Ground-Water Resources of the Bryce Canyon National Park Area, Utah

With a section on THE DRILLING OF A TEST WELL

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1475–M

Prepared in cooperation with the National Park Service, Department of the Interior

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By I. WENDELL MARINE

HYDROLOGY OF THE PUBLIC DOMAIN

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With a Section on the Drilling of a Test Well

By I. Wendell Marine

ABSTRACT

The water need at Bryce Canyon National Park in 1957 was about 1.3 million cubic feet for a tourist season that lasted from the middle of May to the middle of October. To evaluate the adequacy of water-supply sources, a hypothetical future need of 5 million cubic feet of water per season is used. This amount of water might be obtained from the East Fork of the Sevier River, from wells in the alluvium of the East Fork, from Yellow Creek Spring and nearby springs, which are below the canyon rim, or from a well drilled about 2,000 feet to the top of the Tropic shale. Although the present source of water, consisting of wells in the alluvium of East Creek valley, may be an important supplemental source in the future, it will not yield sufficient water in dry years to meet the total demand for water at the park.

The yield of Yellow Creek Spring and nearby springs is estimated at a total of 7.8 million cubic feet of water per season. The springs provide water of satisfactory chemical quality, and are a reliable source even in times of drought. A serious disadvantage of using this source of water is the difficulty of constructing a pipeline over extremely rugged terrain from the source to the lodge and headquarters area.

A well drilled to the top of the Tropic shale of Cretaceous age in the lodge and headquarters area might penetrate two or more aquifers, one at the base of the Wasatch formation of Eocene age and one or more in the Wahweap and Straight Cliffs sandstones of Cretaceous age. The yield of this well would depend to a large degree on the number of fractures encountered. To assure the most favorable conditions for intercepting fracture zones in the bedrock, a test-well site is proposed near the crest of a gentle anticline where tension fractures in the rocks should be common.

Shallow wells in the alluvium of East Creek valley cannot be depended upon to yield sufficient water in times of drought, but they are nevertheless an important source. The water-storage capacity of the alluvium of East Creek valley in the vicinity of the wells of the Utah Parks Co. is estimated at 1.4 million cubic feet. By lowering the water table in the valley uniformly without creating excessively large cones of depression, the alluvium could supply the 1.3 million cubic feet of water per season estimated as the water need in 1957. However, in times of drought this alluvium cannot supply the hypothetical future needs of 5 million cubic feet of water per season.

INTRODUCTION

PURPOSE AND SCOPE

The purpose of this investigation was to appraise the ground-water resources of Bryce Canyon National Park area and vicinity. This appraisal is intended to furnish sufficient information to enable the National Park Service to develop an adequate water supply.

The water system of the National Park Service, which is the only one available for year-round use in Bryce Canyon National Park, consists of 1 well (headquarters well) that yields about 160 gpd (gallons per day), enough to supply the needs of 1 family; one 5,000-gallon storage tank; and pipelines for the distribution of water. The Park Superintendent estimates that about 1,000 gpd was needed to supply the seven families of the National Park Service that domiciled in the park during the winter of 1956–57. During the summer the water system of the National Park Service is connected into the water system of the concessioner (the Utah Parks Co.), and the shortage of water for these families is alleviated. The water-supply system of the concessioner, however, is inadequate to supply all the water needs of the park for an entire season in times of drought. Because the Mission 66 program includes plans for the expansion of the overall facilities at Bryce Canyon National Park, a water supply much larger than that now provided by the concessioner is needed.

Figure 51 shows the general increase in the number of visitors to Bryce Canyon National Park in past years and the estimated future range of attendance under the Mission 66 program. Any water supply that is planned should be able to meet not only the present water needs of the park but also future needs.

The principal objectives of this investigation were to determine the quantity, quality, and dependability of all possible sources of water supply for the park. Because the water supply is needed in the lodge and headquarters vicinity, special emphasis was placed on sources that are within several miles of that area.

LOCATION OF THE AREA

The area of this report is in and adjacent to Bryce Canyon National Park in the Paunsaugunt Plateau region (pl. 24). The park is in Kane and Garfield Counties, south-central Utah, between 37°42′ and 37°26′ north latitude and 112°05′ and 112°17′ west longitude. It is also on the divide between the Paria River, a tributary to the Colorado River, and the East Fork of the Sevier River, which drains into the Great Basin.

FIGURE 51.—Number of visitors to Bryce Canyon National Park, from 1929 to 1956 and range of possible attendance. Data provided by National Park Service.

PREVIOUS INVESTIGATIONS

The geology of the Paunsaugunt Plateau region was described by Herbert E. Gregory in a report (1951) that includes brief discussions of the ground-water resources of the region and of some of the most important wells and springs, and a geologic map that was used extensively in carrying on the present investigation. Williams (1954) gave a synopsis of the stratigraphy and structure of the Paunsaugunt Plateau region. A report by Gregory and Moore (1931) referred in part to the geology of the area. In 1939 the U.S. Geological Survey published a topographic map of Bryce Canyon National Park and adjacent area, which was extremely useful in the present investigation.

A 3-day reconnaissance of the Campbell Canyon Spring and Bryce Canyon Spring areas was made in April 1954 by Ben E. Lofgren, engineer, U.S. Geological Survey. This reconnaissance included no discharge measurements, but on the basis of it Mr. Lofgren suggested to the National Park Service personnel that the Campbell Canyon Spring might be used for a park water supply.

PERSONNEL AND ACKNOWLEDGMENTS

This investigation was made under the direct supervision of Herbert A. Waite, district geologist of the U.S. Geological Survey in charge of ground-water investigations in Utah. Glen T. Bean, Superintendent of Bryce Canyon National Park, and employees of the National Park Service at Bryce Canyon rendered valuable assistance in all phases of the investigation. Donald Price, geologist, Ground Water Branch, assisted the writer for 2 weeks in the field investigations. Robert Burns, former Supervisory Park Ranger, and Robert Ott, of the National Park Service, were very helpful in guiding the writer to significant springs in the area.

GEOGRAPHY

Bryce Canyon National Park lies at the east edge of the Paunsaugunt Plateau, one of the high plateaus of southern Utah, and includes part of the plateau, the rim, and the foothills bordering the plateau at a lower elevation. The altitude of the plateau top in the park ranges from about 7,600 to more than 9,000 feet. The climate of this part of the park is generally cold except in the summer months. The relief in the foothills below the rim is as great as 1,000 feet. The temperature below the rim is generally higher than that on the plateau, and the summers are longer. Figure 52 shows the annual precipitation and departure from normal at Bryce Canyon National Park from 1933 through September 1957. It also shows cumulative departure from normal precipitation. The weather station is at the headquarters, on the plateau.

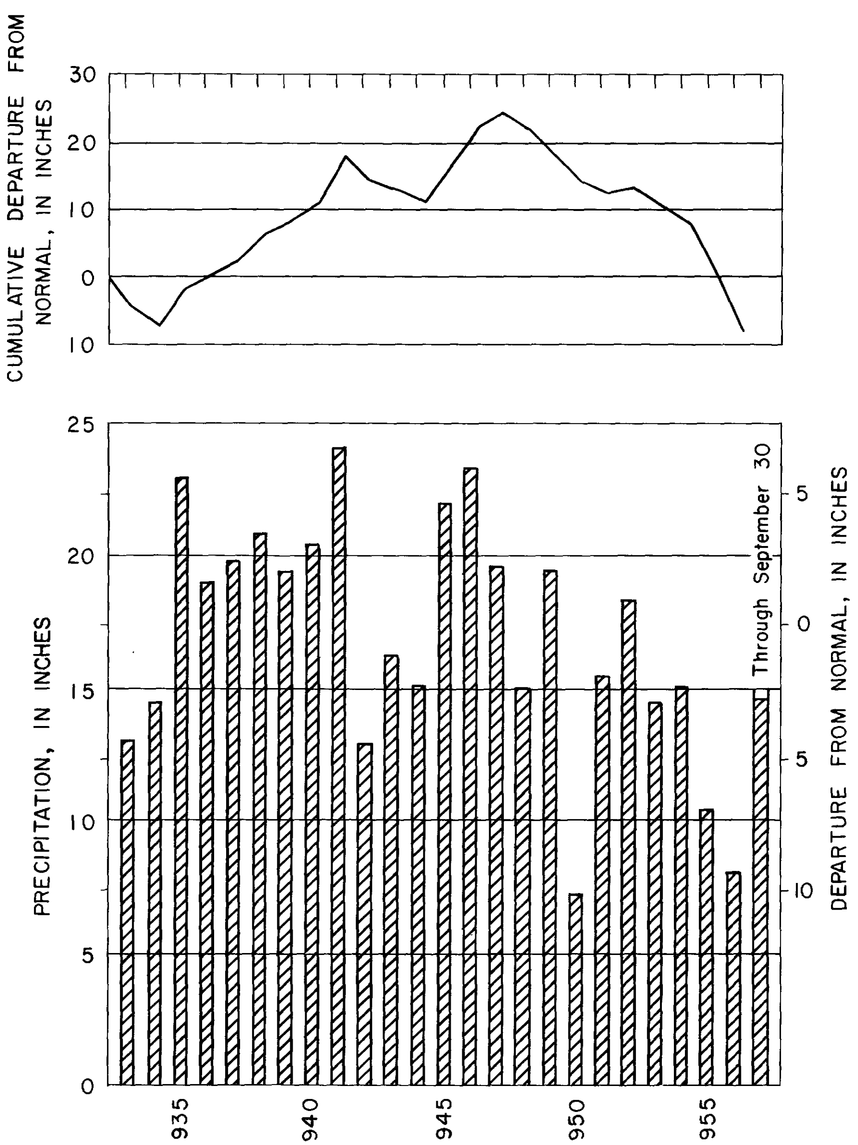

FIGURE 52.—Annual precipitation and cumulative departure from normal at Bryce Canyon National Park, Utah.

WATER USE

The principal water users in Bryce Canyon National Park and vicinity are the public and employees using the National Park Service and concessioner water systems, the town of Tropic, and the Tropic and East Fork Irrigation Co. Other water users in the area obtain

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small supplies from wells or springs. The town of Tropic is supplied from Bryce Spring through a pipeline about 2½ miles long (pl. 24). The Tropic and East Fork Irrigation Co. obtains water from the East Fork of the Sevier River and transmits it by way of the Tropic Ditch across part of the plateau, down Water Canyon, and into the vicinity of the town of Tropic where it is used for irrigation. The diversions of the Tropic and East Fork Irrigation Co. for the last 7 years (1950–56) are listed in table 1. Water is used in Bryce Canyon National Park for general needs at the lodge, cafeteria, and campground and for domestic needs by the personnel of the Park Service and the employees of the Utah Parks Co.

TABLE 1.—*Tropic Ditch diversions of the Tropic and East Fork Irrigation Co.*

[U.S. Geological Survey gaging station 5 miles below Daves Hollow]

Month	Flow in ditch, in acre-feet						
	1950	1951	1952	1953	1954	1955	1956
April	138	------	------	------	------	------	------
May	1, 130	691	976	287	726	518	296
June	1, 110	837	1, 060	549	720	392	360
July	612	427	1, 170	455	490	347	.2
August	650	289	999	178	104	256	3.8
September	263	84	738	107	136	437	212
October	------	68	42	301	1	104	62
Total	3, 900	2, 400	4, 980	1, 880	2, 180	2, 050	934

For many years some water has been supplied to the park facilities from Trough and Shaker Springs, but in 1956 and 1957 these springs were dry. For the past several decades some water has been obtained from springs in East Creek valley. In July 1955 the springs in that valley had so decreased in yield that it became evident that they would not supply water through the rest of the season, and in that month well 1 was drilled (fig. 53). This well was the sole source of water supply for the park from July 1955 to August 1957. It is reported that the springs dried up completely after the well pump was installed and that they did not flow in 1956. In May 1957 there was a small overflow from the spring collector sump (fig. 53), but by June of that year there was none. In February 1957 two additional wells were drilled in East Creek valley. Upon completion the wells were tested by personnel of the Utah Parks Co. to determine their yield. No

FIGURE 53.—Water-supply developments of the Utah Parks Co. in the East Creek valley showing wells 1, 2, and 3; a developed spring (4); the spring-collector sump (5); and the spring pumphouse (6). Note flat-floored valley bordered by bedrock side slopes. Photograph by H. A. Waite.

measurements of water level were made during these tests. The results of each test are summarized as follows:

Well	Yield (gpm)	Time (hr)	Pump setting below land surface (ft)
1	180	8	18
2	90	8	24
3	25	(1)	------------

[1] Tested for short period and pump broke suction.

The average of 4 separate measurements of the discharge of well 1 made at the Utah Parks Co. storage tanks in May 1957 was 55 gpm. Three check measurements were made in July 1957, and still the average was 55 gpm. It should be emphasized that this was the water delivered at the tanks and available for use; it was not necessarily the same as the amount of water discharged by the well, because there may have been leaks in the 4 miles of pipeline between the pump and the tanks. In the parts of the pipeline seen by the writer, however, there were no leaks, and it is assumed in the rest of this report that 55 gpm was the discharge rate of well 1.

Water-level recording gages were installed on wells 2 and 3. The records from these wells show within 15 minutes when the pump on well 1 begins to operate. These recording gages, therefore, are valuable not only to record water-level fluctuations in the basin (fig. 54) but also to indicate the duration of pumping. Table 2 shows the total number of hours that the pump was in operation during each month from April through November 1957.

TABLE 2.—*Monthly pumpage from Utah Parks Co. well field in East Creek valley during 1957 and the net decline in water level each month in well 3*

Month	Total time of pumping (hours)	Water pumped			Net decline in water level (feet)
		Gallons	Cubic feet	Acre-feet	
April	0	0	0	0	0
May	299	986, 700	131, 500	3. 04	1. 1
June	478	1, 577, 400	213, 000	4. 89	2. 5
July	714	2, 356, 200	314, 000	7. 22	3. 0
August	[1] 496	1, 636, 800	219, 100	5. 04	. 8
September	[1] 338	1, 115, 400	148, 700	3. 41	. 4
October	[1] 200	660, 000	88, 000	2. 02	. 2
November	0	0	0	0	0
Total	2, 525	8, 332, 500	1, 114, 300	2, 562	8. 0

[1] Well broke suction on Aug. 2, 1957. Amount of water used from August through October was limited by decreased discharge of pump.

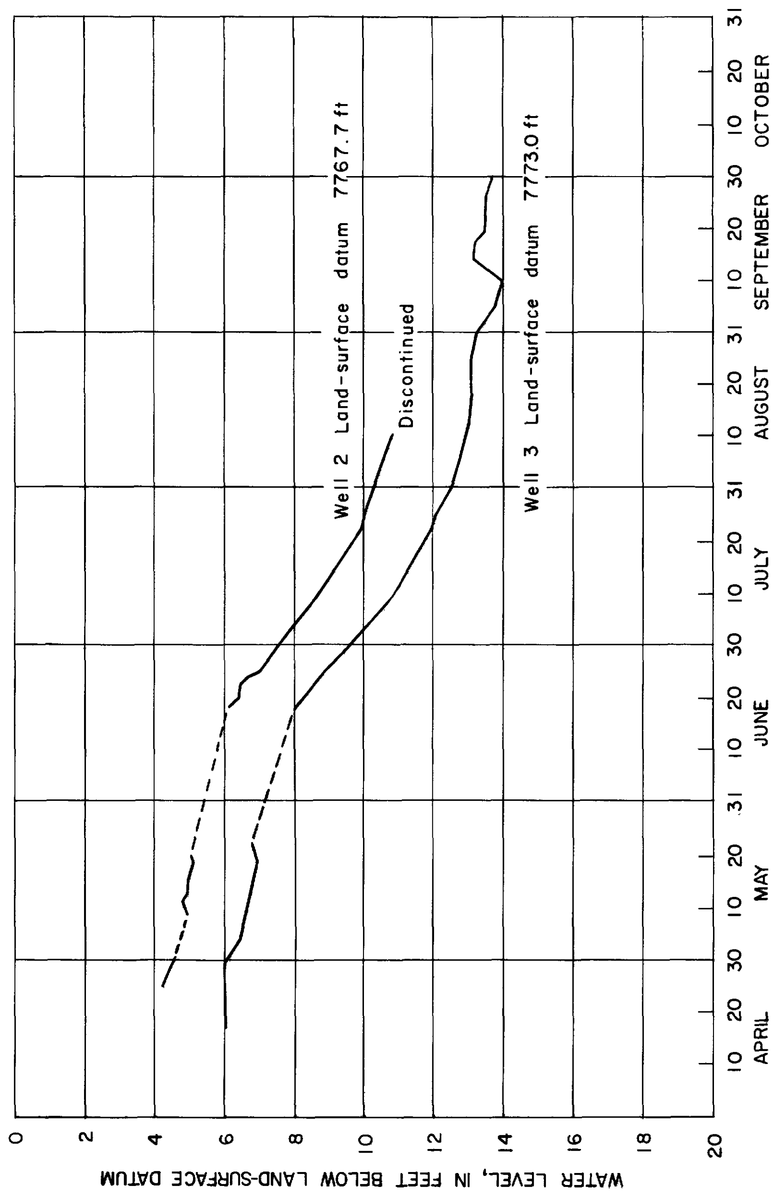

FIGURE 54.—Hydrographs of two observation wells in the alluvium of East Creek valley, April to September 1957. Well 2 is 451 feet from the pumping well; well 3 is 245 feet from the pumping well.

On August 2, 1957, well 1 began to pump air, and from that date to the end of the season the amount of water pumped was not a true indication of the need for water in the park. The amount of water pumped in the first half of the tourist season may be used as a basis for estimating the need for water in the park. During the season, July and August are the months of maximum pumping and May and October the months of least pumping. The pump is started about May 1 and stopped about November 1. Assuming that the pumpage in August is about the same as in July, September the same as June, and October the same as May, it is estimated that the water need for one entire season (as of 1957) is about 1.3 million cubic feet. On the basis of the National Park Service's Mission 66 design of facilities for 500,000 visitors, a water need of about 5 million cubic feet per season has been selected as a basis for the comparison of various sources of water. A summary of these figures is given in table 3.

TABLE 3.—*Summary of quantities of water available from selected sources compared to present water use and estimated water needs in Bryce Canyon National Park, Utah*

	Maximum quantity measured in 1957 (gpm)	Total quantity per 4½-month season		Estimated yield after development work (gpm)	Total quantity per 4½-month season (based on estimated yield)	
		Millions of gallons	Millions of cubic feet		Millions of gallons	Millions of cubic feet
Present water use	55	[1] 9.7	[1] 1.3			
Estimated water need for planning supplies		39	5			
Water available from:						
Alluvium of East Creek	[2] 55	[3] 8.3	[3] 1.1	55	[4] 10	[4] 1.4
Campbell Canyon Spring	28	5.4	.7	50	9.7	1.3
Merrill Ranch Spring	24	4.7	.6	35	6.8	.9
Yellow Creek Spring	81	16	2.1	110	21	2.9
Yellow Creek Spring and Upper Yellow Creek Wash Spring	201	39	5.2	300	58	7.8
Right Fork (of Yellow Creek) Spring	75	15	1.9	75+	14.6+	1.9+
Estimated yield from proposed bedrock well (based on meager information)				[5] 30–300	5.8–58	0.8–7.8

[1] Represents the estimated water requirements in 1957.
[2] Well field would not sustain this yield. Well 1 broke suction on Aug. 2, 1957.
[3] Actual withdrawal from alluvium of East Creek.
[4] Based on a sustained yield of 55 gpm.
[5] Depends on the number of fractures encountered.

GEOLOGY

STRATIGRAPHY

The oldest rock formation known to underlie the Bryce Canyon area is the Redwall limestone of Mississippian age. This formation was penetrated at a depth of 10,189 feet below the surface in an oil test in Johns Valley (table 4) about 12 miles northeast of the lodge and headquarters area (off pl. 24). This same test hole passed through 779 feet of Pennsylvanian strata comparable to the Molas and Hermosa formations. Rocks of Permian age were penetrated in the Lion Oil Co. test hole, 4 miles northwest of the lodge and headquarters area (pl. 24; table 4). These rocks were the Coconino sandstone, the Toroweap formation, and the Kaibab limestone.

TABLE 4.—*Logs of wells and auger holes in the Bryce Canyon National Park area, Utah*

[See pls. 24, 25A for location. All water levels in this table are in feet below land surface]

	Thickness (feet)	Depth (feet)
Headquarters well, National Park Service		
Yield, 160 gpd; diameter, 48 in. to 30 ft, 12 in. to 50 ft, 8 in. to 80 ft.		
Static water level, 49 ft.		
Alluvium: Old dug well	30	30
Wasatch formation:		
Rock	10	40
Fractured rock	10	50
Rock	30	80
Well 1, Utah Parks Co.		
Yield, 180 gpm; diameter, 12 in.		
Alluvium:		
Clay	12	12
Gravel	3	15
Porous formation	9	24
Tight formation	6	30
Wasatch formation: Dry chalky formation	50	80
Well 2, Utah Parks Co.		
Yield, 90 gpm; diameter, 12 in.		
Static water level, 4 ft.		
Alluvium:		
Clay	6	6
Sand and gravel	4	10
Clay	2	12
Gravel	2	14
Clay	4	18
Gravel and sand	8	26
Clay	4	30
Wasatch formation: Rock	----------	30+

TABLE 4.—*Logs of wells and auger holes in the Bryce Canyon National Park area, Utah*—Continued

	Thickness (feet)	Depth (feet)
Daves Hollow Ranger Station, Forest Service		
Yield, 90 gallons per hour; diameter, 6 in. Static water level, 15 ft.		
Alluvium: Clay, sandy, and gravel	20	20
Kaiparowits formation:		
Clay, sandy, gray	15	35
Clay, sandy, gray (water)	15	50
Clay, sandy, gray	60	110
Clay, sandy, gray (very hard)	12	122
Shale, sandy, brown (caving)	3	125
Clay, sandy, gray	82	207
Bryce Canyon Airport, Civil Aeronautics Administration		
Yield, 10 gpm; diameter, 6 in. Static water level, 33 ft.		
Alluvium:		
Conglomerate and hardpan	12	12
Clay, yellow	4	16
Clay, light brown	7	23
Clay, blue-gray	11	34
Clay, gray-brown	9	43
Clay, sandy, light-brown	5	48
Clay, sandy, light	3	51
Kaiparowits formation:		
Sandstone, gray	40	91
Shale, gray	8	99
Shale, sandy, blue	26	125
Shale, sandy, hard, blue	2	127
Shale, sandy, blue	9	136
Shale, sandy, hard, blue	2	138
Shale, sandy, soft	12	150
Sawmill Well, E. A. Crofts		
Yield, 40 gpm; diameter, 6 in. Static water level, 18 ft.		
Alluvium:		
Clay	20	20
Sand (little water)	15	35
Clay	25	60
Gravel (water)	6	66
Kaiparowits formation: Shale, light-gray (no water)	244	310

TABLE 4.—*Logs of wells and auger holes in the Bryce Canyon National Park area, Utah*—Continued

	Thickness (feet)	Depth (feet)
Lion Oil Co. water well		
Yield, 10 gpm; diameter, 6 in.		
Alluvium:		
Sand rock	70	70
Rock formation, porous	6	76
Sand rock	40	116
Rock formation, porous	6	122
Sand rock	8	130
Rock, porous	6	136
Lion Oil Co. oil test		
Kaiparowits formation and Wahweap and Straight Cliffs sandstones	940	940
Tropic shale	1, 305	2, 245
Dakota sandstone	415	2, 660
Morrison formation	1, 965	4, 625
Carmel formation	1, 430	6, 005
Navajo sandstone	2, 075	8, 130
Chinle formation, upper part	598	8, 728
Shinarump member of Chinle formation	129	8, 857
Moenkopi formation	1, 125	9, 982
Timpoweap member of Moenkopi formation	104	10, 086
Kaibab limestone	479	10, 565
Toroweap formation	451	11, 016
Coconino sandstone	205	11, 221
The Pines Motel, Mayo Rich		
Diameter, 6 in.		
Static water level, 15 ft.		
Alluvium: Clay, sandy	10	10
Wasatch formation: Sand rock, red	160	170
Forest Oil Corp. oil test [about 3 miles west of Lion Oil Co. oil test, off pl. 24]		
Wasatch formation	496	496
Kaiparowits formation	155	651
Wahweap sandstone	231	882
Straight Cliffs sandstone	2, 398	3, 280
Tropic shale	1, 130	4, 410
Dakota sandstone	218	4, 628
Winsor formation	507	5, 135
Entrada sandstone	470	5, 605
Carmel formation	586	6, 191
Navajo sandstone	51	6, 242

TABLE 4 —*Logs of wells and auger holes in the Bryce Canyon National Park area, Utah*—Continued

	Thickness (feet)	Depth (feet)
California Co. oil test, Johns Valley No. 1 in sec. 22, T. 35 S. R. 2 W.		
Wahweap and Straight Cliffs sandstones	910	910
Tropic shale	898	1, 808
Dakota sandstone	202	2, 010
Morrison formation	685	2, 695
San Rafael group	955	3, 650
Glen Canyon group	2, 085	5, 735
Chinle formation, upper part	560	6, 295
Shinarump member of Chinle formation	75	6, 370
Moenkopi formation	995	7, 365
Kaibab limestone	923	8, 288
Coconino sandstone	1, 022	9, 410
Formations comparable to Hermosa and Molas formations (combined)	779	10, 189
Redwall limestone	146	10, 335
Logs of auger holes in alluvium of East Creek valley		
AUGER HOLE 1		
Sand, clayey, tan	14	14
Gravel and sand, tan (water)		14½
AUGER HOLE 2		
Sand, clayey, tan	2½.	2½
Gravel and sand, tan (dry)		2½
AUGER HOLE 3		
Soil, dark clayey	2	2
Gravel and clay, light-brown	2	4
Gravel, angular, white (water)	1	5
AUGER HOLE 4		
Clay, sticky, gray-brown	2	2
Sand, clayey, brown	2	4
Gravel, fine; sand and clay, tan	2	6
Gravel, coarse, reddish-white (water)	1	7
AUGER HOLE 5		
Soil, sandy, dark-gray	2	2
Clay, sticky, gray	2	4
Clay, sticky, yellow	4	8
Gravel, sand and clay, yellow (water)		8

TABLE 4.—*Logs of wells and auger holes in the Bryce Canyon National Park area, Utah*—Continued

	Thickness (feet)	Depth (feet)
Logs of auger holes in alluvium of East Creek valley—Continued		
AUGER HOLE 6		
Soil, clayey, black	2	2
Clay, sticky, black	2	4
Clay, sandy, (water)	1	5
AUGER HOLE 7		
In gully about 15 ft below general land surface.		
Bank of gully, red sand	15	15
Red sand	6½	21½
Gravel (dry)	----------	21½
AUGER HOLE 8		
Clay, sandy, dark-gray	8½	8½
Gravel and clay, white	½	9
Sand, reddish-white	1½	10½
Gravel (dry)	----------	10½
AUGER HOLE 9, DAVES HOLLOW		
Pit	4	4
Clay, sticky, red	8	12
Sand, fine, red	1	13
Gravel, reddish-white (dry)	1	14

The thickness and the geologic and hydrologic character of the Mesozoic and Cenozoic rocks underlying Bryce Canyon National Park are given in table 5. Of these formations the oldest shown on the geologic map (fig. 55) is the Winsor formation of Late Jurassic age.

The Mesozoic rocks in table 5 are predominantly sandstone and shale with only minor limestone or conglomerate beds. Except for the Navajo sandstone, most formations have gypsum as a common cementing agent. This mineral is easily soluble, and thus may be present in much of the ground water contained in these beds. Gypsum is not so common in rocks of Cenozoic age, which are mostly limestone or sand and gravel.

TABLE 5.—*Generalized section of the geologic formations in the Bryce Canyon National Park area, Utah*

Based on information obtained from several sources, including Gregory (1951), Gregory and Moore (1931), and Harshbarger and Repenning (1954)]

System	Series	Geologic unit	Thickness (feet)	Depth to bottom of formation[1] (feet)	Physical character	Water supply
Quaternary	Recent and Pleistocene	Alluvium	0–136	0	Gravel, sand, silt, and clay filling the valley bottoms of East Creek, Daves Hollow, and other small streams, and the valley of the East Fork of the Sevier River. Attains maximum thickness in Emery Valley. Fills valley bottoms of Water, Campbell, and Bryce Canyons, Yellow and Sheep Creeks, Swamp Canyon, and other canyons below the rim.	Gravel and sand lenses in the alluvial valleys on the Paunsaugunt Plateau yield as much as 180 gpm to a well. Gravel fill in the canyons below the rim is very porous and in the washes this gravel is very permeable; yields large quantities of water where saturated, but in general the gravel contains water only in the vicinity of bedrock springs, with resultant limited yields.
		—Unconformity—				
Tertiary	Eocene	Wasatch formation	500–700 at the rim. 1,000 at Boat Mesa. 0–700 between the East Fork of the Sevier River and the rim.	500	Upper white beds present on Boat Mesa and Whiteman Bench are white, gray, or light-brown sandstone, conglomerate, and limestone containing siliceous cement and volcanic tuff and ash. Middle pink beds, chiefly pink, gray, and white massive limestone and interbedded sandstone and conglomerate. Basal conglomerate consists of pebbles poorly cemented by calcium carbonate; absent in Swamp Canyon and Yellow Creek; 10 to 30 ft thick at Bryce Point, composed of sandstone and conglomerate; 30 ft thick at Campbell Canyon, composed of lenses of conglomerate in limestone.	The white beds support springs of unstable yield on Whiteman Bench. A few small springs issue from sandy lenses and fractures, but the beds are not likely to yield water to wells. Basal conglomerate beds support several springs just below the rim and in the valley of the East Fork of the Sevier. If lenses of conglomerate are penetrated, the basal conglomerate might yield moderate quantities of water to wells.
		—Unconformity—				
		Kaiparowits formation	Absent in Bryce and Campbell Canyons. 400 in Yellow Creek and Sheep Creek areas.	900	Dark-gray, gray-green, yellow, and tan coarse- and medium-grained arkosic sandstone poorly cemented by calcium carbonate and in part by gypsum and iron oxide. Brown, white, and greenish limestone and blue and purple shale. Contains vertebrate bones, fossil wood, invertebrates, and ironstone nodules and concretions.	Yields water to several springs below the rim. Wells that penetrate this formation have very low yields (10 gpm or less).

		—Unconformity—				
Cretaceous	Upper Cretaceous	Wahweap sandstone	850+	1,750	Yellow and buff fine to medium sandstone, 40 to 60 ft thick in upper part. Interbedded sandstone and shaly sandstone in extensive lenses in lower part. Cemented mainly by calcite, but hard layers are cemented by iron oxide. Contains some gypsum and wood.	These two formations support most of the prolific springs below the rim. Although no water wells penetrate these formations in the Bryce Canyon area, they might yield water to wells in sufficient quantity for a public supply. The extensive sandstone layers make up most of the two formations which are saturated throughout the area; thus, most wells are apt to penetrate water-bearing material. (Lithologic equivalent in the Navajo Indian Reservation yields 20 to 40 gpm.)
		Straight Cliffs sandstone			Tan sandstones make up 95 percent of this formation, and sandstone layers greater than 10 ft thick make up 60 percent. Some of the sand is fine, but most is medium to coarse, and some conglomerates contain pebbles 1 to 3 in. across. Cemented mainly by calcite but in part by some iron oxide. Disseminated gypsum and carbonaceous beds occur.	
		Tropic shale	800	2,550	Bluish-drab clayey to sandy shale; irregularly bedded sandstones; abundantly fossiliferous; gypsum and selenite crystals are common. Contains sand lenses 2 to 15 ft thick and carbonaceous beds.	Very poor water-bearing formation. Forms impermeable barrier along Paunsaugunt fault, causing faultline springs. Sandstone lenses might produce small quantities of water, but such water would be high in calcium and sulfate and probably of unsatisfactory quality.
		Dakota sandstone	30	2,580	Buff-gray medium- to coarse-grained sandstone and conglomerate containing some shale and carbonaceous beds. Sandstones are weakly cemented. Contains some silicified wood.	Springs issue from the base of this formation in the Paria Valley. If sufficient thickness is penetrated, this formation would yield some water to wells. It is saturated everywhere west of the Paunsaugunt fault. The water might be of unsatisfactory quality owing to seepage from the overlying Tropic shale. (Yields 5 to 10 gpm in Navajo Indian Reservation, but water is highly mineralized.)

[1] Representative of depths and thicknesses underlying the vicinity of Paria View observation point in park.

TABLE 5.—*Generalized section of the geologic formations in the Bryce Canyon National Park area, Utah*—Continued

System	Series	Geologic unit	Thickness (feet)	Depth to bottom of formation [1] (feet)	Physical character	Water supply
		—Unconformity—				
Jurassic	Upper Jurassic	Winsor formation	600–700	3, 280	Thin-bedded red- and white-banded arkosic sandstone. Sand is medium- to coarse-grained; cemented by iron oxide, calcite, and gypsum.	Many of the creeks become perennial on or just below the outcrop of this formation. Several springs undoubtedly issue from this formation but only one at the base has been observed. Yields to wells should be moderate to small, but the water may be of poor quality.
		San Rafael group: Unconformity				
		San Rafael group: Curtis formation	110–180	3, 460	Massive gypsum, dense thin-bedded limestone, calcareous sandstone and shale, and gypsiferous very sandy shale.	Very poor water-bearing formation. Would yield very small amounts of highly mineralized water to wells.
		San Rafael group: Unconformity				
		San Rafael group: Entrada sandstone	170–240	3, 630	Thinly stratified friable fine-grained and very fine grained red, brown, and gray sandstone; some limestone, shale, and gypsum beds; contains abundant gypsum, which constitutes the chief cement, and fills cracks. Thickest individual sand bed about 30 ft.	Springs issue at various horizons from the Entrada, but owing to the fine texture of the sand, yields to wells would be small unless abundant fractures improved the permeability. Under the Paunsaugunt Plateau water would probably be highly mineralized.
	Middle Jurassic	San Rafael group: Carmel formation	0–165	3, 795	Regularly interstratified beds of tan and blue-gray shale, limestone, and sandstone, containing smaller amounts of gypsum and conglomerate in both thin and thick lenticular beds.	Very poor water-bearing formation. Water probably highly mineralized.

			Unconformity				
Jurassic and Jurassic(?)		Glen Canyon group	Navajo sandstone	1,200–1,800	5,595	Light creamy-yellow, white, and buff highly crossbedded sandstone. Forms the White Cliffs.	Probably would yield largest amounts of good-quality water of any formation below the Wahweap and Straight Cliffs sandstones. (Yields as much as 70 gpm in the Navajo Indian Reservation.)
			Unconformity				
Triassic	Upper Triassic	Chinle formation	Upper part of Chinle formation	600–800	6,395	Red and brown shale, sandstone, and limestone.	Probably not water bearing.
			Shinarump member	0–115	6,510	Red and gray conglomerate.	May yield a small quantity of water to wells, but water would probably be somewhat mineralized.
			Unconformity				
	Middle(?) and Lower Triassic		Moenkopi formation	500	7,010	Chocolate-brown shale and some sandstone.	Probably not water bearing.

1 Representative of depths and thicknesses underlying the vicinity of Paria View observation point in park.

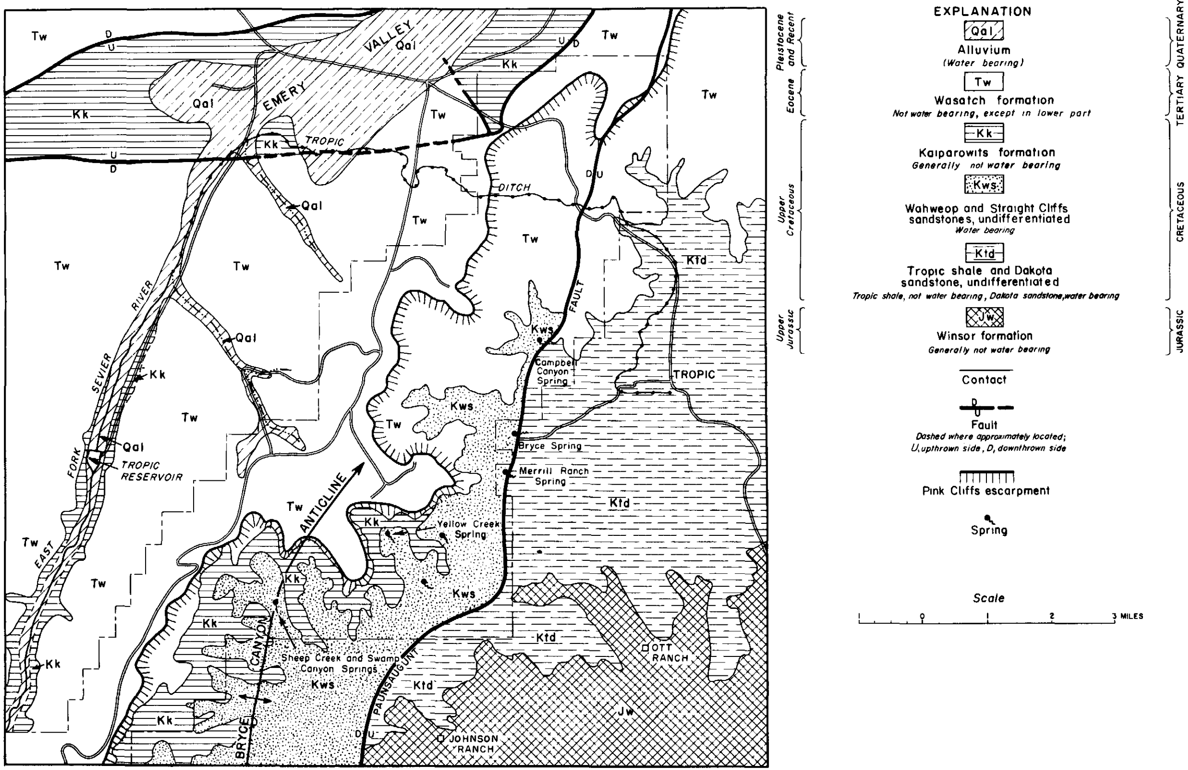

FIGURE 55.—Geologic map of the northern part of Bryce Canyon National Park area, Utah. Modified from Gregory (1951).

STRUCTURE

The principal structural features of the Bryce Canyon National Park area are gently northeastward-dipping beds and several major normal faults. The regional dip of the beds ranges from ½° to 3° north, northeast, and east. Departures from the regional dip are found only in the immediate vicinity of faults and in gentle folds. A gently north-plunging anticline in the vicinity of Willis and Heward Creeks was described by Hager (1957). The axis of this anticline is west of the Pink Cliffs escarpment in the Heward Creek area, but it crosses the escarpment in the vicinity of Sheep Creek.

Faulting is restricted to a few large-scale normal faults; two of these faults—the Paunsaugunt and Sevier—are regional in extent. The Sevier fault is about 7 miles west of the area covered by this report. These two faults trend northward, and the east block of each fault is upthrown in relation to the west block. The Paunsaugunt fault does not coincide with the Pink Cliffs escarpment and, in fact, is not noticeable as a topographic feature of any kind. Two cross faults that trend generally eastward, connecting the Sevier and Paunsaugunt faults, are evident as topographic features—faultline scarps that form the borders of Emery Valley.

Each of these structural features exercises some control on the occurrence and movement of ground water in the bedrock aquifers of the area. Ground water moves through the rocks in the general direction of the regional dip, which accounts for the many springs along the eastern scarp of the Paunsaugunt Plateau. Along the Paunsaugunt fault, springs occur where the eastward movement of ground water is blocked by upfaulted relatively impervious beds, which force the water to rise to the surface. Tension fractures along the axis of the Bryce Canyon anticline (fig. 55) might create secondary permeability and afford an opportunity to obtain successful water supplies from wells penetrating the bedrock.

WATER RESOURCES

SURFACE WATER

In the Bryce Canyon area there are only two perennial surface streams, the East Fork of the Sevier River and the Paria River, but short perennial reaches of tributary streams are fed by springs. The diversions of water by the Tropic and East Fork Irrigation Co. from the East Fork of the Sevier River into the Paria River drainage are shown in table 1. The U.S. Geological Survey gaging station (pl. 24) was installed primarily to record the amount of water in the Tropic Ditch that crosses the divide; it does not necessarily record the total amount of water released from the Tropic Reservoir.

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SPRINGS

The springs of the Bryce Canyon National Park area may conveniently be divided into two groups: those on top of the Paunsaugunt Plateau and those below the rim in the Paria River drainage area. Fluctuations in the flow of springs on top of the plateau are closely related to annual precipitation, whereas fluctuations of the flow of springs below the rim are not. On the Paunsaugunt Plateau are two types of springs—bedrock and alluvial. The bedrock springs on the plateau may, in turn, be divided into those that issue from the white beds of the Wasatch formation and those that issue from the basal conglomerate of the Wasatch formation.

On the plateau several bedrock springs (for example, Shaker, Trough, and Whiteman) occur on the north and east sides of Whiteman Bench (pl. 24). It is thought that these springs occur where permeable beds in the sandy white beds of the Wasatch formation lie in contact with the denser pink limestone beds of the same formation. Inasmuch as all the springs issue from thin alluvium, it is difficult to determine the bedrock source. These springs are recharged by rain and snow that falls on top and around the margins of Whiteman Bench; the yields are unstable and fluctuate in response to variations in the amount and distribution of precipitation. In May 1957 Shaker, Trough, and Whiteman Springs were not flowing. The upper graph in figure 52 shows that in 1956 the cumulative departure from normal precipitation was at the lowest point during the period of record, which probably accounts for the cessation of flow from the bedrock springs on the plateau.

Above the Tropic Reservoir on the plateau are several springs that contribute water to short tributaries of the East Fork (pl. 24). The geologic map (fig. 55) shows that these springs issue from the Wasatch formation just above its contact with the underlying Kaiparowits formation. Gregory (1951, p. 46) states that the basal conglomerate of the Wasatch formation is present near the Tropic Reservoir, and it is thought that the springs issue from this permeable bed. However, these springs were not visited by the writer.

Springs on the plateau whose source is alluvium are probably present in most of the larger valleys. Seven of these springs are in East Creek valley (pl. 25), and these were the only ones visited by the writer. These springs had an insignificant flow in May 1957, and by June all flow had ceased.

The second region of springs is below the rim in the Paria River drainage area, where springs issue from thin patches of alluvium which obscure their bedrock source. The locations of these springs are shown on plate 24, and table 6 gives their altitudes, the geologic formations from which they issue, and their respective stratigraphic positions. The geologic formations and stratigraphic positions from which these springs issue were determined from Gregory's geologic map (1951). Table 7 gives chemical analyses of water collected from selected springs.

Springs and seeps occur at many localities in the foothills below the rim on the east side of the Paunsaugunt Plateau. These are caused by the eastward and northeastward movement of water as it follows the dip of the more permeable beds. Sheep Creek, Swamp Canyon, Yellow Creek Springs, and the springs farther south along the rim are examples of springs that owe their existence to the outcrop of permeable beds. Merrill Ranch, Bryce, and Campbell Canyon Springs are faultline springs. Figure 56 illustrates the mode of occurrence of most faultline springs in this area. The upthrown block of Tropic shale forms a relatively impervious eastern barrier, which forces water from the permeable beds in the Wahweap and Straight Cliffs sandstones to rise to the surface instead of continuing its northeastward movement.

Nearly all the springs below the rim issue from alluvium, which in some places is a thin layer obscuring the bedrock. The water emerging from these springs has a constancy of flow that indicates a bedrock source. If their source were the alluvium in the reentrants, these springs probably would not flow in dry seasons as the alluvium generally is insufficient to store enough water to support the flow, except in wet weather. The recharge area of these springs is restricted to the Paunsaugunt Plateau and immediately adjacent areas. Formations below the Wahweap and Straight Cliffs sandstones probably obtain part of their recharge from areas more distant than the plateau.

Table 6 gives the measured discharge of the springs below the rim in the Bryce Canyon area. Because the conditions at each spring are different, each will be considered separately with respect to its utilization for water supply. Springs north of Campbell Canyon were not visited by the writer, and no measurements of flow or chemical analyses are available.

Campbell Canyon Spring is within the National Park boundary and is 3 miles from the storage tanks of the Utah Parks Co. Water rises in a grassy marsh between two washes that join just below the spring. The water drops about 10 feet from the grassy area to the gravel in the stream wash proper. Within 300 feet of the point where the spring water flows onto the gravel of the wash, all surface water has disappeared. Development work might increase the yield of this spring slightly (table 3). The water is hard but otherwise of good quality (table 7), and, like that of other springs below the rim, the yield is fairly constant. The principal objection to the development of a water supply at this site is the low yield of the spring (table 6).

TABLE 6.—*Records of springs below the Pink Cliffs in the Bryce Canyon National Park area, Utah*

Name of spring [1]	Altitude (ft)	Geologic source	Stratigraphic position	Discharge (gpm)	Date (1957)	Method of measurement	Total lift to Utah Parks Co. storage tanks [2] (ft)	Approximate direct distance to Utah Parks Co. storage tanks (miles)	Remarks
			Above base:						
Upper East Fork (tributary to Cope Canyon).	7,100	Wasatch formation	300 ft				1,020	6.9	Location of spring reported by local residents; not visited by writer.
Lower East Fork (tributary to Cope Canyon).	6,900	do	100 ft				1,220	6.5	Do.
Cope Canyon	6,950	do	150 ft				1,170	6.3	Do.
Water Canyon	7,000	do	320 ft				1,120	4.4	Do.
Mossy Cave	7,250	do	570 ft				870	4.3	Do.
			Below top, at Paunsaugunt fault:						
Campbell Canyon	6,800	Wahweap and Straight Cliffs sandstones.	200 ft	17	May 18	Rectangular weir.	1,320	3.0	
				28	Sept. 24	90° V-notch weir.			
Bryce	6,900	do	350 ft				1,220	2.3	
Merrill Ranch	6,900	do	550 ft	17	May 18	Rectangular weir.	1,220	3.0	
				12	June 21	Cipolletti weir.			
				24	Sept. 25	90° V-notch weir.			
			Below top:						
Yellow Creek	7,220	do	100 ft	81	May 15	Cipolletti weir.	900	2.1	
				43	June 21	do			
				52	Sept. 25	90° V-notch weir.			
Upper Yellow Creek Wash.	7,220	do	do	120	May 15	Float	900	2.1	Total water available at Upper Yellow Creek: May 15, 201 gpm; June 21, 183 gpm; Sept. 25, 172 gpm.
				140	June 21	do			
				120	Sept. 25	do			
Second Yellow Creek Wash.	6,900	do	400 ft	185	June 21	do	1,220	2.9	

Right Fork (of Yellow Creek).	7,220	do	100 ft	75	June 21	do	900	2.1	Location of spring reported by local residents; not visited by writer. Discharge measured 1 mile downstream from reported source.
Third Yellow Creek Wash.	5,800	Winsor formation	600 ft	60	Sept. 25	Visual estimate.			
Swamp Canyon	7,270	Wahweap and Straight Cliffs sandstones.	200 ft	11	May 20	Rectangular weir.	870	3.4	Total water available at junction of Sheep Creek and Swamp Canyon: May 20, 59 gpm; Sept. 24, 36 gpm.
				2	Sept. 24	90° V-notch weir.			
Sheep Creek	7,270	do	do	48	May 20	Rectangular weir.	870	do	
				34	Sept. 24	90° V-notch weir.			
Second Sheep Creek	7,120	do	350 ft	Seep; no flow.	Sept. 24	Visual estimate.	1,000	4.0	
Natural Bridge	8,200	Wasatch formation	At base						Spring seen from rim and plotted on map, but not visited by writer.
Agua Canyon	8,250	do	do						Do.
Ponderosa Canyon	8,100	do	do						Do.
Iron	8,050	Kaiparowits formation.	Above base: 250 ft						Spring shown on 1939 U.S. Geological Survey topographic map. Neither seen nor visited by writer.
Birch	8,100	do	350 ft						Do.
Lonely	7,775	do	At base						Do.
Yovimpa	8,360	Wasatch formation	do						Do.
Riggs	7,500	Wahweap and Straight Cliffs sandstones.	Below top sandstone, 400 ft.						Do.
Gravel	7,750	do	Below top, 150 ft						Do.

[1] See pl. 24 for location and table 7 for chemical analysis of water.

[2] Altitude of storage tanks (8,120) interpolated from topographic map.

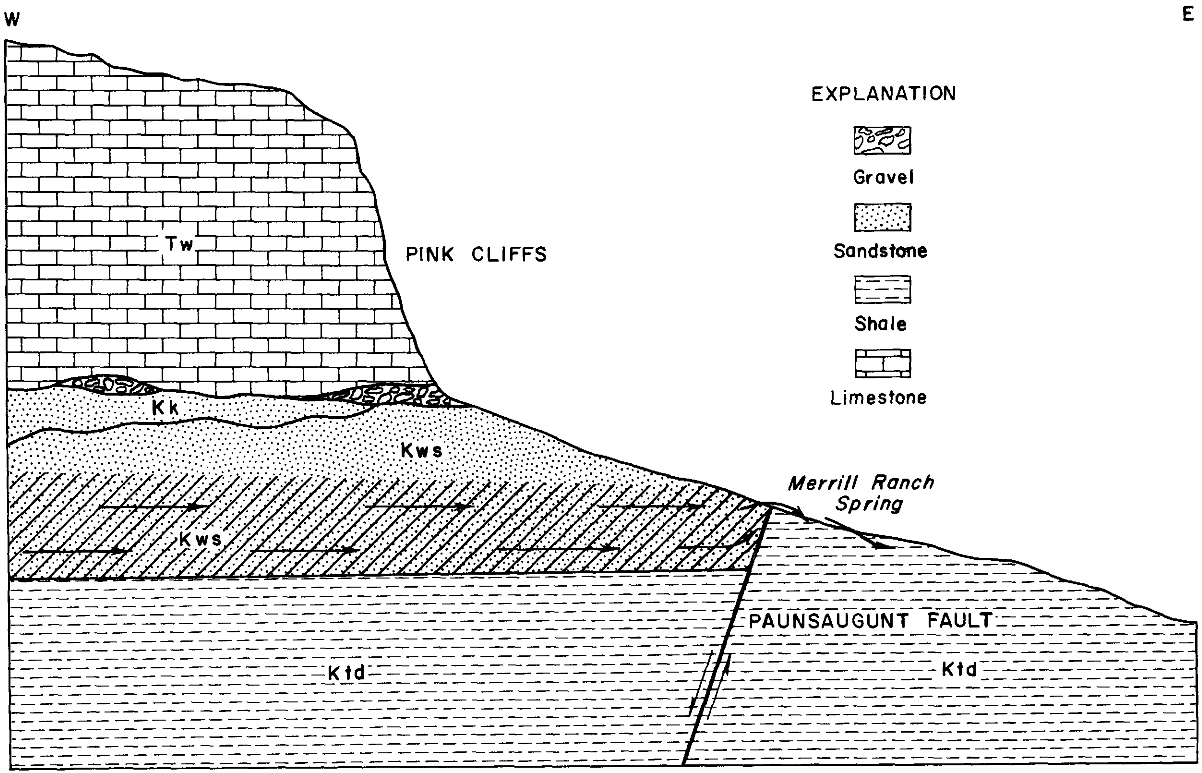

FIGURE 56.—Generalized east-west cross section through Merrill Ranch Spring showing the movement of ground water in relation to the occurrence of all faultline springs in the area. Double-barbed arrows represent direction of water movement; crosshatched area represents zone of saturation. Tw, Wasatch formation; Kk, Kaiparowits formation; Kws, Wahweap and Straight Cliffs sandstones, undifferentiated; Ktd, Tropic shale and Dakota sandstone, undifferentiated.

TABLE 7.—*Chemical analyses of water from selected springs and wells in the Bryce Canyon National Park area, Utah*

[Chemical constituents are given in parts per million]

Source	Geologic source	Date of collection	Specific conductance (micromhos at 25° C)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (sum)	Hardness $CaCO^3$: Carbonate	Hardness $CaCO^3$: Noncarbonate	pH	Analyst [1]	Remarks
Campbell Canyon Spring.	Wahweap and Straight Cliffs sandstones.	10- 5-56	--------	9.6	0.20	36	31	25	241	53	12	1.6	1.0	288	218	------	8.1	A	
		5-18-57	401	10	------	49	22	3.9	249	17	2.0	------	.1	227	214	10	8.1	B	Temperature 57°F.
Merrill Ranch Spring.	do	10-28-56	--------	10	.16	53	51	23	344	84	12	.4	1.1	403	343	------	8.1	A	
Yellow Creek Spring.	do	5-18-57	557	11	------	69	34	2.8	341	33	2.8	------	.0	321	312	32	7.9	B	
		11- 7-56	--------	20	.03	56	43	------	302	52	8.0	.6	.1	------	316	------	8.2	A	
Second Yellow Creek Wash Spring.	Alluvium	6-21-57	698	15	------	73	52	2.5	318	126	5.4	------	.4	431	394	133	7.5	B	
		10-14-57	1,020	15	------	95	71	37	352	293	8.0	------	.4	692	526	237	7.4	B	
Third Yellow Creek Wash Spring.	do	do	2,030	15	------	186	109	167	340	933	18	------	.7	1,600	633	912	7.1	B	
Swamp Canyon Spring.	Wahweap and Straight Cliffs sandstones.	9-29-56	--------	11	.10	120	133	------	545	345	12	.3	.8	------	846	------	7.4	A	
Sheep Creek Spring.	do	11- 9-56	--------	26	.02	93	117	2.0	426	338	10	.3	.0	796	715	------	7.8	A	
		5-20-57	1,160	15	------	137	90	2.8	402	364	8.0	------	.1	815	714	384	7.7	B	
Utah Parks Co. well 1.	Alluvium	5-19-57	442	6.1	.00	45	32	------	299	3.4	4.8	.4	1.5	243	246	1	7.3	B	Boron (B), 0.03 Sodium (Na), 2.4 Potassium (K), 0.5
Bryce Canyon Airport well.	Alluvium and Kaiparowits formation.	5-21-57	350	9.5	------	42	18	5.3	207	11	6.0	------	.2	194	178	8	7.9	B	

[1] A, Utah State Dept. of Health; B, U.S. Geol. Survey.

Bryce Spring supplies drinking and culinary water to the town of Tropic. Residents estimate that the flow is about 1 cfs (cubic foot per second); however, the flow of the spring was not measured by the writer. Gregory (1951, p. 112) said that Tropic received 38 gpm from this spring area.

Merrill Ranch Spring is 1½ miles east of the Pink Cliffs along the Paunsaugunt fault (fig. 56). The water rises in a grassy area, as does that of several of the other springs, but it does not empty into a gravel-bottomed wash as it does at the others. Sandy clay is at the surface in both the source area for the spring, and at the spring. Owing to the clayey nature of the surface material at the spring, it would be difficult to increase the yield of the spring substantially by development work. The yield is small (table 6), and even a 50-percent increase would not provide enough water for the present water need of the park.

Certain of the springs in Yellow Creek offer the best possibility for the development of a water supply from a spring source. The springs in Yellow Creek (pl. 24) have been subdivided for discussion as follows: (1) Yellow Creek Spring and (2) Upper Yellow Creek Wash Spring in the upper reach of Yellow Creek; (3) a marshy area south of Yellow Creek but in the vicinity of (1) and (2); (4) Second Yellow Creek Wash Spring above the junction of Yellow Creek with North Fork; (5) Right Fork (of Yellow Creek) Spring; (6) Third Yellow Creek Wash Spring below Ott Ranch.

Water first appears in Yellow Creek at Upper Yellow Creek Wash Spring (2) and is joined a short distance downstream by water from Yellow Creek Spring (1). It flows downstream for a distance that varies with the amount of water flowing from the two springs and with the season, but in June 1957 it was about a quarter of a mile. Below this the bed of Yellow Creek was dry for a distance of slightly less than a mile. Water appeared again in the channel at the Second Yellow Creek Wash Spring (4). In 1957 all this water was diverted into a ditch parallel to Yellow Creek that carries it to Ott Ranch (pl. 24), but, according to residents of the area, water would be visible in the bed of Yellow Creek all the way to Ott Ranch if it were not diverted. Below Ott Ranch, Yellow Creek was dry to the Third Yellow Creek Wash Spring (6).

The water from the upper spring area (1 and 2) of Yellow Creek is of good chemical quality for domestic needs (table 7), and the quantity is sufficient for the park needs (table 6). An additional advantage of this source is the possibility of expansion as the need for water in the park grows. The principal disadvantage of the upper spring's source is that it is not readily accessible. The upper spring area can be seen from the Paria View observation point (fig. 57),

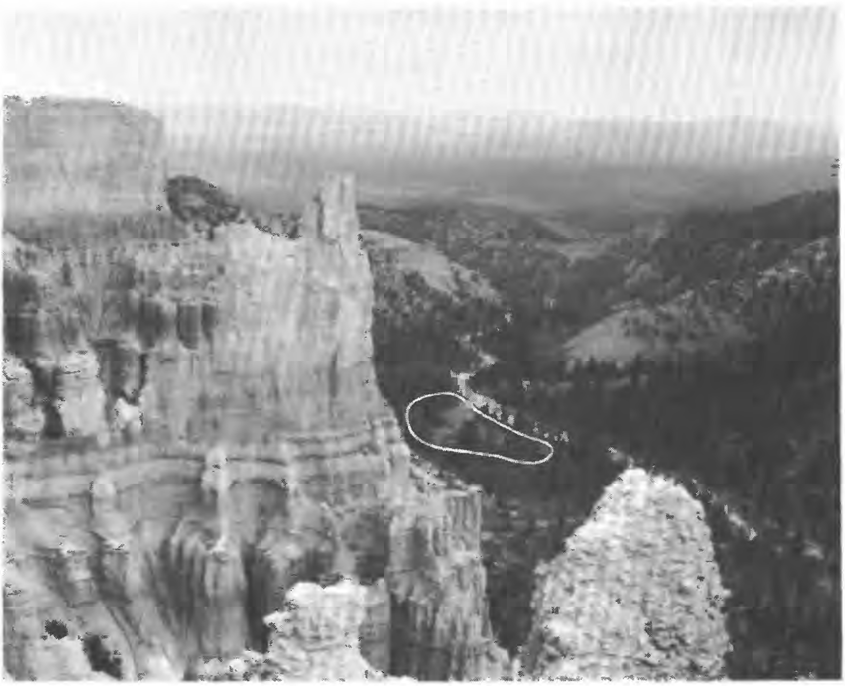

FIGURE 57.—Yellow Creek Spring (circled) and Yellow Creek seen from Paria View observation point. Photograph by H. A. Waite.

and it might be necessary to camouflage any structures placed there, so as not to spoil the view. A pipeline to the top of the rim would be necessary for development of the upper spring area of any of the spring's sources below the rim.

Yellow Creek Spring (1) issues in a grassy marsh covering about 2 acres near the base of the Pink Cliffs. From this spring area the water drops about 10 feet into the bed of Yellow Creek, where the water flows perennially. The relative positions of Yellow Creek Spring and Yellow Creek Wash are shown in figure 57. The water in the channel first appears opposite the upper end of the spring area and probably comes from the same permeable bed in the Wahweap and Straight Cliffs sandstones that supplies the spring. On the south side of the wash is another grassy marsh (3) which suggests an additional outcrop of this permeable bed in the Wahweap and Straight Cliffs sandstones. Although this area is soggy and wet, no visible flow leaves it.

Inasmuch as the measured flow of Yellow Creek Spring (1) and Upper Yellow Creek Wash Spring (2) (table 6) represents only the water at the surface, more water probably could be obtained by proper development work at this source. A substantial part of the water

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flowing at the surface in the permeable wash must be sustained by underflow. Construction of a tile drain under the channel possibly would make available additional water. Any surface works constructed in the wash proper would be subject to destruction by the occasional but violent cloudburst floods that are responsible for emplacing the boulders and cobbles that make up the floor of the wash. Any construction in gravel washes should be planned with the destructive nature of these storms in mind. It is believed by the writer that the amount of surface discharge in Yellow Creek combined with the increased amount available as a result of development work would be sufficient for the park needs for a long time.

At the Second Yellow Creek Wash Spring (4) water appears in the permeable gravel of Yellow Creek Wash. Water from this point flows at the surface in an unlined ditch for more than 4 miles downstream where it is used at Ott Ranch. Water from the Right Fork (of Yellow Creek) Spring (5) disappears into the permeable gravel about 150 yards upstream from the point where the wash joins Yellow Creek. The source of this water was not seen by the writer, and the location of the spring shown on plate 24 was reported by a local resident. Farther down Yellow Creek Wash, water appears again at the Third Yellow Creek Wash Spring (6) but is of very poor chemical quality (table 7).

Table 3 shows that there is sufficient water in the upper spring area of Yellow Creek to supply the park needs. If the upper spring area is developed for a water supply, laying the pipeline for some distance northward before having it ascend the Pink Cliffs might insure that the Right Fork Spring (5) would be conveniently near the pipeline, should additional water be needed in the future.

The Sheep Creek Spring (pl. 24) rises from small amphitheaters in the alluvium of the stream. The Swamp Canyon Spring rises from a grassy marsh several acres in area. The water from Swamp Canyon Spring collects in a channel and flows for several hundred yards before it joins Sheep Creek. The yields from these two springs were measured separately a few score feet above their junction (table 6). Development work at Swamp Canyon Spring probably could increase the yield, but it is doubtful that much could be done to increase the yield of Sheep Creek Spring. The proximity of these springs and the presence of similar chemical constituents in water derived from them indicate that both springs have a common bedrock source in the Wahweap and Straight Cliffs sandstones. The high sulfate and calcium content is noteworthy and strongly suggests that abundant gypsum ($CaSO_4$) is present in the aquifer (table 7). The high content of calcium and sulfate in this water makes it undesirable for a public water supply, although the spring area is probably the most accessible of any below the rim. These springs can be reached by jeep from the lodge and headquarters area. About 1 mile downstream from Sheep Creek Spring, on the side of a hill on the east slope of Sheep Creek valley, is a seep area called the Second Sheep Creek Spring (table 6; pl. 24). This spring issues from the Wahweap and Straight Cliffs sandstones and is unique in that alluvium does not obscure its bedrock source.

Springs south of Sheep Creek were not considered as possible sources of water for the lodge and headquarters area because of the availability of adequate water supplies nearer the area of use.

GROUND WATER IN ALLUVIUM

The area on the Paunsaugunt Plateau underlain by saturated alluvium is small compared with the area underlain by saturated bedrock. However, owing to the greater permeability of alluvium, these areas are of relatively great importance to the water resources of the region. In the Bryce Canyon area, the most significant deposits of alluvium occur beneath the valley bottoms of Emery Valley, the East Fork of the Sevier River, East Creek, Daves Hollow, and smaller tributaries to the East Fork.

EAST CREEK VALLEY

In the summer of 1957 the water supply for Bryce Canyon National Park was obtained first from one well (well 1) and later from two wells (wells 1 and 2) in East Creek valley near the alluvial springs formerly used for a water supply. To determine if the water yield of this valley were sufficient for the park needs and if the valley could support a larger development than existed in 1957, greater emphasis was placed on investigating the ground-water resources of the alluvium in this valley than was given to other bodies of alluvium. This valley is in a favorable location because it is only a little more than 2 miles from the Utah Parks Co. storage tanks and because the pumping lift is only 372 feet.

Because of the water-supply developments in East Creek valley, more information was available on the quantity and dependability of the water yield from this alluvial body than from others. Information on these developments in East Creek valley is included in the section on "Water Use."

The flow of East Creek, when not caused by cloudbursts, is controlled principally by the ground-water level in the adjacent alluvium. Springs and seeps occur only when the amount of water in the alluvium of East Creek valley is in excess of the amount required for saturation and for supplying water-using plants that are abundant in areas of high water table. When sufficient water is released to the surface, it flows down East Creek. In late summer of 1955 and in 1956 and 1957 East Creek did not flow, suggesting that the alluvium in the valley was not saturated to the extent that it had been in previous years.

The cessation of flow in East Creek was due principally to a deficiency of precipitation over a period of years. The upper graph of figure 52 shows the cumulative departure from normal precipitation at Bryce Canyon National Park for the period 1933 through 1956. According to the U.S. Weather Bureau, the normal annual precipitation at Bryce Canyon National Park is 17.34 inches. The cumulative deficiency during the period from 1947 through 1956 amounted to about 33 inches, nearly 2 years' normal supply. The effect that this deficiency of precipitation had on the amount of water stored in the alluvium in East Creek valley is not known, but it probably was substantial.

Some of the recharge to the alluvium comes from bedrock springs. Whiteman Spring, at the toe of Whiteman Bench, is tributary to East Creek, and when the spring flows it supplies some recharge to the alluvium along that stream. Fluctuations in the flow of Whiteman Spring and other bedrock springs on the Paunsaugunt Plateau probably bear a closer relation to the cumulative departure from normal precipitation than to the yearly precipitation. Whiteman Spring was dry in the summer of 1957; therefore, it contributed no recharge to the alluvium of East Creek valley. Although 1957 was a year of above-normal precipitation, several such years may be required to restore the flow of Whiteman Spring to its former normal volume.

A water-level recording gage was in operation on Utah Parks Co. well 3 from April 26, 1957, to October 23, 1957. The hydrograph of this well shows that the water level in the alluvium of East Creek valley continued to decline as long as water was being pumped from the basin, indicating that the withdrawal exceeded the recharge. This is substantiated by the reaction of the water level to intermittent pumping in May 1957. The water level recovered when the pump was turned off, but not to the original static water level.

To determine how much water is stored in the ground-water reservoir in the alluvial valley, the flat valley floor, herein considered to represent the part of the valley underlain by alluvium, was mapped (pl. 25*A*). The slopes of the sides of the valley also were measured at selected points. In constructing the cross sections of the valley fill, it was assumed that the slopes of the valley sides persist beneath the alluvium (fig. 58).

Figure 59 was constructed by combining the cross sections of figure 58 with the section of plate 25*B*. It is believed by the writer that

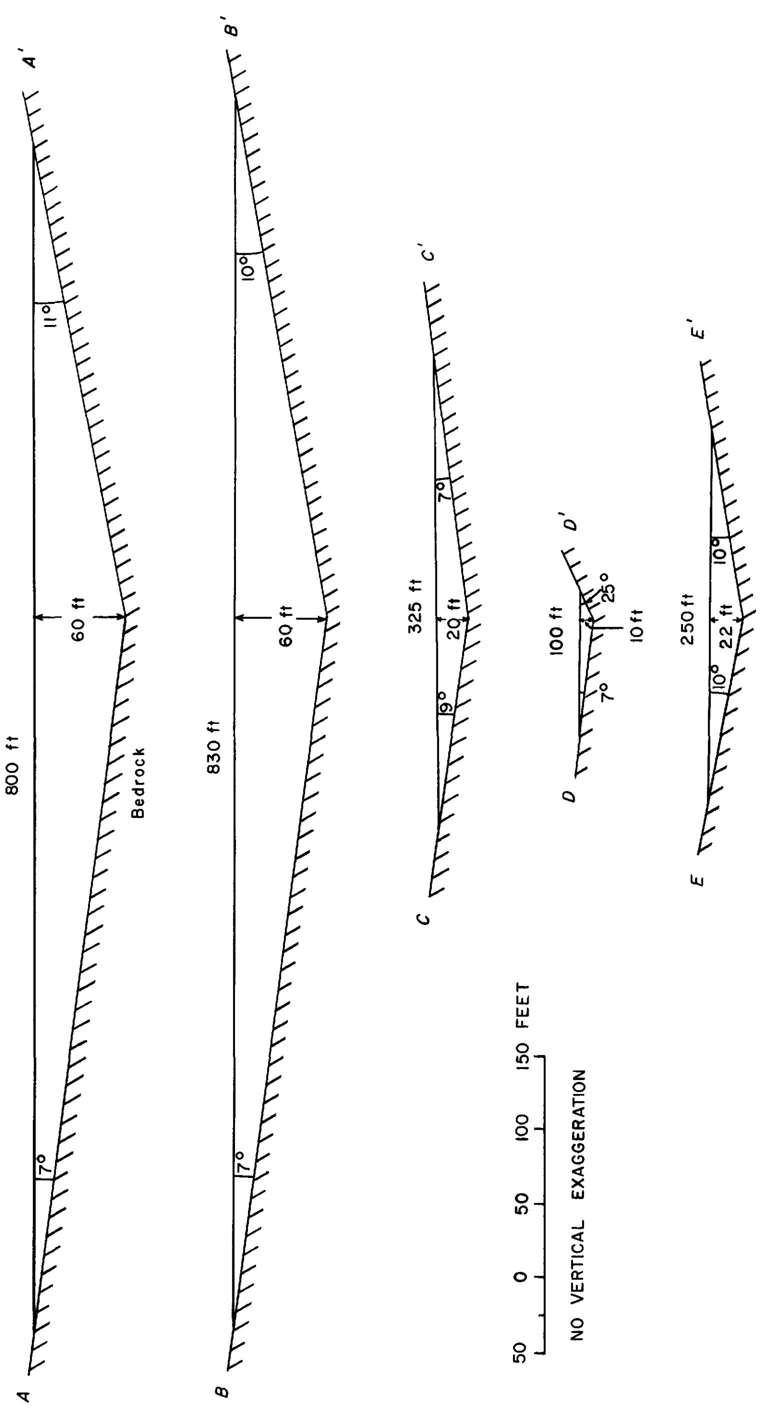

FIGURE 58.—Selected schematic cross sections across East Creek valley showing approximate thickness of alluvium. The locations of the cross sections are shown on plate 25*A*.

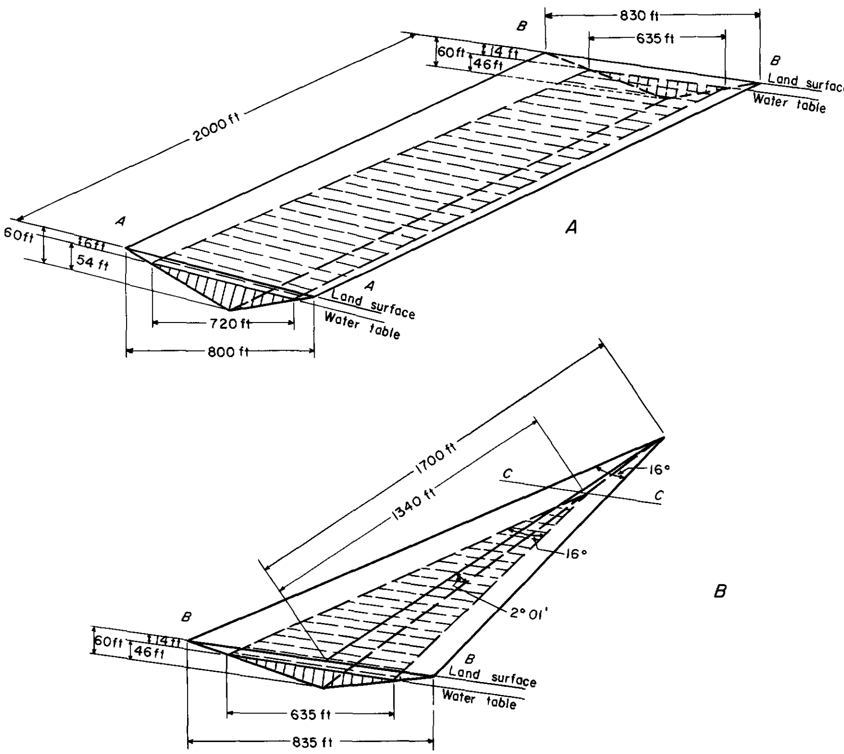

FIGURE 59.—Schematic diagrams of saturated alluvium in parts of East Creek valley, May 1957. *A*, segment between cross sections *A–A'* and *B–B'*; *B*, segment between cross sections *B–B'* and *C–C'*. Locations of cross sections are shown on plate 25*A*.

the resulting geometric figures are representative of the approximate shape and dimensions of the alluvial fill.

On the assumptions that (1) about 32 percent of the alluvium is water bearing (average in wells 1–3; table 4); (2) the specific yield (drainable pore space) of the water-bearing material is about 20 percent; and (3) the total volume of saturated alluvium is about 40 million cubic feet (volume of the parts with the ruled pattern in fig. 59, the volume of ground water in storage in the alluvium between cross sections *A–A'* and *C–C'* is estimated to be about 2.6 million cubic feet. This amount of water might be available to a well that penetrated 60 feet of alluvium, that was equipped with a pump whose bowls were set at the bottom of the well, and that was pumped long enough. None of the wells of the Utah Parks Co. were drilled through as much as 60 feet of alluvium.

The ground-water storage available to the wells of the Utah Parks Co. may be estimated by subtracting the volume of ground water in storage below 25 feet in depth (about 1.2 million cubic feet) from the total storage in East Creek valley. The total volume of ground water available to these wells as of May 1957 thus amounted to about 1.4 million cubic feet.

In this estimate it is assumed that the water table in the alluvium could be lowered in successive stages without the formation of excessively deep cones of depression. In the late summer of 1957 the cones of depression around both the existing wells were steep, and because of this circumstance it was not possible to develop the maximum amount of water from storage.

A chemical analysis of the water from well 1 is shown in table 7. This water is of very good chemical quality, and water of comparable quality probably can be obtained from wells anywhere in the alluvium of East Creek valley.

OTHER ALLUVIUM-FILLED VALLEYS

Ground water probably occurs in the valley of the East Fork of the Sevier River under conditions very similar to those of East Creek valley. Because the drainage area of the East Fork is larger and the volume of alluvium in the valley is larger, the yield of ground water from the East Fork valley would probably be more dependable than that from East Creek valley.

Because the drainage area of Daves Hollow (about 5.4 square miles) is about half that of East Creek (11.2 sq. mi., of which about 9.3 sq. mi. is above the pumphouse), the ground-water yield would probably be less dependable than that from the alluvium of East Creek valley. The yields of wells drilled in Emery Valley are small, which suggests that the water-bearing material is not highly productive. The total ground-water storage of this valley may be large, however.

GROUND WATER IN BEDROCK

The water-bearing properties as well as the geologic characteristics of the Cenozoic and Mesozoic formations that underlie the Bryce Canyon area are shown in table 5. The principal bedrock units that might yield water to a well, from the surface down, are (1) the basal conglomerate of the Wasatch formation, (2) the Wahweap and Straight Cliffs sandstones, (3) the Dakota sandstone, (4) parts of the Winsor formation, (5) the Entrada sandstone, (6) the Navajo sandstone, and (7) the Shinarump member of the Chinle formation.

The basal conglomerate of the Wasatch formation (1) is lenticular and might be missing at any particular place. A well drilled into the basal Wasatch in the vicinity of Bryce Point, where Gregory (1951, p. 46) reported the conglomerate to be 10 to 30 feet thick, might be successful, but there is no evidence to indicate potential yields. Even if a permeable lens of coarse material were penetrated, it might not be extensive enough to yield water perennially.

The Wahweap and Straight Cliffs sandstones (2) support many springs in the area, and in the Yellow Creek vicinity these sandstones yield water in large quantity. Most of the springs issuing from the Wahweap and Straight Cliffs sandstones supply excellent drinking water, but water from Swamp Canyon and Sheep Creek Springs has a high sulfate content (table 7). It is entirely possible that a well drilled into the Wahweap and Straight Cliffs sandstones might encounter water of similarly poor quality.

The Dakota sandstone (3) is thin and for this reason would not be expected to yield large quantities of water. Because the overlying Tropic shale contains abundant gypsum, water from the Dakota sandstone probably would be high in dissolved minerals owing to seepage from above.

It is likely that water from the Winsor formation (4) also would be appreciably mineralized owing to the gypsum contained in the formation.

Water from the Entrada sandstone (5) probably is somewhat mineralized because of the abundance of gypsum in this formation, and yields would probably be small.

The Navajo sandstone (6) is 1,200 to 1,800 feet thick and perhaps thicker, and the minimum depth to the top of the formation is about 3,800 feet. Water from the Navajo sandstone might be of good quality because the sandstone is made up dominantly of quartz sand. The Navajo sandstone might yield water in sufficient quantity to supply the needs of the park.

Water from the Shinarump member of the Chinle formation (7) is probably highly mineralized in this area and could be obtained only by drilling a well 6,500 feet or more deep.

Conclusions about the quality of the water in the several formations are supported by an electric log of one oil test in the area.

If a bedrock test well is attempted, it is recommended that it be drilled to the top of the Tropic shale at a depth of about 2,000 feet, in order to test the entire section of the Wahweap and Straight Cliffs sandstones. Because these are marine sandstones, they are probably fairly uniform but relatively low in permeability under most of the area in which a deep well would be drilled. Any bedrock test well should be located as far as practical from the ground-water discharge area below the rim, and where there is a favorable opportunity to intercept fracture zones in the Wahweap and Straight Cliffs sandstones. The axis of the anticline described by Hager (1957), if extended, passes through Bryce Canyon, although the Bryce Canyon area is beyond the limits of his map. It is therefore recommended that any bedrock test well be located near the crest of this anticline so that the greatest number of tension fractures will be encountered. The location of a recommended test site is shown on plate 24.

It would seem that the chances of obtaining good water between the base of the Wahweap and Straight Cliffs sandstones and the Navajo sandstone are small. Therefore, unless it is intended to drill to the Navajo sandstone, at a depth of about 3,800 feet below the surface at the test site indicated on plate 24, there seems to be little reason to drill below the base of the Wahweap and Straight Cliffs sandstones. Several water-producing sands should be penetrated by a well drilled through the Wahweap and Straight Cliffs sandstones, but whether the yield of such a well would be sufficient for the park needs depends on the amount of fracturing in these formations.

CONCLUSIONS

The Bryce Canyon National Park needed about 1.3 million cubic feet of water for about 250,000 visitors in 1957 (table 3). According to the Mission 66 estimate, water facilities will have to be provided for about 500,000 visitors a year (fig. 51). To evaluate water sources, a hypothetical future requirement of about 5 million cubic feet of water per season was used.

Possible sources of water for the park facilities include (1) surface water from the East Fork of the Sevier River, (2) water from wells in alluvium in the valley of the East Fork or in East Creek valley, (3) water piped up from springs below the Pink Cliffs, and (4) water from one or more wells drilled into bedrock.

Wells in the alluvium of East Creek valley could be an important source of water but not the sole source of water for the park. Although the potential quantity available is small, the quality of the water is good and quite satisfactory for all uses in the park. The low pumping lift to the storage tanks (372 ft) of the Utah Parks Co. makes this source of water a very desirable one. Sufficient water is available from this source to meet all but peak tourist-season needs; during periods of peak demand an additional source is needed.

Of the springs below the Pink Cliffs, only springs in the Yellow Creek area are considered, because of their proximity to the park facilities, and because other springs that are not so close are lacking in either yield or quality. The Yellow Creek springs are dependable and yield water satisfactory in quality and adequate in quantity to supply all water needs created by any foreseeable expansion of the park.

A well drilled to the top of the Tropic shale (about 2,000 ft) should penetrate one or more aquifers in the Wahweap and Straight Cliffs sandstones, and perhaps one at shallower depth at the base of the

Wasatch formation. A well drilled on the plateau about 1½ miles northwest of Yellow Creek Spring (pl. 24) would lie near the axis of an anticline and might penetrate rock made relatively permeable by tension cracks.

DRILLING OF A TEST WELL

On the basis of information given in this report, the National Park Service decided to drill a well into bedrock to test the quantity and quality of water that could be produced from the Wahweap and Straight Cliffs sandstones. The test well was located approximately at the site shown on plate 24 and was to be drilled to the top of the Tropic shale or to 2,000 feet, whichever was shallower.

For the drilling of this test well, the cable-tool method was chosen. This method was preferable to the hydraulic rotary method for the following reasons:

1. It was anticipated that the final yield of the well would be the aggregate of the yield of many thin water-bearing zones. The cable-tool method would make detection of these small zones easier.

2. Because the final yield of the well would probably come from fracture porosity rather than "between-the-grain" porosity, it would be necessary to keep the diameter of the mud-invasion zone to a minimum. This should make development easier after completion of the hole. The bottom of a hole drilled by the cable-tool method is under less fluid pressure than is the bottom of a hole drilled by the rotary method, and therefore has a smaller mud-invasion zone.

3. Because there was a possibility of encountering water of unsuitable chemical quality, it was advisable to have an inexpensive method of obtaining relatively clean water samples. These could be obtained from the bailer.

4. Water-level measurements could be made easily at any time during the drilling of the well.

The rotary method of drilling had two advantages over the cable-tool method.

1. Drilling would be faster.

2. The probability of the sides of the hole caving in would be lessened. However, because this was a test hole, the information produced by the cable-tool method outweighed the mechanical advantages of the hydraulic rotary method. Rotary-air drilling was not considered separately from the hydraulic rotary method because the anticipated saturation of the material penetrated would have demanded conversion to hydraulic rotary when fracture zones were encountered.

The contract for drilling the test well was awarded to Perry Bros. Drilling Co., of Flagstaff, Ariz. Drilling began in August 1959. The first string of casing was 16 inches in diameter, and the hole was about 18 inches. Subsequently the casing size was decreased to 14, then to 12, and finally to 10 inches. Owing to many unexpected caving zones and the onset of winter, the hole was not finished until May 1960.

Many caving zones were encountered in the course of the drilling, ranging from severe cave-ins which buried the drilling bit and broke the cable, to mere sloughing of the side walls. It is difficult to determine the exact location of many of these zones because the material fell into the hole from an unknown height above the bottom. Although there were many caving zones, one seems worthy of particular mention because of its size and persistence. When the depth of the hole was 650 feet, a loose running sand filled it to a depth of 400 feet. It is not known exactly where this sand entered the hole; it may have been at 400 feet, or it may have been the entire zone between the depths of about 500 and 600 feet. The neutron log (pl. 26) shows that it was probably the latter. Other caving zones indicated that the bit could not advance far ahead of the bottom of the casing without trouble. Much of the lower part of the hole was underreamed to prevent these difficulties.

Owing to the problem of caving, four strings of casing of different diameters were used. A record of the depths of each casing size is shown on plate 26.

A composite driller's and sample log is shown under "lithology" on plate 26. The formations penetrated are identified from considerations of the driller's log, sample log, and the gamma ray and neutron logs. The top of the basal conglomerate of the Wasatch formation and the top of the Kaiparowits formation are easily identified. However, owing to the similar lithologies of the two formations, there is less certainty about the top of the Wahweap and Straight Cliffs sandstones. It is believed by the writer that the well did not penetrate the Tropic shale.

Most of the samples of the Wahweap and Straight Cliffs sandstones from the well are blue or gray sandy shale. This is different from the lithology of most of these formations in outcrops below the rim where they consist of tan sandstones alternating with blue shales. In the well the more neutral tan colors may have been obscured by the stronger blues. It is difficult to account for the absence of sandstone in the driller's and sample logs. However, the weakly cemented sandstones may have appeared as loose sand and become mixed with shale from other parts of the hole to give the appearance of sandy shale.

Gamma ray and neutron logs were made to check driller's and sample logs, and are shown on plate 26. They were very helpful in selecting the zones to be perforated (pl. 26); however, they did not show any thick sequences of sandstone. Other factors used in selecting the zones to be perforated were reports of caving zones, water levels measured while the hole was being drilled (pl. 26), and chemical analyses of water samples collected by the bailer while the hole was being drilled (table 8).

Water levels during drilling usually are depressed owing to the increased specific gravity of the muddy water in the hole. When a zone is perforated and cleaned the water level is higher. These two types of water-level information are distinguished on plate 26. The final composite water level of all zones that were perforated and cleaned was 647 feet below the surface. Above this level are several perched water bodies, and below this are several zones that have a much lower water level associated with them.

The well was perforated from the bottom upward, and as each zone or group of zones were perforated and cleaned, a water sample was obtained for chemical analysis. These analyses are given in table 8. While the well was pumping samples were collected also, and the analyses of these samples showed the water to be of similar chemical character to the perforated zone between depths of 860 and 890 feet. The reason for this was that the pumping water level was not below the static level of the better quality water zones. The entire 200 gpm that was finally produced, therefore, came exclusively from the 860 to 890 foot zone or above.

Two pumping tests were made, and a graph of the final one is presented in figure 60. However, it must be emphasized that this was not a test of the water-yielding ability of the lower three perforated zones. The lower two of these zones were bailed at a rate of 20 gpm. The pumping test indicated that the well had a specific capacity of 1.5 gpm per ft of drawdown and that it would yield 200 gpm without excessive drawdown.

Additional measurements have been made on several springs in the area. Because the measurements in table 6 are only indicative of the flows in 1957, the additional measurements are reported in table 9. The well was not pumped for a sufficient length of time to determine whether or not it affected the flow of Yellow Creek Spring.

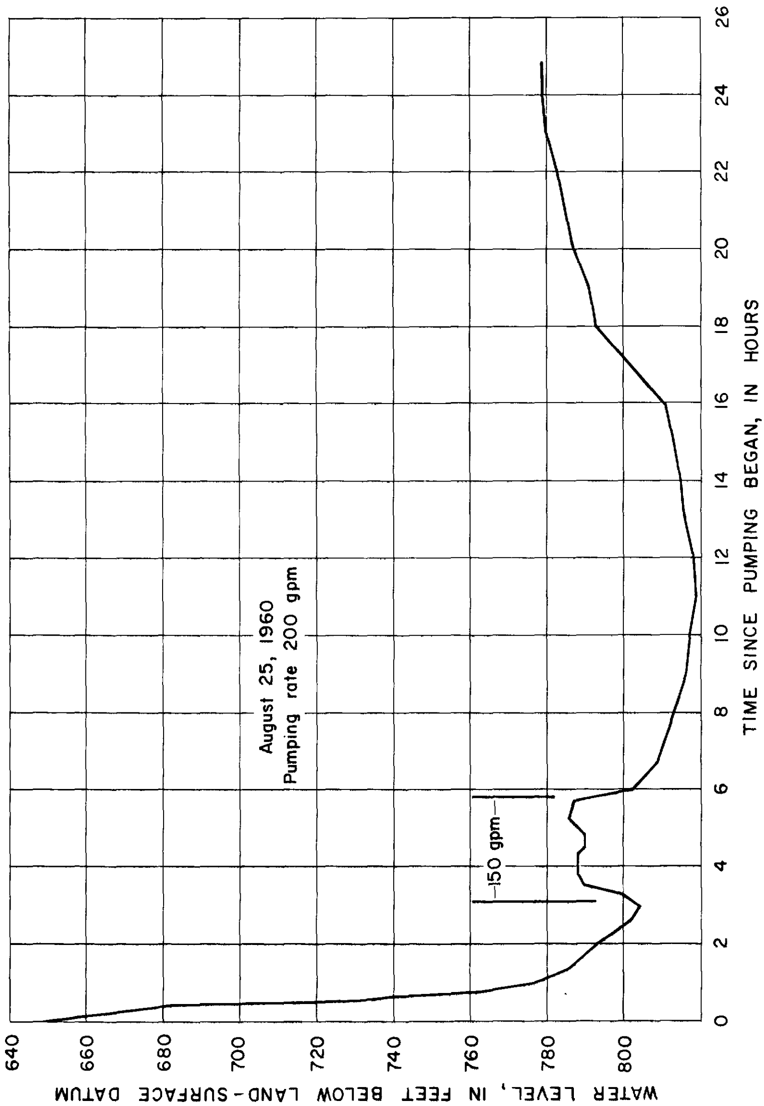

FIGURE 60.—Graph of the water level during pumping of the test well at Bryce Canyon National Park, Utah.

TABLE 8.—*Chemical analyses of water from the test well at Bryce Canyon National Park, Utah*

[Chemical constituents are given in parts per million]

Depth of casing or perforations (feet)	Conditions of collection	Date of collection	Specific conductance (Micromhos at 25° C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	
													Calcium, magnesium	Noncarbonate
270	Bailer, while drilling	Sept. 1959	464	1.7	40	36	9.4	310	6.6	5.5	0.5	252	249	0
1,100	do	Feb. 1960	1,330	6.0	172	82	29	342	512	10	.4	979	766	486
2,000	do	May 1960	450											
1,873-1,920 1,962-1,974	Bailer, after perforating and cleaning.	July 25, 1960	435	7.0	42	16	34	240	37	5.5	.4	260	170	0
1,268-1,282 1,873-1,920 1,962-1,974	do	July 27, 1960	510	7.7	57	29	12	234	91	3.0	.4	510	264	72
860-890 1,268-1,282 1,873-1,920 1,920-1,974	do	Aug. 5, 1960	1,210	8.1	163	82	15	470	365	6.0	.4	870	742	357
313-348 452-478 860-890 1,268-1,282 1,873-1,920 1,920-1,974	Pumping, after 6 hr at 100 gpm.	Aug. 16, 1960	1,230	9.0	168	82	12	476	368	6.0	.4	879	756	366
Do	Pumping, after 42 hr at 200 gpm.	Aug. 25, 1960	1,230											

TABLE 9.—*Measurements of springs below the rim, 1958–60*

Spring	Date	Method of measurement	Discharge (gpm)
Campbell Canyon	June 21, 1958	Weir	12
Merrill Ranch	do	do	12
Yellow Creek	June 20, 1958	do	31
	Aug. 19, 1960	Parshall flume, by National Park Service.	42
	Aug. 26, 1960	do	49
	Aug. 29, 1960	do	48
	Sept. 9, 1960	do	40
	Sept. 16, 1960	do	49
Upper Yellow Creek Wash	June 20, 1958	Float	117
Second Yellow Creek Wash, but water is continuous from Upper Yellow Creek.	do	do	280
Right Fork of Yellow Creek	do	Weir	34

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