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GEOLOGICAL SURVEY CIRCULAR 188

RECONNAISSANCE OF THE GEOLOGY AND GROUND-WATER RESOURCES OF THE PASS CREEK FLATS AREA CARBON COUNTY, WYOMING

By F. N. Visher

WITH A SECTION ON THE CHEMICAL QUALITY OF THE WATER

By W. H. Durum

UNITED STATES DEPARTMENT OF THE INTERIOR
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GEOLOGICAL SURVEY
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for Development of the Missouri River Basin

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RECONNAISSANCE OF THE GEOLOGY AND GROUND-WATER RESOURCES OF THE PASS CREEK FLATS AREA CARBON COUNTY, WYOMING

WITH A SECTION ON THE CHEMICAL QUALITY OF THE WATER

ABSTRACT

The area described in this report is in the central part of Carbon County, Wyo., and covers about 170 sq mi. A reconnaissance of the geology and ground-water resources of the Pass Creek Flats area was made to determine the possibilities of developing ground-water supplies for irrigation.

Formations ranging in age from Late Cretaceous to Recent are exposed in the Pass Creek Flats area. The Mesaverde formation of Late Cretaceous age underlies all of the surface in the western part of the area with the exception of a small area that is underlain by the Lewis shale, also of Late Cretaceous age. The North Park formation of Tertiary (Pliocene?) age underlies the surface in the central and eastern parts. Alluvium of Quaternary age underlies the valley floor of the streams that border most of the area, and terrace deposits border the alluvium in many places. Much of the upland is mantled by thin pediment deposits and slope wash.

No water is developed in the Pass Creek Flats area from the Lewis shale and the Mesaverde formation; however, saturated sandstone beds in the Mesaverde formation probably would yield small quantities of water to wells. The North Park formation ranges in thickness from a feather edge to about 1,700 ft and consists mainly of fine sand and silt. Although the formation yields sufficient water for domestic and stock use, it would be difficult to develop large amounts of water from it. The alluvium consists of sand and gravel and where saturated yields small quantities of water to wells; however, its small thickness precludes the economical development of large amounts of water from it.

The depth to the water table ranges from a few feet to more than 100 ft below the land surface; in the alluvium it is generally less than 10 ft.

Several large springs issue from fault zones in the North Park formation. If wells could be drilled into these fault zones, large supplies of water probably could be developed; however, these fault zones generally are not apparent on the land surface and thus would be difficult to locate.

Except for being hard, the water from both the North Park formation and from the alluvium is of satisfactory quality for irrigation and domestic use. Percentages of sodium were less than 35, and the quantities of boron, fluoride, and nitrate were negligible in samples analyzed for this study. For five samples from the North Park formation, the dissolved solids ranged from 242 to 820 ppm. The hardness of the water was high, ranging from 150 to 451 ppm as calcium carbonate. Dissolved solids in five samples of water from the alluvium ranged from 322 to 638 ppm and hardness ranged from 184 to 401 ppm. The water of low mineral content was the calcium carbonate type, whereas the more mineralized water was the calcium sulfate type.

Ground water that drains to Pass Creek carries a higher concentration of sulfate than does direct inflow water to the North Platte River.

INTRODUCTION

Purpose and scope of the investigation

The purpose of this study was to determine the possibilities of developing ground-water supplies for irrigation in the Pass Creek Flats area. This investigation is one of several that are being made by the United States Geological Survey as a part of the program of the Department of the Interior for the control, conservation, development, and use of the water resources of the Missouri River basin (fig. 1).

The field work upon which this report is based was done from July to October 1950. The work was under the general supervision of A. N. Sayre, chief of the Ground Water Branch, U. S. Geological Survey; G. H. Taylor, regional engineer in charge of ground-water investigations in the Missouri River basin; and S. W. Lohman, district geologist for Colorado and Wyoming; it was under the immediate supervision of H. M. Babcock, engineer in charge of ground-water studies in the North Platte River basin. The quality-of-water studies were under the general supervision of S. K. Love, chief of the Quality of Water Branch, and under the immediate supervision of P. C. Benedict, regional engineer in charge of Missouri River basin water-quality investigations.

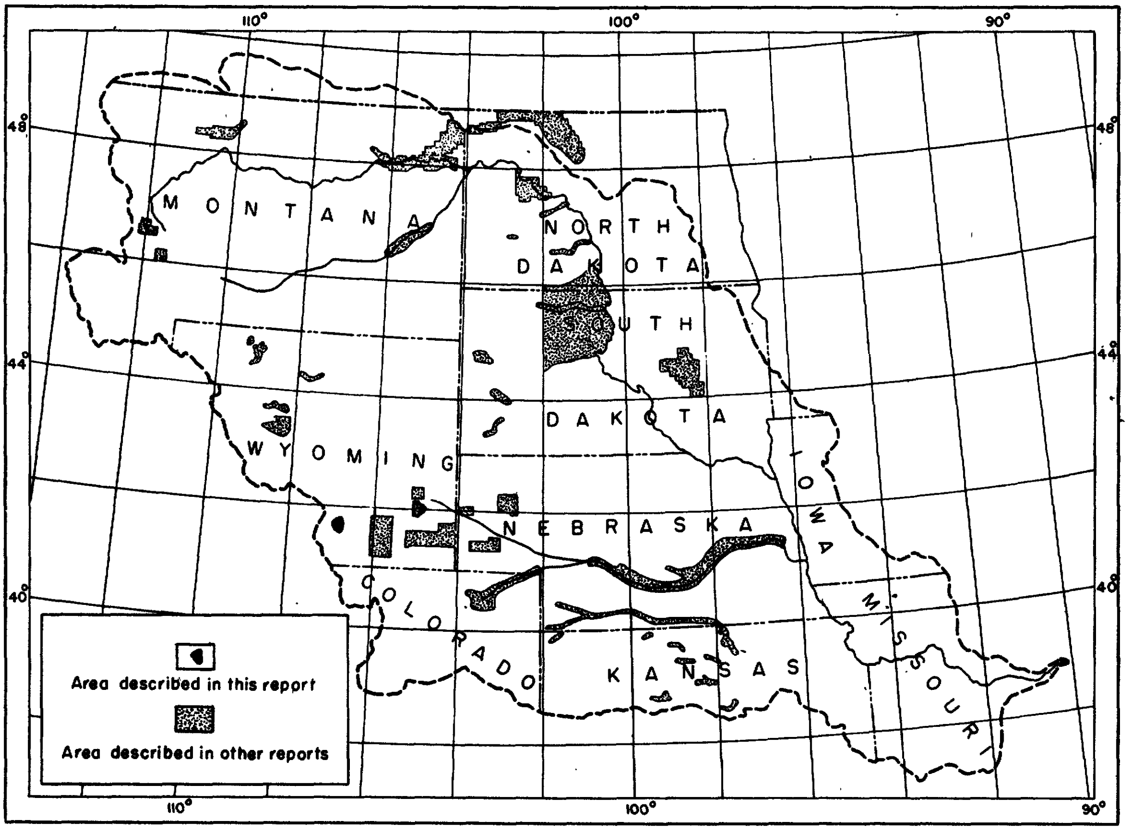

Figure 1. Map of the Missouri River drainage basin showing areas in which ground-water studies have been made under the Missouri Basin development program.

Location and extent of area

The area covered by this report is in the central part of Carbon County in south-central Wyoming. (See fig. 2.) It lies within Tps. 18, 19, and 20 N., Rs. 83 and 84 W., of the sixth principal meridian and base line system and covers about 170 sq mi. The area is bounded on the north and east by Pass Creek, on the west and southwest by the North Platte River, and on the south by Lake Creek. Pass Creek Flats proper is in the northeastern part of the mapped area. (See pl. 1.) Saratoga & Encampment Valley Railroad crosses the area. State Route 130, which runs north-south, is the only paved road. Several county roads, some of which are graveled and maintained throughout the year, traverse the remainder of the area.

Methods of investigation

Well drillers and well owners were contacted to obtain available information on 25 wells and springs in the area. (See table 5.) Most of the information obtained was from memory and did not pertain to the yield and drawdown of the wells. Fourteen of the wells were measured with a steel tape to determine their depth and the depth to water below some fixed measuring point, generally the top of the casing. Reported data are listed for those wells that could not be measured. Five representative wells were selected for periodic observations of water levels to obtain information concerning the seasonal fluctuations of the water table. Chemical analyses were made of 13 water samples that were collected from representative wells and springs and from surface waters.

The geologic and hydrologic field data were recorded on aerial photographs. The map of

The well number shows the location of the well by township, range, section, and position within the section. The first numeral of a well number indicates the township, the second the range, and the third the section in which the well is located. The lower-case letters following the section number locate the well within the section. The first letter denotes the quarter section, the second the quarter-quarter section, and the third the quarter-quarter-quarter section (10-acre tract). The subdivisions of the section are lettered a, b, c, and d in a counterclockwise direction, beginning in the northeast quarter. Two or more wells within a 10-acre tract are distinguished by adding to the well number consecutive numbers beginning with 1.

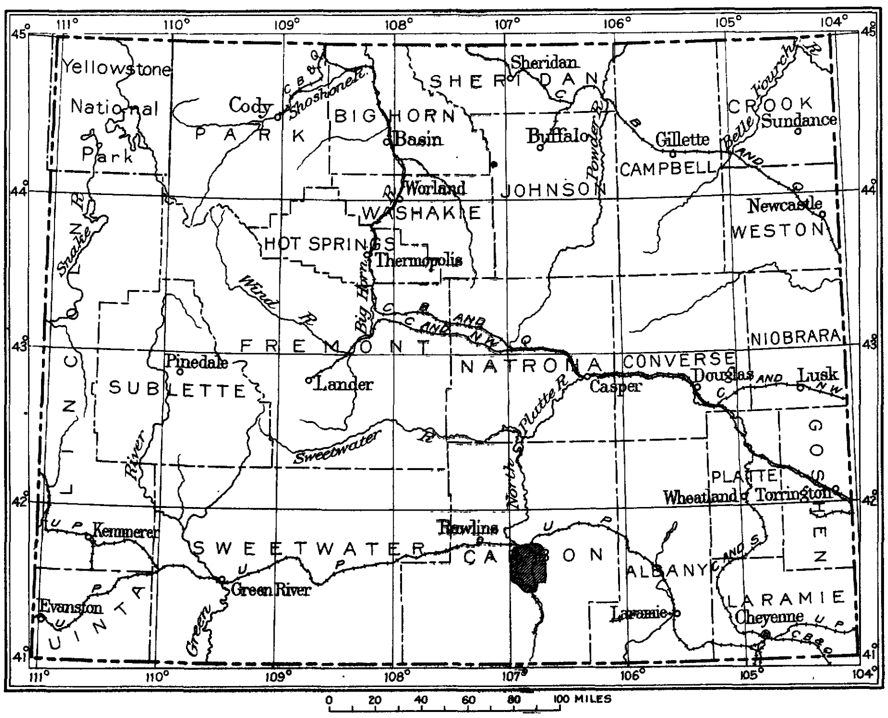

Figure 2. Index map of southeastern Wyoming showing the location of the Pass Creek Flats area.

the area (pl. 1) was compiled from these photographs and from a map prepared by the Wyoming State Highway Department.

The wells and springs that are shown on the map were located within the sections by use of an odometer and by inspection of aerial photographs; their locations are believed to be accurate within 0.1 mile.

Well-numbering system

The wells and springs are numbered according to their location within the Bureau of Land Management system of land subdivision.

A graphical illustration of this well-numbering system is shown in figure 3.

Previous investigations

A study of the geology and coal deposits of east-central Carbon County, Wyo., was made by Veatch (1907).[1] Beckwith (1941) mapped the structure and geology of the Elk Mountain district east of the Pass Creek Flats area. These reports proved helpful during the investigation and aided in the preparation of this report.

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

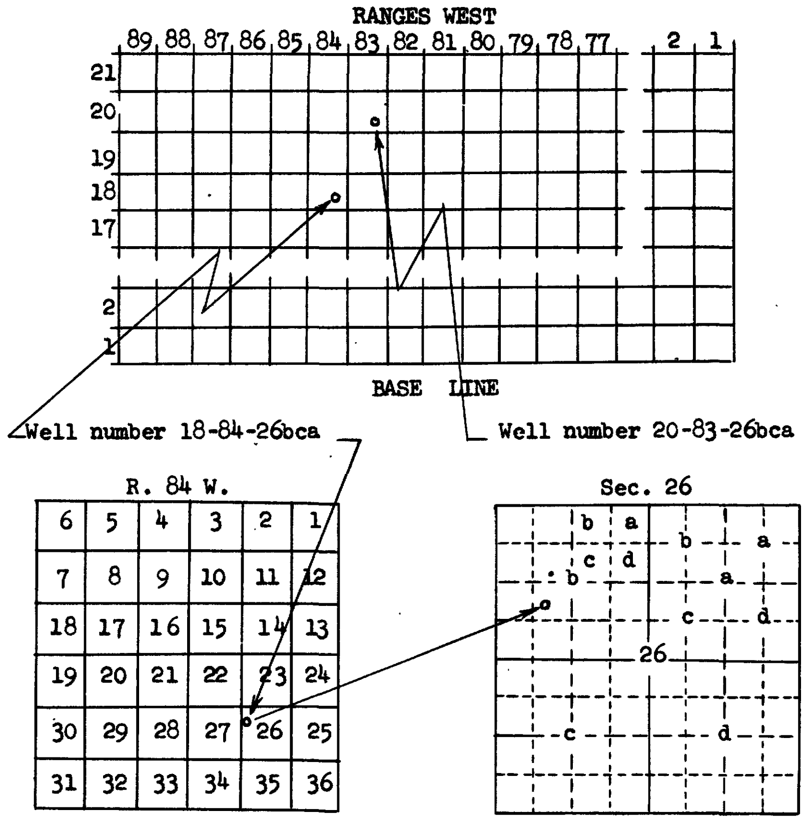

Figure 3. Sketch showing well-numbering system.

GEOGRAPHY

Topography and drainage

The area described is in the northeastern part of the Saratoga Valley, which is included in the Wyoming Basin physiographic province. Immediately to the east is the northern extension of the Medicine Bow Mountains. The highest point, which is in the southern part of the area, is about 7,300 ft above sea level; the lowest point, where Pass Creek joins the North Platte River, is about 6,550 ft above sea level. The total relief, therefore, is about 750 ft.

The high land in the central part of the mapped area consists of a series of broad, flat, east-dipping cuestas. (See fig. 4.) The most eastern of them has a long convex slope, which merges with the broad flood plain of Pass Creek. This slope and the flood plain locally are called Pass Creek Flats. West of the central high land, the cuestas give way to steep slopes and bluffs along the North Platte River.

The area is drained by the North Platte River and two perennial tributaries, Pass Creek and Lake Creek. The North Platte River enters the area from the south, flows in a northwesterly direction for about 10 miles along the southwestern side of the area, and then turns and flows northeastward. The average gradient of the North Platte River in this area is about 8 ft to the mile. Pass Creek enters the area from the east, flows in a northerly direction for about 10 miles, and then swings toward the west and flows to its confluence with the North Platte River. Lake Creek, which drains the southeastern part of the area, flows southwestward to its confluence with the North Platte River.

Climate

The Pass Creek Flats area has a cool arid climate that is characterized by low precipitation, high evaporation, and a wide range in temperature. Usually the summers are mild and the winters are very cold. The average length of the growing season is about 90 days.

The U. S. Weather Bureau has kept climatological records in the area since 1893. According to these records, the normal annual precipitation is 11.10 in. at Saratoga, which is 3 miles south of the area. These records have not been kept continuously, and only the precipitation for years of complete record is shown in figure 5. During the period of

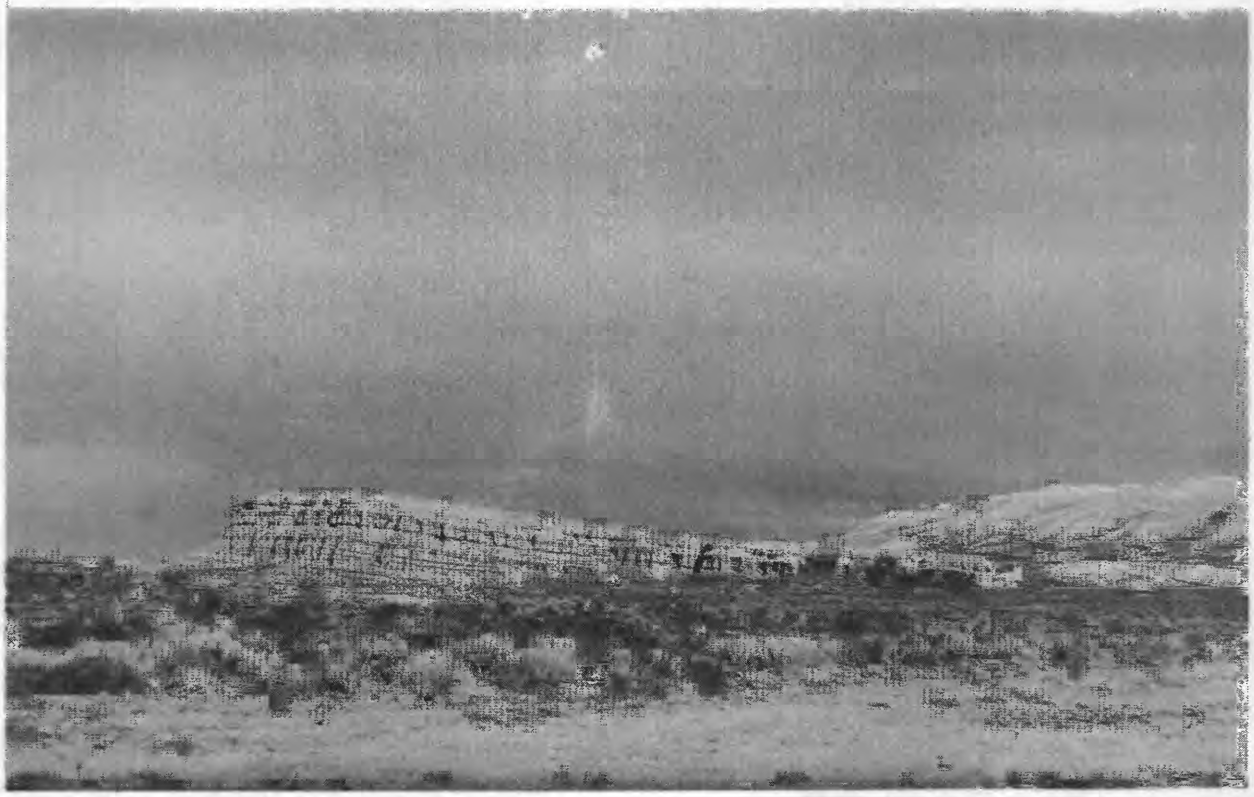

Figure 4. A small eastward-dipping cuesta formed by resistant beds of the North Park formation, in the northwest corner of sec. 9, T. 18 N., R. 84. (Photograph by J. R. Rapp.)

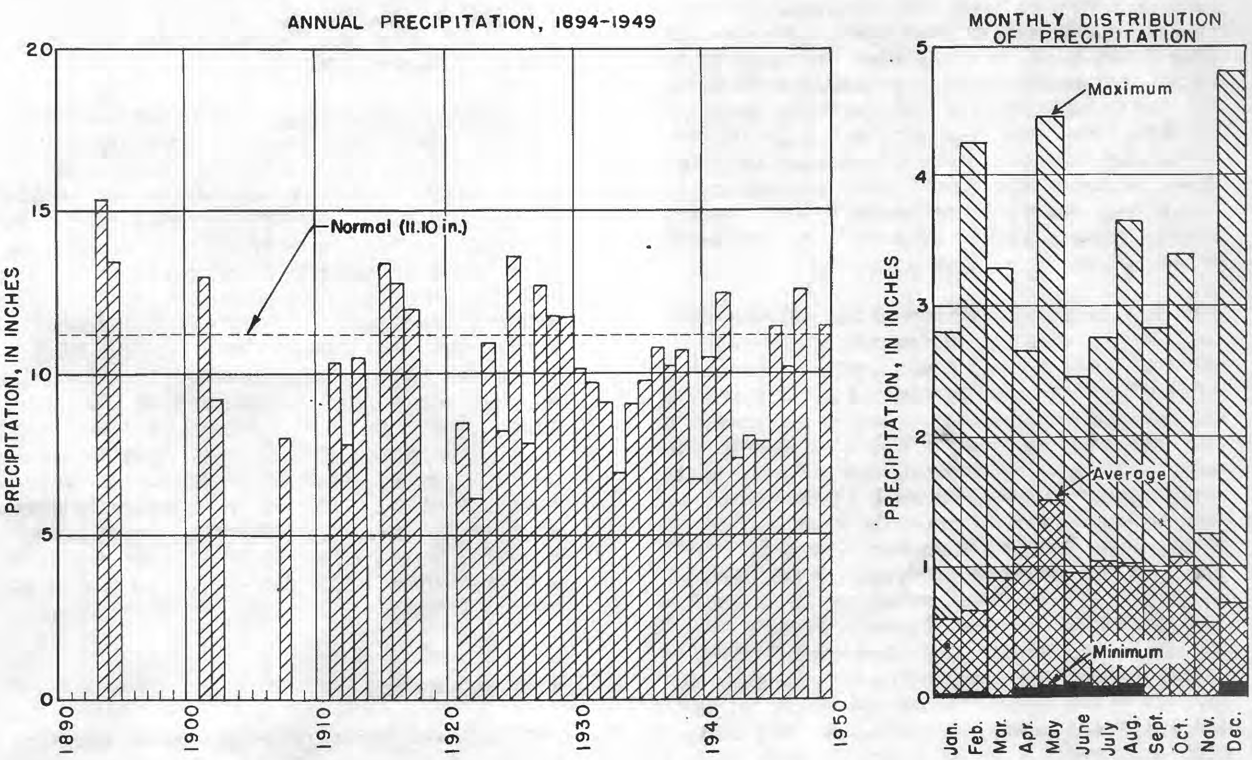

Figure 5. Precipitation records at Saratoga, Wyo., 1894-1949. (From records of the U. S. Weather Bureau.)

record, the annual precipitation ranged from a minimum of 6.44 to a maximum of 15.24 in.

The mean annual temperature at Saratoga is 40.1 F. The highest temperature on record is 103 F and the lowest is -55 F.

Agriculture

The principal occupation is the raising of livestock; most of the land is used for grazing. Some of the land along the streams is used to grow winter feed for livestock. Small diversions for irrigation were made from the North Platte River as early as 1875, and development has since spread over practically all the easily irrigable land along the principal water courses. The irrigation systems consist of inexpensive rock and brush diversion dams and relatively small and easily constructed gravity ditches. The principal crop is hay which, owing to a short growing season, usually yields only one cutting a year. Although dry farming is not common in this area, several thousand acres of land were broken and planted with wheat in 1949 and 1950. This operation is reported to have been successful financially.

GEOLOGY AND GROUND WATER

Land forms

The Wyoming Basin was filled with sediments that were eroded from the surrounding Rocky Mountains during Tertiary time. Because the Pass Creek Flats area is near the edge of the basin, sediments did not accumulate there until the latter part of the Tertiary period. At this time, the fine sand and silt of the North Park formation were deposited on truncated folds of the Cretaceous sedimentary rocks that underlie the basin floor. Later, diastrophism slightly deformed the sediments of the North Park formation.

At the close of Tertiary time streams had established courses across the surrounding mountain ranges, which by then were almost buried in their own debris. Regional uplift during Pleistocene time caused the streams to cut down into the ranges and to excavate the basin filling. Ultimately the Tertiary sediments were removed from much of the area, and the streams cut deep into the older formations. The down cutting was sporadic. At times of comparative stability gravel-mantled pediments, which were graded to the temporary base level of the stream, were formed. During one halt in down cutting, the North Platte River developed a meandering course that is now preserved as entrenched meanders in areas where it was flowing on the older and more resistant rocks. In late Pleistocene time, the streams alternately eroded and deposited, thereby producing a series of terraces, the highest of which is about 100 ft above the present grade of the streams in the area.

Geologic formations and their relation to ground water

Pre-Tertiary rocks

The Pass Creek Flats area is underlain by a considerable thickness of pre-Tertiary sedimentary rocks that lie on granite and other crystalline rocks of pre-Cambrian age. These sedimentary rocks range in age from Cambrian to Late Cretaceous; however, only the Mesaverde formation and the Lewis shale of Late Cretaceous age are exposed in the mapped area. A generalized section of the geologic formations in the area has been adapted from Beckwith (1941, p. 1452) and is given in table 1. The Lewis shale is exposed locally along the northwest margin of the area but does not underlie the area. It is included in the table but otherwise will not be discussed.

The "Dakota sandstone" of Early Cretaceous age and the Sundance formation of Late Jurassic age were reported to have contained water in an oil test well 19-83-28bcb. No information regarding the quantity or quality of the water that was found in these formations is available. In some places west of the North Platte River, where the Mesaverde formation and younger rocks are not present, the shallowest available potable water reportedly is in the "Dakota sandstone" at a depth of about 4,000 ft.

Mesaverde formation.--The Mesaverde formation of Late Cretaceous age consists mainly of brown, gray, and white sandstone and light-gray to carbonaceous shale and includes a few thin coal beds in the upper part. The presence of coal beds indicates that the upper part of the formation is of continental origin and the lower part of marine origin. Massive sandstone members of the formation form bluffs that are several hundred feet high along the North Platte River. The formation is exposed in the western part of the mapped area. The beds of the formation form a part of a large open syncline that plunges northwest by north. Virtually the entire thickness--about 3,500 ft--of the Mesaverde formation is thought to be exposed in the area. No wells penetrating the Mesaverde formation were recorded; saturated sandstone beds, however, probably would yield water to wells.

Tertiary system

North Park formation.--The North Park formation of Pliocene (?) age is composed largely

Table 1.--Generalized section of the geologic formations in the Pass Creek Flats area, Wyo.

[Adapted from Beckwith (1941, p. 1452)]

System	Series	Formation	Physical character	Maximum thickness (feet)	Water supply
Quaternary.	Recent.	Alluvium.	Silt, sand, and gravel.	20	Supplies water to domestic and stock wells.
	? Pleistocene.	Terrace deposits.	.......do........................	20	Generally lies above water table; serves as infiltration area for recharge from precipitation.
Tertiary.	Pliocene (?)	North Park formation.	Fine sand intermixed with some silt and clay; contains thin beds of sandstone, volcanic ash, limestone, and chert.	1,700	Supplies water to domestic and stock wells.
Cretaceous.	Upper Cretaceous.	Lewis shale.	Predominantly dark-gray shale.	3,000	Ground-water possibilities not known, but probably poor.
		Mesaverde formation.	Brown, gray, and white sandstone interbedded with light-gray to carbonaceous shale. Thin coal beds in the upper part.	3,500	Ground-water possibilities not known, but sandstone beds should yield water.
		Steele shale.	Predominantly dark-gray shale.	3,100	Yields little or no water.
		Niobrara formation.	Buff shaly limestone units at the top, near the middle and at the base; separated by beds of gray to black shale.	700	Ground-water possibilities not known.
		Carlile shale.	Dark-gray to black shale.	420	Do.
		Frontier formation.	Predominantly black shale. The Wall Creek sandstone member, about 30 ft thick, is at the top.	650	Do.
	Lower Cretaceous.	Mowry shale.	Black siliceous shale.	165	Do.
		Thermopolis shale.	Dark-gray shale with thin sandy beds. Locally, at the top of the formation is a thin sandstone ("Muddy sand").	110	Do.
		Cloverly formation.	Upper unit of locally quartzitic sandstone ("Dakota sandstone"); middle unit of gray and green sandy shale; lower unit of conglomeratic sandstone.	130	Contains water of varying quality.
Jurassic.	Upper Jurassic.	Morrison formation.	Shale of various colors containing thin beds of sandstone and fresh-water limestone.	300	Ground-water possibilities not known.
		Sundance formation.	Upper part consists of green shale and shaly sandstone; lower part consists of massive white sandstone grading downward into alternating white and red sandstone beds.	280	Contains water of unknown quality.
Triassic.		Jelm formation.	Coarse-grained, thin-bedded maroon and white sandstone beds. Lenses of maroon conglomerate with fragments of limestone and red shale.	150	Ground-water possibilities not known.
? Permian.		Chugwater formation.	Brick-red shale and shaly sandstone.	850	Do.
Carboniferous.	Pennsylvanian.	Tensleep sandstone.	Buff, cross-bedded sandstone.	300	Do.
		Fountain formation.	Beds of red sandstone, shaly sandstone, white limestone, and pink arkosic grit.	150	Do.
	Mississippian.	Madison limestone.	White massive limestone.	40	Do.
Cambrian.			Local lenses of gray quartzite.	0-15	Do.
Pre-Cambrian.			Pink potash granite, gray to pink injected gneiss, black and green schist, and metadiabase.		Would not be expected to yield water.

of fine sand that is intermixed with some silt and clay. The formation also contains thin sandstone layers, and a few thin beds of volcanic ash, limestone, and chert. Locally, at the base of the formation and near the mountains, the fine material is admixed with coarse angular sand and gravel. The North Park formation is exposed throughout the central and eastern part of the mapped area. It unconformably overlies the older rocks and has a dip to the east that ranges from 4° to 11°. In the northern part of the mapped area is a north-trending normal fault, with the downthrown side on the west. The formation is mantled with Quaternary deposits in much of the area, and no structure can be observed. The thickness of 1,700 ft of the formation that was penetrated in oil test well 19-83-28bcb is probably about its maximum thickness in the area.

The North Park formation is the most extensive aquifer in the area. It yields sufficient water for domestic and stock use; however, because this formation is fine-grained and is not very permeable, the development of large amounts of water from it would be difficult. Also, the fine sand and silt of the formation tend to enter and fill the wells.

Three springs, which are shown on plate 1, issue from the North Park formation. Spring 20-84-16dda issues from a fault zone, and the other springs probably also issue from fault zones. Spring 18-83-30ca is reported to flow about 1,300 gpm, spring 19-83-10bdb was estimated to flow about 500 gpm, and spring 20-84-16dda was estimated to flow about 100 gpm. The only possible locations for the development of sufficient quantities of water for irrigation would be along the fault zones; the location of these fault zones, however, is extremely difficult, because in most places they lack surface expression.

Quaternary system

Quaternary deposits in the Pass Creek Flats area include a series of stream-laid terrace deposits, which are at different levels above the streams; alluvium, which underlies the flood plains of the present streams; and pediment deposits and slope wash, which form a thin mantle over much of the area. Inasmuch as the pediment deposits and slope wash are of little hydrologic importance, only the alluvium and the terrace deposits are shown on the map. The contact between the terrace and pediment deposits is gradational; therefore, some of those that are shown as terrace deposits may be pediment deposits.

Terraces.--The terrace deposits are of Pleistocene age and consist of sand, gravel, and silt. They occur in the valleys of the North Platte River and its principal tributaries. The terrace deposits along the tributaries are thin, extend only over small areas, and are difficult to identify; hence only the thicker, more extensive deposits that occur along the North Platte River were mapped. Each of the several terraces is a remnant of a former flood plain that was formed by a period of lateral cutting and deposition and a subsequent period of down cutting and erosion. At the beginning of each new period of down cutting, the river tended to occupy the right side of its flood plain; thus most of the remnants of the terraces are on the left-hand or west side of the river. This tendency of the stream to occupy the right-hand side of its flood plain is thought to be caused by the earth's rotation, which deflects streams to the right in the northern hemisphere.

The terrace deposits along the North Platte River range in thickness from a feather edge to more than 20 ft; the deposits along the tributary streams generally are less than 5 ft thick. The terrace deposits generally are above the water table; hydrologically they serve chiefly as infiltration areas for precipitation.

Alluvium.--The alluvium of Pleistocene and Recent age, which underlies the flood plains of the North Platte River and its tributaries, is composed of silt, sand, and gravel. In general the alluvium is wide where the streams flow across the poorly consolidated sediments of the North Park formation and is narrow where they flow across the more resistant rocks of Cretaceous age. The alluvium along the North Platte River ranges in width from about ¼ mile to about 1½ miles, and that along Pass Creek ranges in width from about ¼ mile to about 1 mile. The alluvium along the North Platte River is about 20 ft thick where the highway bridges cross the river at Saratoga, which is about 3 miles south of the area, and at Fort Steele, which is about 5 miles north of the area.

The alluvium yields adequate quantities of water for domestic and stock use. About half the wells in the area obtain water from the alluvium for these purposes. Because of the small saturated thickness of the material it would be difficult to develop sufficient water for irrigation.

Physical and hydrologic properties of the North Park formation

The quantity of water that a material will yield to wells and the rate at which water will move through the material depend upon the physical and hydrological properties of

Table 2.--Physical and hydrologic properties of samples of the North Park formation

Location	Mechanical analyses (percent by weight)					Porosity (percent by volume)	Specific yield (percent by volume	Coefficient of permeability (gpd per sq ft)
	Medium sand (0.50-0.25 mm)	Fine sand (0.25-0.125 mm)	Very fine sand (0.125-0.0625 mm)	Silt (0.0625-0.004 mm)	Clay (less than 0.004 mm)			
SE¼ sec. 9, T. 18 N., R. 84 W.............	1.0	10.1	50.8	32.1	6.0	35.5	16.4	0.9
NE¼ sec. 14, T. 18 N., R. 84 W.............	.1	3.9	67.5	18.5	10.0	36.0	22.3	4
Do................	.1	24.5	47.4	19.2	8.8	30.8	19.0	5
Average.......	.4	12.8	55.2	23.3	8.3	34.1	19.2	3.3

the material. In order to determine these properties of the North Park formation, analyses were made of three representative samples that were collected from fresh exposures of the formation in road cuts within the area. Quantitative analyses of the samples were made under the supervision of A. I. Johnson in the hydrologic laboratory of the U. S. Geological Survey in Lincoln, Nebr. These analyses included mechanical analysis and the determination of the coefficient of permeability, the porosity, and the specific yield. The results of the analyses are summarized in table 2.

Mechanical analyses

A mechanical analysis of granular material consists of separating the grains of different sizes into groups and determining what percentage, by weight, each size group constitutes of the total sample. Grain sizes smaller than 0.0625 mm were determined by the hydrometer method of wet analysis, and sizes larger than 0.0625 mm were determined by wet sieve analysis. The average percentages in the three analyzed samples are 0.4 percent medium sand, 12.8 percent fine sand, 55.2 percent very fine sand, 23.3 percent silt, and 8.3 percent clay.

Porosity

The porosity of a rock or rock aggregate is its property of containing interstices without regard to size, shape, or arrangement of the openings. Porosity is expressed quantitatively as the percentage of the total volume of the rock that is occupied by interstices. In a saturated rock, the porosity is practically the percentage of the total volume of the rock that is occupied by water. The porositites of the samples range from 30.8 to 36.0 percent by volume and average 34.1 percent.

Specific yield

The specific yield of a water-bearing material is defined as the ratio of the volume of water that a saturated aquifer will yield by gravity to its own volume. The specific yield of a material is equal to the porosity minus the specific retention, which is the quantity of water that a material will retain against the pull of gravity if it is drained after having been saturated. The specific retention is expressed as the ratio of the retained water to the total volume of the material. The specific yields of the tested samples range from 16.4 to 22.3 percent and average 19.2 percent--that is, a cubic foot of the saturated material, if allowed to drain for a long period, will yield about 0.192 cu ft of water.

Permeability

The coefficients of permeability of the samples were determined by using a variable head permeameter. Laboratory methods similar to those used in determining permeability of these samples have been described by V. C. Fishel (Wenzel, L. K., 1942, pp. 59-68). Samples used were in a disturbed condition. The coefficients of permeability range from 0.9 to 5 and average 3.3--that is, 3.3 gpd of water at 60 F would percolate through a cross section 1 mile wide and 1 ft thick under a hydraulic gradient of 1 ft to the mile.

Occurrence, source, and movement of ground water

Ground water in the Pass Creek Flats area occurs in the pore spaces of the materials that underlie the area. The depth below which these materials are saturated--that is, the depth to the water table--ranges from a few feet to more than 100 ft below the land surface. In the alluvium that underlies the flood plain of the streams, the water level is generally within 10 ft of the surface.

Recharge to the ground-water reservoir in the area is derived from precipitation that falls as rain or snow and from seepage from irrigation. Part of the total precipitation is discharged as surface runoff, part is used by growing plants, part is evaporated, and tne remainder percolates to the water table. The percentage of the precipitation that reaches the water table is probably very small. A large amount of irrigation water percolates to the water table in the irrigated areas.

Ground water moves from areas of high altitude or head to areas of low altitude or head in the direction of the hydraulic gradient, and, if all other factors are constant, the rate of movement is proportional to the gradient. Generally the direction of movement in this area is toward the streams. In the northern part ground water in the North Park formation moves northwest toward the lower end of Pass Creek. In the southern part the movement of ground water is to the southwest toward Lake Creek and the North Platte River. No information is available on the movement of ground water in the Mesaverde formation, but the movement probably is down dip.

Ground-water discharge

Ground water is discharged by evaporation and transpiration through springs, as surface flow in stream channels, and from wells. No attempt was made to determine the amounts of water that were discharged by these various processes. The amount of water that is discharged by evaporation and transpiration varies with the season; the rates of both are greatest during the growing season, when the temperatures are highest. The amount of evaporation and transpiration is probably large in areas where seepage from irrigation has caused the water table to be near the surface. Ground water is discharged from springs and as surface flow in stream channels throughout the year; the amount discharged by wells is small. No irrigation wells and only a few domestic and stock wells are in the area.

Fluctuations of water levels

Water levels rise when the amount of water that reaches the water table from precipitation and irrigation exceeds the amount that is discharged from the ground-water reservoir, and conversely water levels fall when discharge exceeds recharge. In the part of the area that is not irrigated, the precipitation entering the ground during the growing season is used by the plants or is held in the soil --hence very little of this moisture reaches the water table. During the nongrowing season, however, the plants do not use water, and the water levels may rise. In the irrigated area the water levels rise during the early part of the irrigation season. Toward the end of the irrigation season, the water levels fall rapidly owing to the large withdrawal of ground water by evaporation and transpiration. When the plants are dormant, the recharge from precipitation exceeds the discharge and water levels rise again. There is a pronounced rise of the water table during the spring because of the rather sudden addition of water to the ground-water reservoir as the ground thaws out. In the spring, as the frost leaves the ground progressively from the surface downward, the ground becomes saturated with water from the rains and melting snow. When the last of the frost disappears this perched water generally sinks rapidly and causes a sharp rise of the water table.

Five wells were selected for the regular measurement of ground-water levels in the area; water-level measurements for these wells are given in table 3.

Table 3.--Water levels in observation wells in the Pass Creek Flats area, Wyo.

[Feet below land surface]

18-84-7dad

Date	Water level	Date	Water level
July 26, 1950	7.76	Apr. 26, 1951	8.98
Sept.19	9.58	May 23	8.71
Oct. 27	9.83	June 25	6.47
Nov. 17	9.53	July 31	8.39
Dec. 12	9.41	Sept.22	9.58
Feb. 10, 1951	9.08	Apr. 16, 1952	9.01
Mar. 23	9.12		

19-83-4dda

Date	Water level	Date	Water level
July 25, 1950	6.89	Apr. 26, 1951	6.61
Sept.18	7.51	May 23	3.91
Oct. 27	7.62	June 25	4.14
Nov. 17	7.20	July 31	4.35
Dec. 12	7.06	Sept.22	7.80
Feb. 10, 1951	6.75	Apr. 16, 1952	6.58
Mar. 23	6.78		

19-83-26cad

Date	Water level	Date	Water level
Sept.19, 1950	2.08	Apr. 26, 1951	0.55
Oct. 27	2.31	May 23	+.62
Nov. 17	1.42	June 25	.24
Dec. 12	.71	July 31	.23
Feb. 10, 1951	.68	Sept.22	2.72
Mar. 23	.95	Apr. 16, 1952	.52

19-84-15dbd

Sept.19, 1950	115.44	Nov. 17, 1950	116.23
Oct. 27	116.08	Dec. 12	115.19

Table 3.--Water levels in observation wells in the Pass Creek Flats area, Wyo.--Con.

19-84-15dbd--Continued

Date	Water level	Date	Water level
Mar. 23, 1951	115.33	July 31, 1951	115.07
Apr. 26	115.29	Sept.22	115.12
May 23	115.62	Apr. 16, 1952	115.27
June 25	115.29		

20-83-28bab

Date	Water level	Date	Water level
Aug. 1, 1950	18.35	Apr. 26, 1951	17.57
Sept.18	18.20	May 23	17.40
Oct. 27	18.27	June 25	17.14
Nov. 17	18.07	July 31	17.06
Dec. 12	17.03	Sept.22	17.16
Feb. 10, 1951	18.24	Apr. 16, 1952	17.40
Mar. 23	18.29		

CHEMICAL QUALITY OF THE WATER

In the planning of water-development projects, the quality of ground and surface water is as important as the quantity of available supplies. If water is sought to meet municipal or industrial growth, low limitations must be placed on the mineral constituents of the supply. Likewise for areas to be irrigated, the quality of the irrigation water, drainage returns, and the chemical character of the ground water are important in determining the most effective use of the waters on lands downstream. Adverse trends in the water quality may be detected readily by routine analytical testing of the water. In this section on water quality the type and concentration of the dissolved constituents and the water temperature are discussed. As other characteristics of the water, including the amounts of suspended material, biological and pathogenic organisms, and organic pollutants, require consideration in accordance with the specific use to which the water may be put, they are not considered in this report.

Natural surface and ground waters contain variable amounts and kinds of dissolved constituents as a result of the solvent action of water on minerals and rocks. When the water is applied to land, a part is used, a part is retained in the soil, and the surplus, if any, moves downward or laterally through the soil and substrata. The water retained in the soil generally becomes more concentrated in dissolved mineral substances because of evaporation and plant utilization. In irrigated areas the drainage waters generally are more concentrated than the waters applied to the lands, and the quality of the drain waters may preclude further use.

Thirteen samples of ground and surface water in the Pass Creek Flats (see fig. 6) were collected on September 18-19, 1950. Of these, five samples were from the North Park formation, five from the alluvium, and three from streams. The individual ground-water supplies are used as follows:

Physical description of ground-water supplies in the Pass Creek Flats

Location	Depth	Source	Use
18-83-30ca	.....	Spring	Domestic--irrigation.
19-83-9cbb	217	Well	Domestic--stock.
19-83-10bdb	.....	Spring	Stock.
19-83-26caa	160	Well	Domestic.
20-84-16dda	.....	Spring	Stock.
18-84-7dad	11.5	Well	Domestic.
19-83-4dda	17	Well	Domestic.
19-83-16bda	12	Well	Domestic.
19-83-25cbb	19.6	Well	Domestic--stock.
19-85-34caa	12	Well	Domestic.

Analytical data for the 13 samples are tabulated in table 4. These results are the basis for determining the suitability of the supplies for domestic and irrigation uses but are not an indication of the sanitary condition of the water.

All water samples except one were the calcium bicarbonate type; the water from spring 20-84-16dda was the calcium sulfate type. Because of similarity in composition of the dissolved minerals, the small number of samples probably suffices to define the general character of water in the Tertiary and Quaternary deposits that border the streams, except possibly in the lower reaches. The data should not be used in defining the quality of water in the deeper formations or where unusual conditions exist in the Tertiary and Quaternary deposits.

Physical and chemical relationships in the water

Graphic representation of the maximum and minimum concentrations (see fig. 7) shows the similarity of the water from the Tertiary and Quaternary deposits. Although the water in well 18-84-7dad was somewhat higher in dissolved solids than that in spring 18-83-30ca, it had about the same composition except for a larger percentage of sulfate. The percentage of sulfate, as equivalents per million, in the water from 18-84-7dad was 11 as compared with a percentage of 5 in the sample from 18-83-30ca. Likewise, the compositions of the samples from 20-84-16dda and 19-83-25cbb were similar, particularly with respect

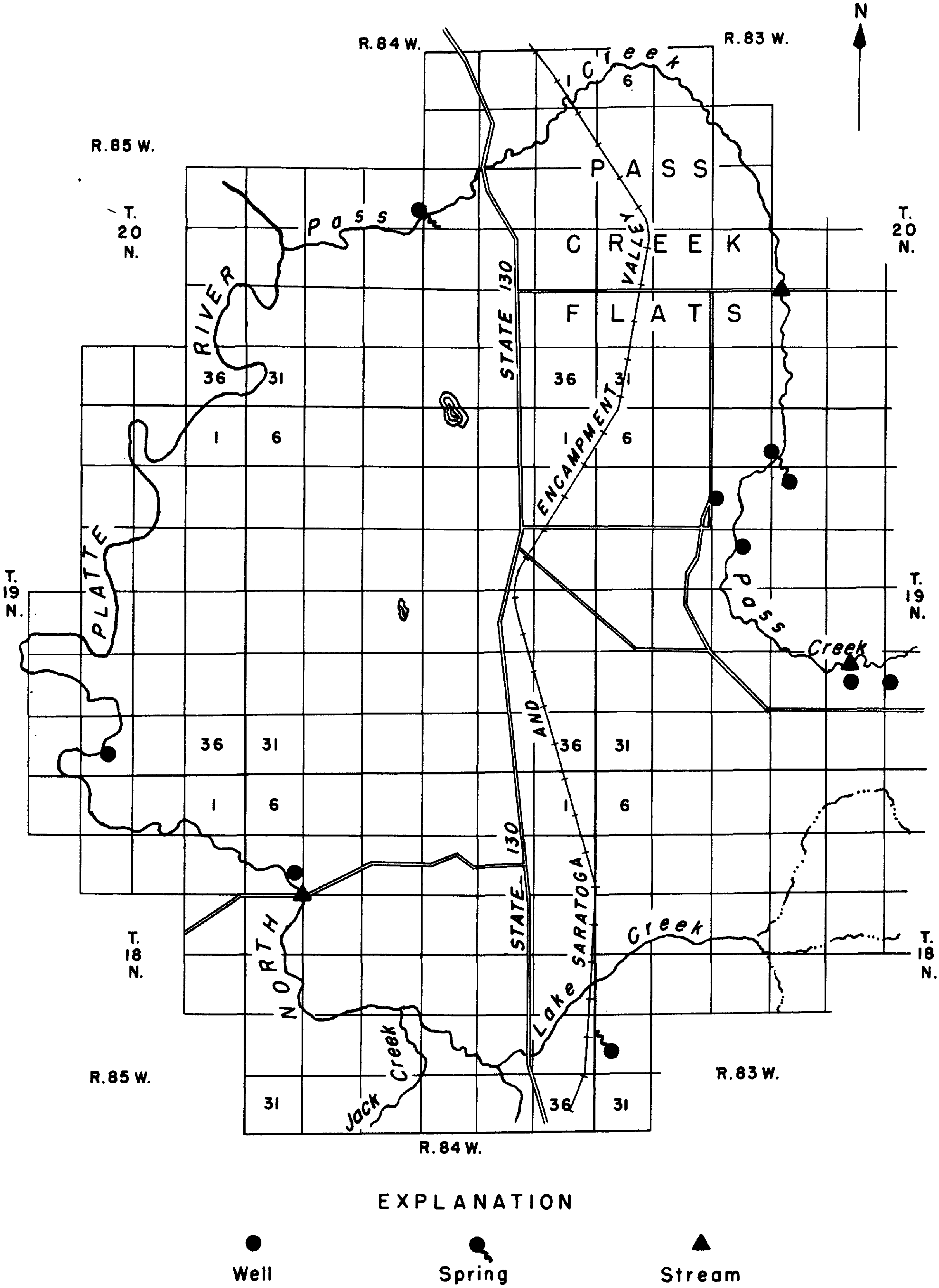

Figure 6. Map of the Pass Creek Flats area, showing location of wells, springs, and streams at which samples were collected.

Table 4.--Chemical analyses of waters in the Pass Creek Flats area, Wyo.

[Analytical results in parts per million except as indicated]

Location and source	Depth of well (feet)	Date of collection (1950)	Temperature (°F)	pH	Specific conductance (micromhos at 25 C)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$		Percent sodium
																			Total	Noncarbonate	
North Park formation:																					
18-83-30ca	Spring	9-19	49	7.9	331	40	0.06	54	4.5	9.4	6.6	190	16	4.5	0.3	1.4	0.05	242	153	0	11
19-83-9cbb	217	9-19	..	7.6	425	22	.30	57	1.9	36	7.0	223	44	3.5	.3	.3	.05	284	150	0	33
19-83-10bdb	Spring	9-18	51	7.8	545	39	.05	83	12	19	5.6	256	83	6.5	.2	.7	.00	378	255	45	14
19-83-26caa	160	9-19	..	7.6	847	19	.42	146	19	25	4.3	369	155	26	.3	3.2	.00	592	443	140	11
20-84-16dda	Spring	9-18	47	7.9	1,080	33	.06	137	27	71	6.6	198	373	46	.1	1.1	.35	820	451	289	25
Alluvium:																					
18-84-7dad	11.5	9-19	..	7.3	454	16	.05	64	6.0	30	1.8	217	54	9.0	.3	.8	.05	322	184	6	25
19-83-4dda	17	9-18	50	8.3	572	19	.21	89	15	22	7.1	a299	82	3.0	.3	.6	.10	386	284	39	14
19-83-16bda	12	9-19	..	7.3	720	18	.53	113	19	25	2.8	362	108	5.5	.3	.6	.00	476	360	63	13
19-83-25cbb	19.6	9-19	..	7.4	899	23	.06	122	23	49	13	330	198	25	.3	5.9	.00	638	401	130	20
19-85-34caa	12	9-19	55	8.5	574	20	.96	72	15	39	2.8	b255	91	15	.5	.8	.05	394	242	33	26
Surface water:																					
North Platte River																					
SE¼ sec. 7, T. 18 N., R. 84 W.	.....	9-19	..	8.1	364	16	.26	42	9.1	22	2.8	134	770	7.5	.3	.8	.05	244	142	32	25
Pass Creek																					
NW¼ sec. 27, T. 20 N., R. 83 W.	.....	9-18	..	8.3	635	20	.14	80	21	30	5.4	c196	178	6.5	.3	.2	.05	460	287	126	18
NW¼ sec. 26, T. 19 N., R. 83 W.	.....	9-19	..	7.6	551	14	.04	76	15	23	3.0	195	130	4.0	.3	1.8	.00	372	250	90	16

a Includes equivalent of 9 ppm of carbonate (CO_3).
b Includes equivalent of 10 ppm of carbonate (CO_3).
c Includes equivalent of 7 ppm of carbonate (CO_3).

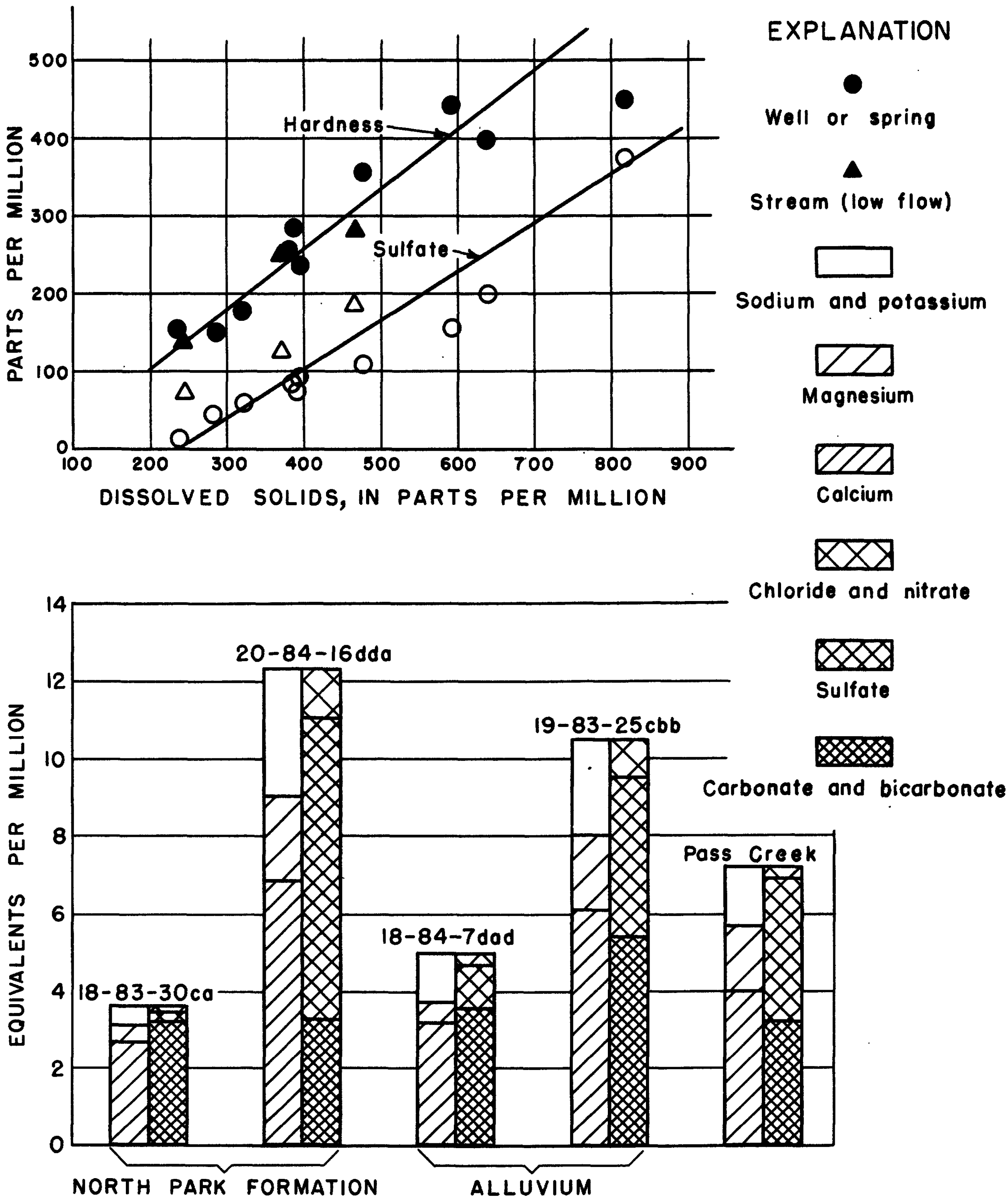

Figure 7. Bar diagrams of analyses and chemical characteristics of water in the Pass Creek Flats area.

to the cations. The more concentrated water, which was from spring 20-84-16dda, however, had a somewhat larger proportion of sulfate.

In the upper diagram in figure 7, hardness and sulfate, in parts per million, are plotted against dissolved solids. It is apparent from the linear trend in the plotted data that hardness and sulfate are proportional to increase or decrease in mineral content, which indicates that mineral accretion is largely that of calcium and magnesium sulfate, probably as gypsum or selenite. The scarcity of data precludes correlation of changes in the chemical character of the ground water downstream.

North Park formation

The range in dissolved solids for five water samples from the North Park formation was 242 to 820 ppm; all but one sample were the calcium bicarbonate type. The quantities of the minor constituents--boron, nitrate, and fluoride--were low, but the iron content was as much as 0.42 ppm. The very low iron content of three spring samples indicates that some iron was precipitated at the place of issuance and prior to sampling. It is of interest, although not necessarily significant, that the mineral content of the different spring waters was inversely related to flow. For example, spring 18-83-30ca, which had an estimated flow of 1,300 gpm, had the lowest mineral content of 242 ppm, whereas spring 20-84-16dda, which had a flow of 100 gpm, had the highest mineral content of 820 ppm.

The percentages of sodium in the water were low, and the waters were hard. Percentage of sodium ranged from 11 to 33, and hardness ranged from 150 to 451 ppm.

Alluvium

Except for a lower range in dissolved solids, the chemical character of water from the alluvium is similar to that from the North Park formation. Dissolved solids ranged from 322 to 638 ppm; hardness ranged from 184 to 401 ppm. As with water from the North Park formation, the quantities of minor constituents--boron, nitrate, and fluoride--were low. Unlike the water from the North Park formation, however, two of the samples had small amounts of free carbonate. The surface sample in Pass Creek that was collected about 3 miles downstream from one of these wells also contained a small amount of carbonate (7 ppm).

Surface water

Two samples from Pass Creek and one sample from the North Platte River were collected at low flow. The waters were of moderately low mineral content. The dissolved solids concentration in the North Platte River water, 244 ppm, was composed largely of calcium bicarbonate, whereas the dissolved solids concentration of two samples of Pass Creek water, 372 and 460 ppm, contained significant quantities of calcium sulfate. The downstream change in mineral content in Pass Creek was small and was due largely to accretion of sulfate. It is likely that groundwater inflow to Pass Creek carries a higher sulfate content than inflow to the North Platte River; furthermore, the sulfate content of Pass Creek is probably indicated in the water of the North Platte River below its confluence with Pass Creek. The Mesaverde formation, which crops out along the North Platte River, contains carbonaceous shale and is not believed to be a heavy contributor of sulfate to water that drains to the streams, although specific data are lacking.

Periodic downstream increase in salinity in Pass Creek and North Platte waters probably can be expected, particularly during the irrigation season as the surface waters are rediverted to the irrigated tracts. Normally the materials in the alluvium and North Park formation (as indicated from the chemical quality of the water) would be expected to yield relatively small amounts of sodium either to ground or surface water in the area. However permanently high percentages of sodium can be avoided only if water levels are maintained sufficiently low to prevent deposition of salts in the soil and at the surface.

Relation of quality of water to use

Domestic

Ground water is the principal source of domestic supplies, and 8 of the 10 groundwater samples are from wells or springs that are used for some domestic purposes.

The dissolved solids concentration of the waters analyzed was less than 1,000 ppm, which is considered by the U. S. Public Health Service (1946, pp. 382-383) to be about maximum for general acceptability. However, waters of higher mineral concentration are often palatable and are commonly used. Most of the water exceeded 180 ppm hardness above which the water is considered to be very hard. The extremely hard waters, as in the samples

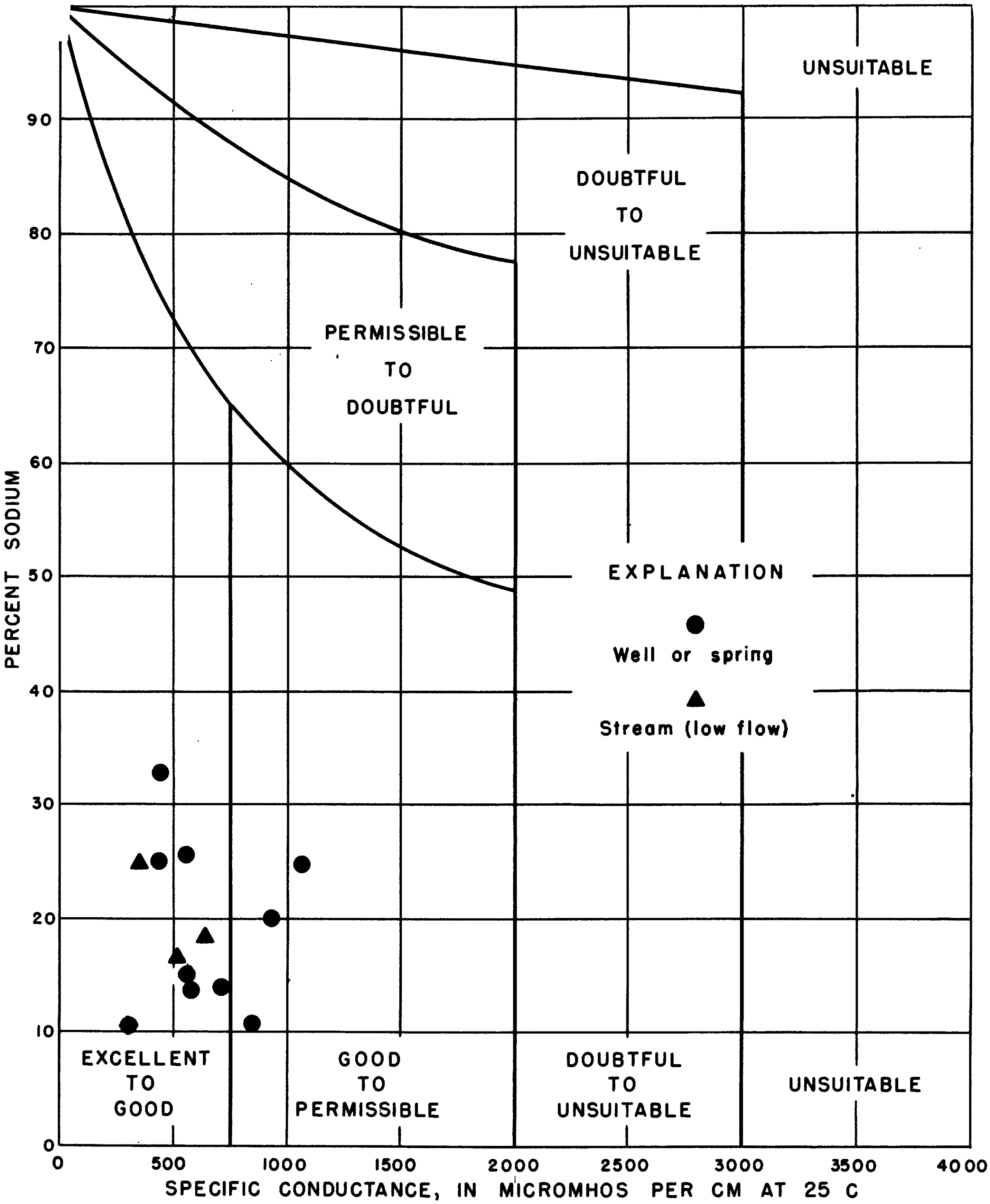

Figure 8. Classification of waters in Pass Creek Flats area for irrigation use. (After Wilcox.)

from well 19-83-26caa and spring 20-84-16dda, contained larger quantities of sulfate than are desired in drinking supplies. The analyses indicate further that troublesome quantities of iron may be encountered in some supplies. Three samples exceeded 0.3 ppm iron, above which deposition of iron from the water is likely to occur. Neither fluoride nor nitrate was in solution in troublesome quantities.

The waters were cool, ranging in temperature from 47 F in one spring to 55 F in one of the shallow wells in the alluvium.

Irrigation

One spring is used for irrigation, and because this water is low in total concentration of dissolved solids, percentage of sodium, and quantity of boron, no present problem exists with reference to the quality of the water for irrigation. However, successful irrigation is contingent upon many other factors, such as soil composition, permeability, drainage, irrigation practices, and crop tolerances (Wilcox, 1948, pp. 25-26). The suitability of the individual water samples in Pass Creek Flats, as defined by the chemical quality alone, is illustrated in figure 8. The water classes are determined by the quantity of mineral substance, which is indicated by the specific conductance and by the percentage of sodium. All waters analyzed rated "excellent to good" or "good to permissible," and in all likelihood other unsampled water in the Tertiary and Quaternary deposits in the area normally would be classified similarly.

CONCLUSIONS

Sufficient supplies of ground water are available for domestic and stock use in the Pass Creek Flats area from the alluvium and the North Park formation, but it would be difficult to develop sufficient supplies of water for irrigation. The alluvium of the North Platte River and its tributaries consists of sand and gravel; the deposits, however, are too thin for the economical development of large amounts of ground water. The North Park formation is thick and consists predominantly of fine-grained materials; the low permeability of the formation makes it difficult to develop sufficient quantities of ground water for irrigation.

If wells were drilled into fault zones like those that conduct water to the springs in the area, larger amounts of water probably could be obtained. No information is available concerning the amount of water that could be obtained from pre-Tertiary formations; however, these formations are not likely to be practical sources of irrigation water.

Results of analyses of 13 ground and stream samples in the Pass Creek Flats define the character of the water in the alluvium and in the North Park formation as being hard and either calcium bicarbonate or calcium sulfate in type. Dissolved solids ranged from 242 to 820 ppm; hardness ranged from 150 to 451 ppm. Hardness and sulfate are proportionate to increase or decrease in mineral content, which indicates that mineral accretion is largely that of calcium and magnesium sulfate.

The chemical character of water in the alluvium is very similar to that of the North Park formation. The alluvium water had a smaller range in dissolved solids and more significant quantities of iron; but, like the North Park formation, the quantities of boron, nitrate, and fluoride were low.

Except for the hardness of the water and occasional troublesome quantities of sulfate and iron, the water is palatable. At present irrigation is almost entirely by surface-water diversion; the ground-water supplies, however, are sufficiently low in percentage of sodium, dissolved solids, and boron to rate at least "good to permissible." Chemical characteristics of surface water at low flow were similar to those of ground water adjacent to the stream.

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Table 5.--Records of wells and springs in the Pass Creek Flats area, Wyo.

Well number: See text for description of well-numbering system.
Type of well: Dr, drilled well; Du, dug well; Sp, spring.
Depth of well: Measured depths are given in feet and tenths below measuring point; reported depths are given in feet below land-surface datum.
Type of casing: C, concrete, brick, or tile pipe; P, iron or steel pipe; W, wood.
Geologic source: Qa, alluvium; Tnp, North Park formation.
Method of lift (first letter): C, cylinder; Cf, centrifugal; F, natural flow; J, jet; N, none.
Type of power (second and third letter): E, electric motor; H, hand operated; N, none.
Use of water: D, domestic; N, none; S, stock, I, irrigation.
Measuring point: Ls, land surface; Tbc, top of board cover; Tc, top of casing.
Depth to water: Measured depths to water level are given in feet, tenths, and hundredths; reported depths are given in feet.
Remarks: Ca, sample collected for chemical analysis; D, discharge in gallons a minute (E, estimated; R, reported); T, temperature in degrees Fahrenheit.

Well no.	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Geologic source	Method of lift and type of power	Use of water	Measuring point: Description	Measuring point: Distance above (+) or below (-) land surface (feet)	Distance to water level below measuring point (feet)	Date of measurement	Remarks
18-83-10dbb	Rocky Mt. Sheep Co.	Dr	41.1	8	P	Tnp	N	N	Tc	+1.8	20.31	7-24-50	
-16dbd	W. N. Eaton........	Dr	63	4	P	Tnp	C,H	S	Ls	....	20	1949	
-30ca	U. S. Fish Hatchery	Sp	....	..	...	Tnp	F	D,I	...	....	......	....	D1,300R, T49, Ca.
18-84-7dad	H. G. Corpening....	Du	11.5	72	...	Qa	C,H	D	Tbc	0	7.76	7-26-50	Ca.
-26dda	F. Schilt..........	Dr	35	4	P	Tnp	J,E	D	Tc	-3.5	9.63	7-25-50	T51.
19-83-4dda	A. Welton..........	Dr	17	8	P	Qa	Cf,H,E	D	Tc	+.3	7.19	7-25-50	Ca.
-5bcc1	Unknown............	Dr	....	10	P	Tnp	N	N	Tc	0	90.05	10- 4-50	
-5bcc2	.....do............	Dr	....	13	P	...	N	N	Tc	+.7	78.54	10- 4-50	Oil test.
-9cbb	R. Campbell........	Dr	217	8	P	Tnp	J,E	D,S	Ls	....	20	1950	Ca.
-10bdb	C. L. Welton.......	Sp	....	..	...	Tnp	F	S	...	....	......	....	D500E, T51, Ca.
-10dad	R. Welton..........	Du	15	48	C	Tnp	C,E	D	Tbc	0	13.46	10- 5-50	
-16bda	G. C. Austin.......	Du	12	48	...	Qa	C,H	D	...	....	......	....	Ca.
-25cbb	R. A. Ault.........	Du	19.6	42	W	Qa	J,E	D,S	Tbc	0	4.20	7-25-50	Ca.
-26caa	R. Welton..........	Dr	160	6	P	Tnp	C,H	D	Ls	....	4	1945	Ca.
-26cad	.....do............	Du	10.2	72	...	Qa	C,H	S	Tbc	+.7	2.78	9-19-50	
-28bcb	G. L. Reasor.......	Dr	3,879	..	...	...	N	N	...	....	......	....	Oil test.
-34aaa	R. Ault............	Du	25	8	P	Tnp	C,H	D	Ls	....	15	1950	

19-84-15dbd	Rocky Mt. Sheep Co.	Dr	600	4	P	Tmp	N	N	Tc	+.9	116.34	9-19-50	
19-85-34caa	H. Johnson.........	Du	12	48	C	Qa	C,H	D	Ls	....	9	1950	T55, Ca.
20-83-27aaa	F. Widner..........	Dr	100	6	P	Tmp	J,E	D	Ls	....	12	1950	
-28aba	.....do............	Dr	22.7	6	P	Tmp	N	N	Tc	+.4	8.78	....	
-28bab	County.............	Dr	33.1	3	P	Tmp	N	N	Tc	+2.7	21.05	8- 1-50	
-28ccd	W. W. Weaver.......	Dr	55.1	6	P	Tmp	C,H	N	Tc	0	17.30	7-23-50	
-34cca	Campbell Brothers..	Du	8.2	48	...	Qa	C,E	D	Tbc	+1.0	5.94	10- 4-50	
20-84-16dda	Rocky Mt. Sheep Co.	Sp	....	..	...	Tmp	F	S	...	....	......	....	D100E, T47, Ca.