Streamflow, in cubic feet per second																	
		Aug. 15, 1968		May 16, 1969		July 23, 1969		Sept.25, 1969		Nov. 11, 1969		Aug. 16, 1971		Sept.21, 1971		Sept.22, 1972		Sept.27, 1972	
		Flow	Loss	Flow	Loss	Flow	Loss	Flow	Loss	Flow	Loss	Flow	Loss	Flow	Loss	Flow	Loss	Flow	Loss
13012800	Cottonwood Creek at outlet of Jenny Lake	138		244		240		37.5		18.7		271		72.0				71.4	
			25		30		11		7.4		5.5		17		13.7				5.9
13012850	Cottonwood Creek above Glacier Gulch	113		214		229		30.1		13.2		254		58.3				65.5	
	Tributary inflow													3.5					
															10.9				
13012860	Cottonwood Creek below Glacier Gulch													50.9					
	Tributary inflow													2.0					
															24.6				
13012880	Cottonwood Creek above Taggart Creek													28.3		49.6			
	Tributary inflow															11.6			
																	0.6		
13013000	Cottonwood Creek near Moose															60.6			

The measurements shown in the preceding tables are considered accurate within 5 to 8 percent. Some of the variation in losses at similar magnitudes of streamflow may be due to the accuracy of the measurements. However, measurements indicate that the streams consistently lose in flow, and the losses generally increase as streamflow increases.

The set of measurements made on Pilgrim Creek September 20, 1971 indicates that the stream lost 10.0 ft^3/s (0.28 m^3/s) between station 13010440 and station 13010465, a distance of 3.1 miles (5.0 kilometers), for an average loss of 3.2 ft^3/s per mile (0.06 m^3/s per kilometer). Measurements made September 21, 1972 indicate that 11.5 ft^3/s (0.33 m^3/s) was lost between the combined flow at station 13010390 on the main stem above East Fork and station 13010420 on East Fork and the flow at station 13010445 on the main stem below East Fork, a distance of 1.5 miles (2.4 kilometers), for an average loss of 7.7 ft^3/s per mile (0.14 m^3/s per kilometer). Part of this loss occurred from the main stem and part from East Fork. These measurements also indicate that Pilgrim Creek lost 63 percent of its flow in the 3.1-mile (5.0-kilometer) reach on September 20, 1971 and that Pilgrim Creek and East Fork lost 53 percent of their combined flow in the 1.5-mile (2.4-kilometer) reach on September 21, 1972.

The measurements made on Cottonwood Creek September 21, 1971 indicate that the stream lost 49.2 ft^3/s (1.39 m^3/s) between stations 13012800 and 13012880, a distance of 4.2 miles (6.8 kilometers), for an average loss of 11.7 ft^3/s per mile (0.20 m^3/s per kilometer). Measurements made September 22, 1972 suggest that little water was lost from the stream below station 13012880. Cottonwood Creek lost 68 percent of its flow in the 4.2-mile (6.8-kilometer) reach below station 13012800 on September 21, 1971. Cottonwood Creek was observed to have no flow near the mouth of Beaver Creek (about 0.7 mile below station 13012880) (1.1 kilometers) on October 8, 1968. National Park Service personnel reportedly have observed no flow in Cottonwood Creek at station 13012880 during the late fall in some years.

Streamflow data--including measurements, determinations from stage-discharge relationships at gaging stations, and estimates--from the Snake River and its tributaries were used to determine gain in flow of the Snake River between Jackson Lake and Moose. On October 14, 1971, the flow of the Snake River at Moose, station 13013650, was measured as 1,570 ft^3/s (44.4 m^3/s), and near Moran, station 13011000, was determined from stage-discharge relationships as 680 ft^3/s (19.2 m^3/s). Tributary inflow in the reach was about 380 ft^3/s (10.8 m^3/s), as determined by stage-discharge relationships at gaging stations on Pacific Creek and Buffalo Fork and estimates of flow of Spread, Ditch, and Cottonwood Creeks. Therefore, on October 14, 1971 the gain in flow of the Snake River, other than from tributary inflow, was about 510 ft^3/s (14.4 m^3/s) in the reach between Jackson Lake and Moose.

On October 16, 1972, the flow of the Snake River at Moose, station 13013650, and above Cottonwood Creek, station 13012760, were measured as 1,720 and 1,330 ft^3/s (48.7 and 37.6 m^3/s), respectively, and the Snake River near Moran, station 13011000, was determined from stage-discharge relationships as 690 ft^3/s (19.5 m^3/s). Tributary inflow in the reach was about 585 ft^3/s (16.6 m^3/s); tributaries with flows of 5 ft^3/s (0.14 m^3/s) or more were measured within a few days of October 16 or flows were determined from stage-discharge relationships, and the smaller ones were estimated. Gain in flow of the Snake River, other than tributary inflow, on October 16, 1972 was 445 ft^3/s (12.6 m^3/s) in the reach between Jackson Lake and Moose. Of this amount, the gain in flow between the Snake River near Moran, station 13011000, and above Cottonwood Creek, station 13012760, was about 100 ft^3/s (2.8 m^3/s), and that between the Snake River above Cottonwood Creek, station 13012760, and at Moose, station 13013650, was about 345 ft^3/s (9.8 m^3/s). The upper reach (gain in flow of 100 ft^3/s) (2.8 m^3/s) is 17.5 miles (28.2 kilometers) long, for a gain in flow of 5.7 ft^3/s per mile (0.10 m^3/s per kilometer); the lower reach (gain in flow of 345 ft^3/s) (9.8 m^3/s) is 7.0 miles (11.3 kilometers) long, for a gain in flow of 49.3 ft^3/s per mile (0.87 m^3/s per kilometer).

The flow of Cottonwood Creek at the outlet of Jenny Lake, station 13012800, and Ditch Creek below South Fork, station 13013530, were measured a sufficient number of times during 1968-72 to establish relationships between the flow and the stage of each stream. Additional observations were made of the stage of each stream during 1971-72. The yearly high-water marks for 1971 and 1972 were observed and converted to stage data, and the dates of the peak discharge for the year were estimated. Discharge data were determined from the stage data. Periodic determinations of discharge of Cottonwood and Ditch Creeks at the above-mentioned stations during 1971-72 are shown in the following table:

Station 13012800 Cottonwood Creek			Station 13013530 Ditch Creek		
Date	Time (24 hour)	Discharge (cubic feet per second)	Date	Time (24 hour)	Discharge (cubic feet per second)
1971			1971		
June 9	0930	1/ 441	June 7	1000	1/ 221
24	1350	1,200	20	----	2/ 400
25	----	2/ 1,300	24	0945	200
30	1700	680	30	1430	130
July 7	1640	650	July 6	0900	90
Aug. 16	0930	1/ 271	Aug. 13	1415	1/ 8.09
Sept. 21	1000	1/ 72.0	Sept. 23	1010	4
Oct. 18	1435	50	Oct. 18	1010	5
1972			1972		
May 12	1415	80			
June 5	----	2/ 1,100	June 5	----	2/ 600
12	1305	950	9	1540	250
July 7	1145	500	July 7	1620	35
Aug. 30	1425	130	Aug. 29	1520	4
Sept. 20	1305	100	Sept. 20	1500	4
27	1315	1/ 71.4			
Oct. 20	1400	80	Oct. 20	1720	10

1/ Streamflow measurement.

2/ Probable peak discharge for the year.

Streams in Jackson Hole gain or lose water because they are commonly underlain by moderately to highly permeable aquifers of sand, gravel, and cobbles, and the stream level is continuous with the water table. If the stream level is higher than the adjacent water table, the stream loses water. If the stream level is lower than the adjacent water table, the stream gains water. In general, reaches of streams in Jackson Hole that are topographically high lose water and those that are topographically low gain water.

Ground water

Aquifers in alluvium and glacial deposits are recharged by precipitation and by water from streams. Some of the water from precipitation and melting snow percolates to the water table. During periods of high flow in the streams, the hydraulic gradient, at least adjacent to the stream, is toward the aquifer, and water moves from the stream to the aquifer. As streamflow declines, the hydraulic gradient reverses adjacent to gaining streams but remains toward the aquifer adjacent to losing streams. Although precipitation is greatest in winter and spring, recharge to aquifers is greatest in late spring and summer when precipitation occurs mostly as rain, snow is melting, and streamflow is highest. Recharge to aquifers also occurs as water from irrigated lands and leakage from canals and ditches percolates to the water table.

Aquifers in rocks other than alluvium and glacial deposits are recharged also by precipitation. Water percolates to the water table through interstices in sandstone, siltstone, and shale in areas where these rocks crop out. Also, water percolates to the water table through fractures in gneiss, granite, basalt, and other hard rocks and through fractures and solution openings in limestone and dolomite in areas where these rocks crop out. Most of the recharge to aquifers in consolidated rocks probably occurs from rainfall and melting snow; however, some recharge may occur by seepage from streams flowing over outcrops of consolidated rocks. Recharge to an aquifer may occur from discharge from another aquifer, particularly in faulted areas.

Ground water moves from areas of recharge to areas of discharge. Ground water discharges at springs and seeps commonly in topographically low areas and in streambeds. The flow of streams is increased significantly where ground water discharges into streams.

Water-table contours were drawn to show the configuration of the water table in alluvium and glacial deposits in Jackson Hole and in some of the valleys of streams that are tributaries to the Snake River (fig. 6). Control for the contours was altitude of water level in wells (determined by subtracting depth to water from altitude of land surface--table 1), altitude of water surface where streams coincide with the water table, and altitude of springs. Altitude of land surface at wells and altitude of water surface in streams and springs were determined from Geological Survey 1:24,000-scale topographic maps with 20- or 40-foot (6- or 12-meter) contour intervals. Most water levels in wells used for control for the contours were measured in June; however, a few water levels during July and October were used because water levels were not measured in June in these wells.

Figure 6.--Water-table contour map of part of Jackson Hole and nearby stream valleys.

A diagrammatic section across Jackson Hole shows the position of the water table (fig. 7). Line of the section is shown in figure 6.

Water levels measured in selected observation wells show that the water table fluctuates seasonally (table 5). Configuration of the water table, therefore, may be different in small areas at other times of the year. Water levels in wells near Pilgrim and Cottonwood Creeks are commonly more than 30 feet (9 meters) lower in October than they are in June (table 5). However, the magnitude of water-level fluctuations is less in other areas, and the configuration of the water table in most of Jackson Hole and nearby stream valleys as shown in figure 6 would not change significantly at other times of the year.

In general, ground water moves in a direction perpendicular to water-table contours; therefore, contours bending upstream indicate gaining streams and those bending downstream indicate losing streams. Contours perpendicular to streams indicate neither gaining nor losing streams.

The water-table contours shown in figure 6 indicate that ground water in alluvium and glacial deposits in Jackson Hole moves toward the Snake River and the lower reaches of Pacific Creek and Buffalo Fork, but moves parallel to or away from Pilgrim, Spread, Ditch, Cottonwood, Lake, and Fish Creeks and the Gros Ventre River. Ground water, therefore, discharges into the Snake River and the lower reaches of Pacific Creek and Buffalo Fork, and the streams gain in flow. Pilgrim, Spread, Ditch, Cottonwood, Lake, and Fish Creeks and the Gros Ventre River either lose in flow or neither gain nor lose in flow. Streamflow data indicate that the Snake River gains in flow from Jackson Lake Dam to Moose and that Pilgrim and Cottonwood Creeks lose in flow through most of their lengths.

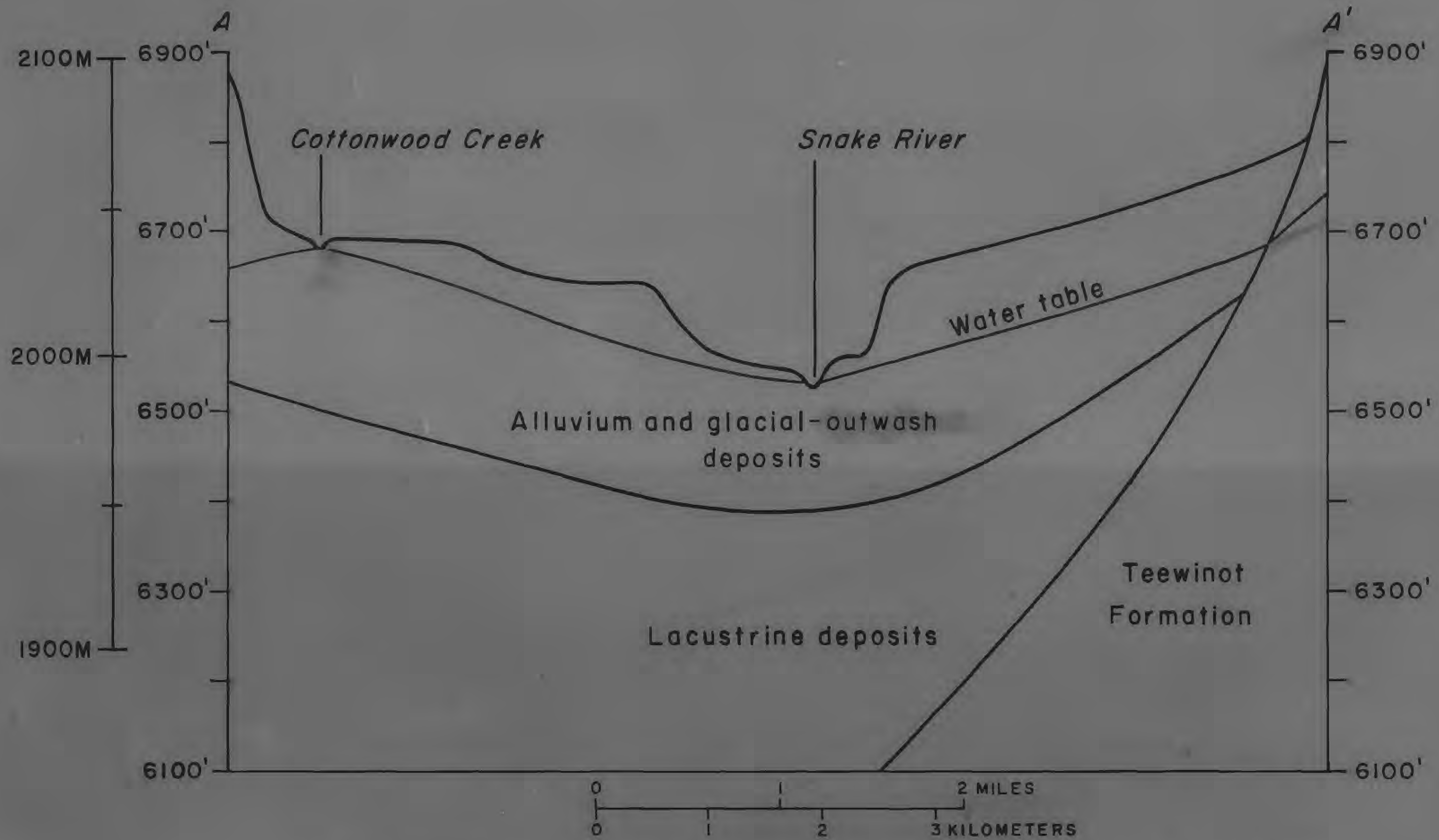

Figure 7.--Diagrammatic section A–A' across Jackson Hole.

The transmissivity of the aquifer in alluvium and glacial deposits in Jackson Hole can be estimated by using the water-table contour map (fig. 6) and streamflow data. Transmissivity is the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient (Lohman, 1972, p. 6). The ground-water flow lines shown in figure 6 were drawn perpendicular to the water-table contours from the points on the Snake River where streamflow measurements were made. The flow lines define the segments of the aquifer that contribute the ground water discharging to the river in that reach. Ground water discharges from segments on both sides of the river in this reach. Transmissivity of the segments in cubic feet per day per foot is the ground-water discharge in cubic feet per second times 86,400 (the number of seconds in a day) divided by the widths of the segments in miles and the average gradient in feet per mile. The ground-water discharge on October 16, 1972 was 345 ft^3/s (9.8 m^3/s); widths of the segments total 11.5 miles (18.5 kilometers) (measured along the 6,600-foot water-table contour on both sides of the river); and the average gradient is 70 feet per mile; therefore, the transmissivity is about 37,000 cubic feet per day per foot (3,400 cubic meters per day per meter).

In the reach between Jackson Lake Dam and Moose, the ground-water discharge from the segment west of the Snake River on October 16, 1972 was considered to be half of 445 ft^3/s, or 222.5 ft^3/s (6.3 m^3/s); width of the segment is 16 miles (26 kilometers) (measured along the 6,750-foot water-table contour); and the average gradient is 50 feet per mile; therefore, the transmissivity of the aquifer west of the river is about 24,000 cubic feet per day per foot (2,200 cubic meters per day per meter). If the width of the segment were measured along the 6,700-foot water-table contour as 13 miles (21 kilometers), the transmissivity would be about 30,000 cubic feet per day per foot (2,800 cubic meters per day per meter). Most of the ground-water discharge from the west side of the Snake River between Jackson Lake Dam and Moose probably occurs below the point where the 6,700-foot contour crosses the river; consequently, the average transmissivity of the aquifer west of the river is about 30,000 cubic feet per day per foot (2,800 cubic meters per day per meter). The average transmissivity of the alluvium and glacial deposits on both sides of the river between Jackson Lake Dam and Moose is about 30,000 cubic feet per day per foot (2,800 cubic meters per day per meter).

The specific capacity (yield per unit of drawdown) of a well that might be drilled in alluvium and glacial deposits between Jackson Lake Dam and Moose can be approximated by using a graph showing relation of well diameter, specific capacity, and coefficients of transmissibility and storage (Meyer, in Bentall, 1963, p. 339). The coefficient of transmissibility was formerly used for transmissivity and was expressed in gallons per day per foot. The coefficient of storage is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head and ranges from 0.1 to 0.3 (dimensionless) and averages about 0.2 in most unconfined aquifers (Lohman, 1972, p. 8). The aquifer in alluvium and glacial deposits is unconfined and the transmissivity is about 30,000 cubic feet per day per foot (2,800 cubic meters per day per meter), or about 200,000 gallons per day per foot, and the coefficient of storage is about 0.2. From the graph, the specific capacity at the end of 1 day, in gallons per minute per foot of drawdown, would be 120 for a 6-inch (15-centimeter) diameter well and 130 for a 12-inch (30-centimeter) diameter well. Based on this approximation, a 12-inch (30-centimeter) diameter well drilled in the aquifer would yield 1,300 gpm (4,900 l/m) with a drawdown of 10 feet (3 meters) at the end of 1 day.

The possible effects of one discharging well upon another well or upon a stream or lake could be calculated using the estimated values of transmissivity and coefficient of storage (Lohman, 1972, p. 55-56). Thus, wells could be spaced to minimize drawdown caused by interference between wells. With continued pumping, the area of influence of a discharging well may reach a stream or lake, and drawdown in the well then would cease if water from the stream or lake recharged the aquifer.

Quality of water

Water samples were collected from wells, streams, and springs to determine the general chemical quality of water in Grand Teton National Park. Chemical analyses of water from wells are shown in table 6; chemical analyses of water from streams and springs are shown in table 4. Locations of the wells, surface-water data collection sites, and springs are shown in figure 2.

Chemical constituents are expressed in milligrams per liter or in micrograms per liter in this report. A microgram equals 1 thousandth of a milligram. The U.S. Geological Survey prior to October 1, 1967, and some other agencies, reported concentrations of chemical constituents in parts per million. For practical purposes, concentrations less than 7,000 parts per million are equal to those in milligrams per liter. Common constituents also may be expressed in milliequivalents per liter. Values in milliequivalents per liter are determined by multiplying the milligrams per liter by the reciprocals of the combining weights of the appropriate constituents.

The drinking water standards published by the U.S. Public Health Service (1962) can be used in evaluating the quality of the water. The following recommended limits are summarized from pages 7 and 8 of the above-mentioned report:

Substance	Concentration (milligrams per liter)
Chloride (Cl)	250
Fluoride (F)	1/ 1.7 to 2.4
Iron (Fe)	.3
Nitrate (NO_3)	45
Sulfate (SO_4)	250
Dissolved solids	500

1/ Limits of fluoride vary according to annual average of maximum daily air temperature. At Grand Teton National Park, the upper limit is probably 1.7 mg/l (milligrams per liter) and the optimum concentration is probably 1.2 mg/l. The U.S. Public Health Service (1962, p. 8) states, "Presence of fluoride in average concentrations greater than two times the optimum values***shall constitute grounds for rejection of the supply."

The U.S. Geological Survey, in order to have a uniform policy in classifying water hardness in the United States, uses the following classification:

Hardness range (milligrams per liter)	Adjective rating
0 - 60	Soft
61 - 120	Moderately hard
121 - 180	Hard
>180	Very hard

The National Park Service periodically collects samples from water supplies used by the public, employees, and concessionaires in the park. Detailed analyses are made of these samples, including trace elements. Chemical analyses of water from selected supplies in 1965 and in 1971 are shown in the following tables. The dates the samples were collected in 1965 are not known, but they were received in the laboratory on August 9, 1965 and probably were collected just prior to that date. The chemical constituents sought in analyzing water from these supplies are within the recommended limits of the drinking water standards of the U.S. Public Health Service.

Chemical analyses of water from selected supplies in 1965

[Analytical results in milligrams per liter. Analyses by Wyoming Department of Agriculture.]

Constituent	Leeks Lodge, well 46-115-26bbb	Colter Bay Village, spring near Pilgrim Mountain and well 46-114-29dca	Jackson Lake Lodge, spring near lodge	Elbo Ranch, well 43-115-24cdd	Jenny Lake Lodge, outlet of String Lake	Jenny Lake campground, Jenny Lake	Beaver Creek residential area, Taggart Creek
Arsenic (As)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barium (Ba)	.0	.0	.0	.0	.0	.0	.0
Cadmium (Cd)	< .005	< .005	.005	< .005	< .005	< .005	< .005
Chloride (Cl)	8.9	3.5	7.1	31.2	7.1	5.3	10.6
Chromium (Cr^{+6})	.00	.00	.00	.00	.00	.00	.00
Copper (Cu)	.0	.0	.0	.0	.03	.0	.0
Fluoride (F)	.03	.03	.30	.65	.30	.02	.02
Iron (Fe)	.0	.0	.0	.0	.01	.0	.08
Lead (Pb)	.00	.00	.00	.00	.00	.00	.00
Manganese (Mn)	.00	.00	.00	.00	.00	.00	.00
Nitrate (NO_3)	2.2	.0	.0	1.1	.0	.0	.0
Selenium (Se)	.00	.00	.00	.00	.00	.00	.00
Silver (Ag)	.00	.00	.00	.00	.00	.00	.00
Sulfate (SO_4)	6.7	4.3	4.8	56.2	3.4	1.0	8.2
Zinc (Zn)	1.25	.02	.7	.04	.25	.15	.3
Dissolved solids	114	122	162	340	36	38	44

< Less than value shown.

Chemical analyses of water from selected supplies in 1971

[Analytical results in milligrams per liter. Analyses by U.S. Environmental Protection Agency.]

Constituent	Colter Bay Village, spring near Pilgrim Mountain	Jackson Lake Lodge, spring near lodge	Elbo Ranch, well 43-115-24cdd	Buffalo Fork Entrance Station, well 45-114-23ccd	Beaver Creek residential area, Taggart Creek
	Oct. 26, 1971	Oct. 27, 1971	Nov. 17, 1971	Nov. 17, 1971	Nov. 17, 1971
Arsenic (As)	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Barium (Ba)	< .05	< .05	.3	< .05	< .05
Cadmium (Cd)	.00	.00	.003	.00	.00
Chloride (Cl)	<10	<10	48	<10	<10
Chromium (Cr^{+6})	.00	.00	.00	.00	.00
Cobalt (Co)	.00	.00	.004	.00	.00
Copper (Cu)	.003	.002	.013	.009	.049
Fluoride (F)	< .1	.15	.32	.27	< .10
Iron (Fe)	.004	.004	.044	.019	.017
Lead (Pb)	.00	.00	.00	.00	.00
Manganese (Mn)	.00	.00	.011	.00	.008
Mercury (Hg)	< .0005	.0030	< .0005	< .0005	< .0005
Nickel (Ni)	.00	.00	.016	.007	.00
Nitrate (NO_3)	1.8	1.6	1	1	< 1
Selenium (Se)	< .002	< .002	< .005	< .005	< .005
Silver (Ag)	.00	.00	.003	.003	.00
Sulfate (SO_4)	<25	<25	42	<25	<25
Zinc (Zn)	.00	.003	.17	1.5	.003
Dissolved solids	119	173	440	136	34

< Less than value shown.

Data on the quality of ground water in and near Grand Teton National Park are not as extensive as data on quality of surface water. Most wells in the park penetrate only alluvium and glacial deposits. Many of the wells are near streams. Because of the interchange of surface and ground waters near streams, quality of the ground water is similar in many places to the quality of the nearby surface water. Quality of the water in some bedrock aquifers can be determined by sampling springs. Some springs, however, issue from unconsolidated rock, and the quality of water from these springs may be influenced by the unconsolidated rocks as well as by the underlying bedrock.

The quality of ground water varies with the lithology of the geologic units, and the quality of surface water varies with the lithology and the season. Streams flowing over similar types of rocks commonly have similar chemical quality of water. Seasonal variations in the quality of surface water occur because runoff from snowmelt and precipitation has low dissolved solids, and base flow made up of ground water discharging into the stream channels may have relatively high dissolved solids. Factors such as temperature, acidity, and salinity affect the solubility of constituents and the quality of water; however, waters from similar geologic and hydrologic sources have similar percentages of key constituents.

All water sampled in and near the park has relatively high bicarbonate in comparison to other constituents. Most of the bicarbonate, however, is from atmospheric carbon dioxide dissolved in surface water and from carbon dioxide concentrated in soil by vegetation and dissolved by water percolating to the water table. Bicarbonate is high from dissolved carbonate rocks in limestone terrane.

Concentrations of constituents other than bicarbonate, groups of constituents, and ratios of selected constituents in water are indicative of a geologic terrane or a hydrologic source of the water. Many streams in and near the park, however, have water from more than one geologic terrane.

Groups of analyses of water from similar geologic terranes or hydrologic sources have been examined for similarity of concentration of constituents. The constituents are shown in milligrams per liter or micrograms per liter and, for common constituents, in milliequivalents per liter. The percent sodium (ratio of sodium to total cations), Ca/Mg (ratio of calcium to magnesium), and SO_4/Cl (ratio of sulfate to chloride) are also shown. Selected chemical analyses of water from four geologic terranes, or sources, are shown in the following tables:

Chemical analyses of water from three streams and a spring in Precambrian rocks.

[Analytical results in milligrams per liter (mg/l), milliequivalents per liter (meq/l), or micrograms per liter (μg/l), except as indicated. Analyses by U.S. Geological Survey.]

Constituent	13012780 Outlet of Leigh Lake		13012790 Cascade Creek		13012900 Taggart Creek		13016150 spring at Teton Village	
	Sept. 7, 1972		Sept. 7, 1972		Sept. 22, 1972		Oct. 26, 1972	
	mg/l	meq/l	mg/l	meq/l	mg/l	meq/l	mg/l	meq/l
Silica (SiO_2)--------	2.2	-----	2.1	-----	1.8	-----	14	-----
Iron (Fe) (μg/l)-----	20	-----	20	-----	20	-----	0	-----
Calcium (Ca)---------	2.8	0.140	3.9	0.195	4.0	0.200	23	1.13
Magnesium (Mg)-------	.4	.033	.8	.066	.9	.075	1.9	.16
Sodium (Na)----------	.6	.027	.4	.018	.4	.018	2.7	.12
Potassium (K)--------	.7	.018	.6	.016	.5	.013	.9	.02
Bicarbonate (HCO_3)---	12	.197	17	.279	19	.312	84	1.38
Carbonate (CO_3)------	0	.000	0	.000	0	.000	0	0
Sulfate (SO_4)--------	5.1	.107	3.6	.075	4.1	.086	1.6	.03
Chloride (Cl)--------	.0	.006	.9	.026	1.8	.051	.0	.00
Fluoride (F)---------	.1	.006	.1	.006	.1	.006	.1	.00
Nitrate (NO_3)--------	.01	.001	.09	.007	.02	.002	.7	.01
Boron (B) (μg/l)-----	0	-----	10	-----	30	-----	20	-----
Dissolved solids-----	18	-----	21	-----	23	-----	86	-----
Hardness as $CaCO_3$----	9	-----	13	-----	14	-----	65	-----
Specific conductance (micromhos at 25°C)--	15	-----	30	-----	30	-----	133	-----
pH (units)-----------	7.1	-----	6.9	-----	7.3	-----	7.4	-----
Temperature (°C)-----	15.5	-----	8.0	-----	10.5	-----	6.5	-----
Discharge (cfs)------	45.2	-----	49.4	-----	11.4	-----	-----	-----
Total cations--------	-----	.218	-----	.295	-----	.306	-----	1.43
Total anions---------	-----	.418	-----	.393	-----	.457	-----	1.42
Percent sodium-------	-----	12	-----	6	-----	6	-----	8
Ca/Mg----------------	-----	4.2	-----	3.0	-----	2.7	-----	7.1
SO_4/Cl---------------	-----	17.8	-----	2.9	-----	1.7	-----	-----

Chemical analyses of water from a well and three springs in the Madison Limestone.

[Analytical results in milligrams per liter, milliequivalents per liter, or micrograms per liter, except as indicated. Analyses by U.S. Geological Survey.]

Constituent	Well 42-115-11aac		13013570 Kelly Warm Spring		13014460 spring at Teton Valley Ranch		13017200 warm spring at Warm Spring Ranch	
	July 27, 1972		Sept. 17, 1971		Sept. 17, 1971		Oct. 26, 1972	
	mg/1	meq/1	mg/1	meq/1	mg/1	meq/1	mg/1	meq/1
Silica (SiO_2)---------	16	-----	18	-----	13	-----	16	-----
Iron (Fe) (µg/1)------	10	-----	10	-----	10	-----	10	-----
Calcium (Ca)----------	54	2.695	56	2.795	53	2.645	37	1.85
Magnesium (Mg)--------	19	1.563	19	1.563	17	1.399	17	1.38
Sodium (Na)-----------	6.4	.279	6.5	.283	5.9	.257	6.4	.28
Potassium (K)---------	2.1	.054	2.5	.064	1.7	.044	2.8	.07
Bicarbonate (HCO_3)----	175	2.695	192	3.147	182	2.983	181	2.97
Carbonate (CO_3)-------	0	.000	0	.000	0	.000	0	.00
Sulfate (SO_4)---------	75	1.562	91	1.895	73	1.520	26	.53
Chloride (Cl)---------	2.0	.057	2.6	.074	2.3	.065	.3	.01
Fluoride (F)----------	.8	.043	.5	.027	.5	.027	.6	.03
Nitrate (NO_3)---------	.07	.005	.08	.006	.06	.005	.3	.01
Boron (B) (µg/1)------	30	-----	30	-----	20	-----	30	-----
Dissolved solids------	262	-----	291	-----	256	-----	195	-----
Hardness as $CaCO_3$-----	210	-----	220	-----	200	-----	160	-----
Specific conductance (micromhos at 25°C)--	440	-----	430	-----	410	-----	325	-----
pH (units)------------	7.4	-----	7.7	-----	8.0	-----	8.0	-----
Temperature (°C)------	19.0	-----	26.0	-----	17.5	-----	25.5	-----
Discharge (cfs)-------	-----	-----	10.4	-----	4.64	-----	.88	-----
Total cations---------	-----	4.591	-----	4.705	-----	4.345	-----	3.58
Total anions----------	-----	4.362	-----	5.149	-----	4.600	-----	3.55
Percent sodium--------	-----	6	-----	6	-----	6	-----	8
Ca/Mg-----------------	-----	1.7	-----	1.8	-----	1.9	-----	1.3
SO_4/Cl----------------	-----	27.4	-----	25.6	-----	23.4	-----	53.0

Chemical analyses of water from three streams in Mesozoic rocks.

[Analytical results in milligrams per liter, milliequivalents per liter, or micrograms per liter, except as indicated. Analyses by U.S. Geological Survey.]

Constituent	13012500 Spread Creek		13013530 Ditch Creek		13014400 Gros Ventre River	
	Aug. 18, 1971		Aug. 13, 1971		Oct. 13, 1971	
	mg/l	meq/l	mg/l	meq/l	mg/l	meq/l
Silica (SiO_2)---------	11	-----	11	-----	5.8	-----
Iron (Fe) (μg/l)------	10	-----	10	-----	10	-----
Calcium (Ca)----------	40	1.996	39	1.947	51	2.545
Magnesium (Mg)--------	8.5	.700	6.8	.560	13	1.070
Sodium (Na)-----------	3.9	.170	8.6	.375	7.4	.322
Potassium (K)---------	1.6	.041	1.3	.034	1.0	.026
Bicarbonate (HCO_3)----	184	3.016	160	2.623	160	2.623
Carbonate (CO_3)-------	0	.000	0	.000	0	.000
Sulfate (SO_4)---------	7.3	.152	25	.521	71	1.479
Chloride (Cl)---------	.3	.009	.9	.026	1.2	.034
Fluoride (F)----------	.5	.027	.0	.000	.1	.006
Nitrate (NO_3)---------	.04	.003	.02	.002	.01	.001
Boron (B) (μg/l)------	10	-----	30	-----	20	-----
Dissolved solids------	164	-----	171	-----	229	-----
Hardness as $CaCO_3$-----	130	-----	130	-----	180	-----
Specific conductance (micromhos at 25°C)--	272	-----	300	-----	383	-----
pH (units)------------	7.9	-----	8.1	-----	8.0	-----
Temperature (°C)------	12.5	-----	19.0	-----	7.0	-----
Discharge (cfs)-------	11.4	-----	8.09	-----	266	-----
Total cations---------	-----	2.907	-----	2.916	-----	3.963
Total anions----------	-----	3.207	-----	3.172	-----	4.143
Percent sodium--------	-----	6	-----	13	-----	8
Ca/Mg-----------------	-----	2.9	-----	3.5	-----	2.4
SO_4/Cl----------------	-----	16.9	-----	20.0	-----	43.5

Chemical analyses of water from two streams in Tertiary rocks.

[Analytical results in milligrams per liter, milliequivalents per liter, or micrograms per liter, except as indicated. Analyses by U.S. Geological Survey.]

Constituent	13010440 Pilgrim Creek Sept. 21, 1972		13011500 Pacific Creek Oct. 17, 1972	
	mg/l	meq/l	mg/l	meq/l
Silica (SiO_2)---------	7.8	-----	13	-----
Iron (Fe) (µg/l)------	20	-----	20	-----
Calcium (Ca)----------	28	1.398	29	1.43
Magnesium (Mg)--------	4.8	.395	4.7	.39
Sodium (Na)-----------	4.8	.209	4.3	.19
Potassium (K)---------	.6	.016	1.2	.03
Bicarbonate (HCO_3)----	123	2.016	107	1.76
Carbonate (CO_3)-------	0	.000	0	.00
Sulfate (SO_4)---------	6.2	.130	9.9	.21
Chloride (Cl)---------	.6	.017	.7	.02
Fluoride (F)----------	.1	.006	.2	.01
Nitrate (NO_3)---------	.00	.000	.0	.00
Boron (B) (µg/l)------	10	-----	20	-----
Dissolved solids------	113	-----	116	-----
Hardness as $CaCO_3$-----	90	-----	91	-----
Specific conductance (micromhos at 25°C)--	190	-----	190	-----
pH (units)------------	8.5	-----	7.8	-----
Temperature (°C)------	11.0	-----	5.0	-----
Discharge (cfs)-------	14.0	-----	219	-----
Total cations---------	-----	2.018	-----	2.04
Total anions----------	-----	2.169	-----	2.00
Percent sodium--------	-----	10	-----	9
Ca/Mg-----------------	-----	3.5	-----	3.7
SO_4/Cl----------------	-----	7.6	-----	10.5

Streams flowing on Precambrian rocks in the Teton Range have low dissolved solids. The water is soft and contains only small amounts of constituents sought in chemical analyses. Water from the spring near Teton Village is moderately hard and contains considerably more silica, calcium, bicarbonate, and dissolved solids than water in the streams. In general, water from Precambrian rocks in the Teton Range is of excellent chemical quality.

Of the Paleozoic formations, hydrologic data are available only from the Madison Limestone. Chemical analyses of water from a well and one of a group of warm springs at Teton Valley Ranch that are known to be from the Madison are shown. These analyses and one from nearby Kelly Warm Spring are almost identical, indicating that the source of water at Kelly Warm Spring probably is the Madison. Kelly Warm Spring issues from unconsolidated rock. Water from a warm spring at Warm Spring Ranch is similar to that known to be from the Madison, although water from the spring at Warm Spring Ranch has less calcium, sulfate, choloride, and dissolved solids than the others. The similarity, however, suggests that the source of water at the spring at Warm Spring Ranch may be the Madison. These analyses suggest that water in the Madison is hard or very hard, and, although the temperatures indicate a deep-seated source, all chemical constituents that were determined are below recommended limits.

Streams flowing on Mesozoic rocks receive dissolved solids from several different kinds of rocks; consequently, water in the streams varies in chemical quality. Water in the Gros Ventre River has more calcium, magnesium, and sulfate than water from Spread and Ditch Creeks. Water in the streams is hard, but all chemical constituents that were determined are below recommended limits.

Streams flowing on Tertiary rocks have lower dissolved solids than streams flowing on Mesozoic rocks. Water from Pilgrim and Pacific Creeks is moderately hard, and all chemical constituents that were determined are below recommended limits.

Chemical analyses of water from the Snake River in and near Grand Teton National Park show that the water is generally of good quality (table 4). The water is soft or moderately hard and increases in hardness in a downstream direction through the park. Water in the river upstream from the park, station 13010200, is relatively high in silica, fluoride, and boron. These constituents commonly are high in both thermal and nonthermal water on the rhyolite plateau that includes much of Yellowstone National Park (Cox, 1973, p. 72-75). Some of the tributaries of the Snake River originate in the southern part of the rhyolite plateau. The fluoride concentration of 1.9 mg/l at station 13010200 is greater than the recommended limit of 1.7 mg/l but is less than the concentration of 2.4 mg/l that constitutes grounds for rejection of such a supply. The fluoride concentration decreases downstream as water lower in fluoride is added to the river, and fluoride in the water in the river at Moose, station 13013650, is not appreciably different from that in other streams in Grand Teton National Park.

The chemical quality of ground water in Jackson Hole is affected by the chemical quality of water in nearby streams. In general, ground water is of excellent quality on the west side of the valley near streams flowing from the Teton Range. On the east side of the valley, ground water is higher in dissolved solids near Spread and Ditch Creeks and the Gros Ventre River than it is near Pilgrim and Pacific Creeks. Ground water near the Snake River is generally of good chemical quality.

All ground and surface waters analyzed during this study are potable and would be satisfactory, as far as chemical quality is concerned, for public, domestic, or commercial supplies.

Water resources near selected sites

At the beginning of this study, the National Park Service needed hydrologic data to plan additions or improvements to water supplies at Colter Bay Village, Jenny Lake Lodge, Jenny Lake campground, and Shadow Mountain. Since that time, the water requirements and the need for data at specific sites probably have changed. Although detailed hydrologic studies were not made at any of the above-mentioned sites, enough data were collected during this study to help in planning detailed hydrologic studies, including test drilling, near the sites.

Colter Bay Village

Additional wells could be drilled in the Pilgrim Creek valley to increase the water supply for Colter Bay Village and Jackson Lake Lodge. Tests indicate that wells that would yield a few hundred gallons per minute of water each could be drilled in the valley. Yields of as much as 1,000 gpm (3,800 l/m) per well may be obtained in parts of the valley (McGreevy and Gordon, 1964, p. 24). Test wells should be drilled to determine the greatest thickness of saturated material for well locations. Wells should be properly spaced to avoid interference that would result in decreases in yields.

The yield of well 46-114-29dca could be increased. The yield was 275 gpm (1,040 l/m) on July 12, 1972, and the water level after the well had been pumped for several days was 20.86 feet (6.36 meters) below land surface. The drawdown, based on water levels in nearby wells, was about 5 feet (1.5 meters). The well is 201 feet (61.3 meters) deep; consequently, the drawdown and the yield could be increased.

Apparently, a small ground-water supply independent of the present supply is desired for winter use at Colter Bay Village. The most convenient location for wells is between the water tank, about 1.5 miles (2.4 kilometers) northeast of Colter Bay Village, and the village. Wells in this area would be in glacial moraine, and yields probably would not be greater than 10 gpm (38 l/m) per well.

Test wells could be drilled in a valley about 0.2 mile (0.3 kilometer) west of the water tank or near the shore of Jackson Lake near the visitor center at Colter Bay Village. The valley near the water tank has a gravel floor and an intermittent stream. Apparently, the gravel is not thick enough to store enough water during spring runoff to maintain the flow of the stream throughout the year. A well near the visitor center might tap clayey sand and gravel similar to that in well 46-115-34ddc (table 2). If saturated material is thick enough, wells at these two locations may yield 10 gpm (38 l/m) each.

Jenny Lake Lodge

A ground-water supply may be needed to replace the surface-water supply for Jenny Lake Lodge and a picnic area near the eastern shore of String Lake. Yields of wells would be small if they were drilled in glacial-moraine deposits near String and Jenny Lakes. Yields would be greater if wells were drilled in glacial-outwash deposits east of the moraines.

Test wells could be drilled in glacial-outwash deposits between Jenny Lake Lodge and Burned Ridge to determine the thickness of saturated material. If a well were drilled about 1 mile (1.6 kilometers) east of Jenny Lake Lodge, the water level would be 100 to 150 feet (30 to 46 meters) below land surface, based on the difference between the altitudes of the water table (fig. 6) and the land surface. Therefore, if the thickness of the glacial-outwash deposits is 200 feet (61 meters), the thickness of saturated permeable material would be 50 to 100 feet (15 to 30 meters), and the yield of the well may be less than 100 gpm (380 l/m). If a well about 1 mile (1.6 kilometers) east of Jenny Lake Lodge did not yield enough water, wells drilled progressively farther southeast probably would have greater thicknesses of saturated permeable material and greater yields.

Jenny Lake campground

A ground-water supply may be needed to replace the surface-water supply from Jenny Lake for the campground, museum, consessionaire facilities, and residences near the south end of the lake. Yields of wells would be small if they were drilled in glacial-moraine deposits near the lake. Yields would be greater if wells were drilled in glacial-outwash deposits south and east of the moraines.

A well could be drilled near a bridge over Cottonwood Creek about 0.4 mile (0.6 kilometer) south of the outlet of Jenny Lake that would tap glacial-outwash deposits or alluvium. The water level would be less than 50 feet (15 meters) below land surface, and the thickness of saturated permeable material probably would be more than 100 feet (30 meters). Ground water in this area is recharged by seepage from Cottonwood Creek. A well at this location probably would yield more than 100 gpm (380 l/m).

Shadow Mountain

A water supply may be needed for future National Park Service facilities near the eastern boundary of the park near the base of Shadow Mountain. A ground-water supply might be obtained from wells drilled in the Teewinot Formation in this area. Beds of limestone probably would yield the largest quantities of water, as much as 100 gpm (380 l/m) per well, from the Teewinot. A ground-water supply also might be obtained from wells drilled in alluvium and glacial-outwash deposits in Antelope Flats west of Shadow Mountain. The thickness of saturated permeable material probably ranges from less than 50 feet (15 meters) in the eastern part of Antelope Flats to more than 100 feet (30 meters) in the western part. Therefore, the yield per well probably would be less than 100 gpm (380 l/m) in the eastern part of Antelope Flats and more than 100 gpm (380 l/m) in the western part.

Conclusions

Potable ground-water supplies can be developed in places by drilling wells in alluvium, glacial deposits, lacustrine deposits, and some consolidated rocks in and near Grand Teton National Park. Yields of as much as 1,000 gpm (3,800 l/m) of water per well could be obtained from alluvium and glacial-outwash deposits in Jackson Hole and in some of the valleys of streams that are tributaries to the Snake River. Each well in glacial-moraine deposits would yield from a few gallons per minute from clay and silt to as much as 100 gpm (380 l/m) of water from sand and gravel. Lacustrine deposits would yield only a few gallons per minute of water per well.

The Madison Limestone of Mississippian age may yield several hundred gallons per minute of water per well. The Teewinot Formation of Tertiary age may yield as much as 100 gpm (380 l/m) of water per well. The Gallatin Limestone and the Flathead Sandstone of Cambrian age and the Bighorn Dolomite of Ordovician age may yield several tens of gallons per minute of water per well. Rocks of Precambrian age, sandstone beds of Pennsylvanian and Jurassic age, sandstone and conglomerate beds of Cretaceous and Tertiary age, conglomerate beds of Quaternary and Tertiary age, and rhyolitic rocks of Quaternary age may yield a few tens of gallons per minute of water per well. Other consolidated rocks in and near Grand Teton National Park probably would not yield more than 10 gpm (38 l/m) of water per well.

Streamflow is greatest during May-July as a result of melting snow. Streamflow declines during the summer and fall and is lowest in the winter. Pilgrim and Cottonwood Creeks lose in flow as the streams cross permeable rocks. The Snake River gains in flow between Jackson Lake Dam and Moose as a result of ground water discharging into the stream.

Ground water in alluvium and glacial deposits in Jackson Hole moves toward the Snake River and the lower reaches of Pacific Creek and Buffalo Fork, but moves parallel to or away from Pilgrim, Spread, Ditch, Cottonwood, Lake, and Fish Creeks, and the Gros Ventre River. An average transmissivity of 30,000 cubic feet per day per foot (2,800 cubic meters per day per meter) was estimated for the alluvium and glacial deposits between Jackson Lake Dam and Moose.

All ground and surface waters sampled and analyzed during this study are potable and would be satisfactory, as far as chemical quality is concerned, for public, domestic, or commercial supplies. A sample from the Snake River upstream from the park had a fluoride concentration greater than the limit for drinking water recommended by the U.S. Public Health Service but less than the concentration that constitutes grounds for rejection of such a supply. The fluoride concentration in the river decreases downstream, and at Moose it is not appreciably different from that in other streams in the park.

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Basic data

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TABLE 1)

Table 2.--Logs of selected wells in and near Grand Teton National Park

Lithology and hydrology	Thickness (feet)	Depth (feet)
42-115-9bdb, Gros Ventre campground		
Alluvium:		
Clay and gravel	18	18
Pea gravel and sand	12	30
Gravel and sand	5	35
Gravel, sand, and clay	17	52
Pea gravel and sand	8	60
Gravel	18	78
Gravel, sand, and clay	14	92
Gravel and sand	8	100
Sand and silt	12	112
Gravel, sand, and silt	38	150
42-115-11acc, Phillip Wilson		
Teewinot Formation:		
Gravel and brown clay	30	30
White sandstone	15	45
Gravel and brown clay	69	114
White sandstone; water	26	140
White clay	15	155
White sandstone; water	28	183
Limestone	2	185

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
42-116-1bbc, Circle EW Ranch		
Alluvium:		
Boulders and some clay	3	3
Gravel and boulders	14	17
Large gravel and silt	30	47
Pea gravel and silt; some water	6	53
Fine and coarse sand; good water	2	55
Gravel and coarse sand; good water	10	65
Gravel, silt, and sand; fair water	8	73
Fine and coarse gravel	7	80
42-116-5aca, JY Ranch		
Glacial-moraine deposits:		
Top soil	2	2
Large boulders and chips of granite	17	19
Clay and chips of granite	26	45
Coarse sand and chips of granite	15	60
Fine sand and chips of granite	8	68
Pea gravel	5	73
Rock 1.5 to 2 inches in diameter	17	90
Lacustrine deposits:		
Quicksand	20	110
Probably quicksand	30	140
White sand, very hard; water	20	160

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
42-116-14bdc, Jackson Hole Airport		
Alluvium:		
Boulders and gravel	20	20
Silt and boulders	15	35
Silt and gravel	5	40
Sand and gravel	10	50
Gravel	5	55
Gravel; good water	5	60
Gravel and sand; water	16	76
Sand; some water	4	80
42-116-34bda, Jackson Hole Country Club		
Alluvium:		
Silt and boulders	10	10
Clay and boulders	15	25
Clay and gravel	5	30
Washed gravel; water	20	50
Gravel and small amount of sand; water	5	55
Coarse sand and some gravel; water	12	67
Sand and coarse gravel; water	15	82
Coarse gravel and some sand; water	3	85
Gravel; good water	5	90
Sand and small gravel; good water	5	95
Clay and small amount of gravel	6	101

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
43-115-24dab, U.S. National Park Service		
Alluvium:		
Cobbles; contains gravel	11	11
Teewinot Formation:		
Claystone, silty, sand, greenish-gray to brown; moist; sandy zones below 20 feet contain water	17	28
Sand and gravel, poorly sorted; sand is fine to very coarse grained, angular to rounded; gravel is fine to coarse, angular	5	33
Sandstone, very fine grained, brown, well-sorted, subrounded to rounded	2	35
43-115-26cad, Clark Moulton		
Alluvium:		
Clay	9	9
Clay, some gravel, and big boulders	16	25
Clay, gravel, and boulders	38	63
Clay and gravel	14	77
Clay and sand	5	82
Bentonite and sand	10	92
Clay, sand, and gravel	2	94
Sand	8	102
Sandy clay	9	111

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
43-115-26cad, Clark Moulton--continued		
Teewinot Formation:		
Shells and clay	31	142
Gummy clay	18	160
Clay and gravel	20	180
Silt and gravel	38	218
Hard rock	3	221
Soft clay and gravel	7	228
Clay	18	246
Bentonite	18	264
Chalk rock	17	281
Blue clay and pea gravel	31	312
Bentonite and some gravel	6	318
Blue clay and pea gravel	10	328
Pea gravel and bentonite	7	335
Firm bentonite rock	3	338
Loose bentonite	2	340
Firm bentonite	4	344
Loose bentonite	1	345
Alternately firm and loose bentonite	8	353

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
43-115-29bcc, C. M. Thompson		
Alluvium:		
Soil	5	5
Clay and gravel	7	12
Gravel and some clay	10	22
Gravel	23	45
Gravel; some water	7	52
Pea gravel; good water	8	60
Pea gravel and coarse sand	10	70
Sand, pea gravel, and silt	12	82
Cement gravel and sand; no water	1	83
43-115-30acc, unknown		
Alluvium:		
Clay	5	5
Boulders and clay	12	17
Boulders, gravel, and clay	10	27
Boulders and gravel	3	30
Coarse gravel	5	35
Boulders and gravel	15	50
Cement gravel; good water	3	53
Gros Ventre Formation:		
Tan shale; no water	17	70

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
43-116-11adb, Joseph Clark		
Alluvium:		
Clay and boulders	60	60
Pea gravel	45	105
43-116-14dca, Halfmoon Ranch		
Allvuium:		
Boulders, coarse gravel, and sandy dirt	2	2
Boulders and coarse gravel	5	7
Loose gravel	23	30
Loose gravel; water	10	40
Loose gravel; good water	5	45
Half-inch gravel; good water	15	60

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
43-116-25aad, 4 Lazy F Ranch		
Alluvium:		
Boulders and coarse gravel	15	15
Loose gravel	25	40
Fine sand	5	45
Quicksand	10	55
Sand	10	65
Clay	20	85
Sand	5	90
Clay	10	100
Pasty gray sand	10	110
Sand	12	122
Sand and gravel	4	126
Sandstone	11	137
Sand and gravel	2	139

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
43-116-25ddb, Moose Enterprises		
Alluvium:		
Soil and large boulders	3	3
Boulders and sand	12	15
Gravel and sand	5	20
Cement gravel	5	25
Sand and gravel	10	35
Gravel; water	5	40
Silt	4	44
Gravel; water	6	50
43-116-34ddb, E. Anderson, E. Lemon, and E. Wittmer		
Alluvium:		
No log available	60	60
Sand	10	70
Sand and silt	10	80
Sand, gravel, and silt	20	100
Lacustrine deposits:		
Blue clay	35	135
Green clay	170	305
Brown claystone	15	320
Brown clay	35	355

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
44-114-8ddd, Moose Head Ranch		
Alluvium:		
Gravel and cobbles 1 to 6 inches in diameter; water	38	38
Lacustrine deposits or shale of Cretaceous age:		
Bluish shale	182	220
44-116-14aad, U.S. National Park Service		
Glacial-moraine deposits:		
Gravel and silt	4	4
Gravel and clayey sandy silt; water at 9 feet	6	10
45-113-7dca, Jim Braman		
Alluvium:		
Top soil	8	8
Sandy clay	5	13
Sand and small pea gravel; water	17	30
Rock 1 to 2 inches in diameter; water	3	33

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
45-113-29cba, Ernest Cockrell		
Alluvium:		
Clay	15	15
Muddy sand	25	40
Silt	13	53
Gravel and silt	12	65
Hard gravel	10	75
Silt and gravel	5	80
Hard gravel and boulders	5	85
Hard gravel and silt	5	90
Hard gravel	25	115
Gravel and sand; water	13	128

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
45-114-19baa, U.S. Bureau of Reclamation		
Glacial-moraine deposits:		
Silt and gravel	5	5
Boulders and sand; water	5	10
Gravel and sand	7	17
Bivouac Formation:		
Conglomerate, coarse; contains gravel and cobbles	33	50
Rhyolite, gray and green	74	124
Claystone	7	131
Conglomerate, quartzite gravel in sandy matrix	19	150
Claystone or tuff; contains gravel and cobbles	10	160
Conglomerate, quartzite gravel in sandy matrix; contains basalt fragments	42	202
Sandstone, mostly fine-grained	3	205
Conglomerate, quartzite and volcanic-rock gravel in sandy matrix; contains some clay; water 212-216 feet	11	216

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
45-114-23ccd, Buffalo Fork Entrance Station		
Alluvium:		
Soil	3	3
Gravel, sandy, silty, fine and very fine	10	13
Sand, very fine to coarse, with very fine to fine gravel; very little water	15	28
Gravel, mostly very fine and fine, with sand and coarse gravel; water, yielded 30 gpm	3	31
Lacustrine deposits:		
Sand, very fine to very coarse grained	5	36
Sand and gravel; water, yielded 5 gpm	8	44
Clay, silty and sandy	5	49
Shale of Cretaceous age:		
Clay, dark-brown to black; contains fragments of coal	3	52
Shale, silty and sandy, dark-bluish-gray; contains fragments of coal	3	55

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
45-115-25bca, Signal Mountain Lodge		
Glacial-moraine deposits:		
Gravel, sand, silt, and clay, unsorted	59	59
Sand, fine- to coarse-grained and fine and medium gravel; water, yielded 15 gpm 46 to 60 feet	1	60
Sand, very fine and fine-grained	4	64
Sand, coarse and fine gravel; water, yielded 15 gpm	1	65
Sand, medium-grained to very coarse grained and fine gravel; water, yielded 10 gpm	3	68
Sand, medium-grained to very coarse grained; water, yielded 30 gpm	2	70
Sand, medium-grained to very coarse grained; unsorted; very little water	20	90
Clay, silt, and sand, unsorted	40	130
Sand, very fine to very coarse grained, with some gravel, unsorted; some water	5	135
Sand, medium-grained to very coarse grained, poorly sorted	24	159
Sand, very coarse and fine gravel, well sorted; water, yielded 20 gpm	1	160
Sand, very fine to very coarse grained, fairly to poorly sorted; very little water	46	206

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
46-114-29adc, U.S. National Park Service		
Alluvium:		
Gravel, sand, silt, and clay with some cobbles-------	12	12
Sand, very fine to very coarse grained, with fine gravel; water, yielded 15 gpm----------------------	9	21
Sand, very fine to very coarse grained, with fine and medium gravel; water, yielded 30 gpm 31-36 feet---	18	39
Sand, coarse-grained and very coarse grained, and fine gravel, fairly sorted------------------------	16	55
Sand, very fine to very coarse grained, poorly sorted	5	60
Sand, medium-grained and very fine gravel, well sorted; contains black and red grains---------------------	3	63
Clay, sand, and very fine gravel; contains black and red grains---------------------------------------	3	66
Sand, very fine to very coarse grained, with some fine gravel; contains mostly black and red grains; water, yielded 20 gpm-----------------------------	4	70
Colter Formation:		
Clay, light-gray and white; contains black and red grains---	5	75
Sand, gravel, and clay, light-gray and white; contains black and red grains---------------------	8	83
Clay and sand, light-gray and white; contains black and red grains-----------------------------	14	97

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
46-114-29dbc, U.S. National Park Service		
Alluvium:		
Gravel, sand, silt, and clay, unsorted; cobbles above 20 feet; some water 31-36 feet	36	36
Sand, very fine to very coarse grained, and fine gravel; water, yielded 20 gpm 36-38 feet	6	42
Gravel, very fine to medium; water, yielded 40 gpm	6	48
Sand, very fine to very coarse grained, and medium gravel; water, yielded 30 gpm 52-53 feet, yielded 20 gpm 56-57 feet	14	62
Sand, very fine to very coarse grained, and very fine gravel, silty, clayey	22	84
Gravel, sand, silt, and clay, poorly sorted	2	86
Sand, very fine grained to very coarse grained, and fine gravel, fairly sorted	7	93
Sand, very fine to very coarse grained, with silt, clay, and gravel, poorly sorted	7	100

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
46-114-29dca, Pilgrim Creek well		
Alluvium:		
Gravel, sand, silt, and clay, unsorted	11	11
Sand, very fine to very coarse grained, and very fine gravel; yielded some water 15-20 feet	9	20
Sand, medium-grained to very coarse grained, and fine gravel; yielded some water	11	31
Sand, medium-grained to very coarse grained, and fine to coarse gravel; water, yielded 50 gpm	5	36
Sand, very fine to very coarse grained, and very fine gravel; water, yielded 25 gpm 39-42 feet, and 30 gpm 49-54 feet	21	57
Sand, coarse-grained and fine gravel; water, yielded 20 gpm 57-59 feet	11	68
Sand, very fine to very coarse grained, and very fine and fine gravel; contains streaks of clay; water, yielded 20 gpm 72-73 feet, 30 gpm 78-79 feet, 60 gpm 86-90 feet, 30 gpm 95-96 feet, 20 gpm 110-114 feet, 25 gpm 110-119 feet, 30 gpm 126-130 feet, 10 gpm 133-134 feet, 10 gpm 147-151 feet	83	151
Sand fine- and coarse-grained, and pea gravel	34	185
Gray quicksand	7	192
Gray quicksand and gravel	9	201

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
46-115-22add, AMK Ranch		
Glacial-moraine deposits:		
Gravel and boulders	15	15
Clay and gravel	5	20
Gravel	30	50
Cement gravel	5	55
Cement gravel and boulders	5	60
Gravel; some water	5	65
Gravel	25	90
Cement gravel	7	97
Gravel	2	99
Gravel; water	4	103
Cement gravel	7	110
Gravel	4	114
Gravel; water	1	115
Cement gravel	2	117
Gravel; water	3	120
Cement gravel	20	140
Gravel; water	2	142
Silt and gravel	2	144
Gravel; water	5	149

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
46-115-34ddc, U.S. National Park Service		
Gravel and cobbles	3	3
Clay, sandy, brown; damp	1	4
Gravel, clayey	1	5
Sand and gravel, clayey; sand is medium to very coarse grained; gravel is fine to coarse; water below 10 feet	17	22
Sand and gravel, slightly clayey; sand is medium to very coarse grained; gravel is fine to medium	4	26
Gravel(?); unable to sample	12	38
Sand and gravel, clayey	5	43
Sand and gravel, clayey, silty	2	45

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
47-115-29dca, U.S. National Park Service		
Glacial-moraine deposits:		
Top soil--	2	2
Gravel, sand, silt, and clay, unsorted---------------	15	17
Sand, silt, and clay; contains gravel and boulders---	11	28
Gravel, sand, silt, and clay, unsorted---------------	1	29
Boulders, sand, silt, and clay-----------------------	3	32
Alluvium:		
Gravel, sand, silt, and clay, unsorted---------------	10	42
Sand, silt, clay, and very fine gravel---------------	7	49
Clay, silt, sand, and gravel, unsorted---------------	3	52
Sand, very fine to fine gravel, with clay, fairly sorted; water, yielded 5 gpm----------------------	2	54
Sand, very fine to very coarse grained, and very fine gravel, with clay and silt-------------------	15	69
Sand, medium-grained to very coarse grained, with very fine gravel; water, yielded 20 gpm------------	9	78
Frontier Formation:		
Clay, very fine grained to very coarse grained sand, and very fine gravel, greenish-gray; no water------	5	83

Table 2.--Logs of selected wells--continued

Lithology and hydrology	Thickness (feet)	Depth (feet)
47-115-32abb, Lizard Creek campground		
Alluvium:		
Top soil	3	3
Clay, very fine to very coarse grained sand, and very fine gravel	39	42
Sand, medium-grained to very coarse grained, and very fine to fine gravel; water, yielded 20 gpm	4	46
Sand, very fine grained to very coarse grained, with a little very fine gravel, poorly sorted	4	50
Clay, silt, very fine to very coarse grained sand, and very fine gravel	5	55
Sand, fine-grained to very coarse grained, and very fine gravel; water, yielded 50 gpm	13	68
Sand, fine-grained to very coarse grained, with very fine and fine gravel, clayey; water, yielded 10 gpm	4	72
Sand, very fine to very coarse grained, and very fine gravel, poorly sorted; water, yielded 20 gpm	24	96
Sand, very fine to very coarse grained, with some very fine gravel; water, yielded 6 gpm	5	101