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Subsurface Water Geology of Spanish Fork Quadrangle, Utah County, Utah*

THOMAS R. MARKLAND
Idaho Highway Department

ABSTRACT.—This study was made between March and September of 1959 to determine the source, movement, physical and chemical properties of subsurface ground water and effect of faulting on the subsurface water.

Spanish Fork Quadrangle is underlain by unconsolidated Quaternary sediments derived from Paleozoic rocks in the Wasatch Mountains. Pre-Lake Bonneville sediments are coarse grained and have not been totally penetrated by wells. Lake Bonneville sediments are interbedded with coarse and fine outwash from Spanish Fork, Peteetneet and Santaquin Creeks. Recent fan deposits overlie Lake Bonneville sediments and in places streams have cut through these unconsolidated materials. A fault zone of Recent age within the area displaces unconsolidated valley sediments.

More than 300 pumping and flowing wells have been drilled in the area. In this study 154 wells were chosen, 72 for their location and depth, 22 wells for observation wells, and seven wells with available records covering a 24-year period. A piezometric surface map was constructed from the available records and data obtained by the writer Water samples from 22 wells were analyzed for chemical constituents.

Pumping wells in the area are of two types: (1) shallow artesian pump wells less than 200 feet deep, and (2) deep pump wells deeper than 200 feet. Throughout the area these wells vary in static level, and discharge between 5 and 925 gallons of water per minute depending upon their location and fineness of aquifer sediments.

Flowing wells are of two types: (1) shallow flowing wells above 200 feet, obtaining water from between 85 and 110 feet and 150 and 180 feet, with discharge between 3 and 35 gallons of water per minute, and (2) deep flowing wells from below 200 feet which have discharges ranging between 6 and 200 gallons per minute. Artesian heads increase seven feet for every fifty feet of increased depth if transmissibility of aquifers is uniform.

Springs occur within and around the valley where Quaternary sediments have been displaced by faulting. One hot spring, along a fault near the town of Benjamin furnishes 95 degree F. water to the Arrowhead Resort.

Principal aquifers of the area are coarse interbedded pre-Lake Bonneville Quaternary sediments and coarse sediments of the Pleistocene Lake Bonneville Group. Hydrostatic pressures from the aquifers vary between 1 and 44 feet above the surface. Sediments of the post-Provo stage are of minor importance as subsurface aquifers.

The piezometric surface is not of uniform gradient, but indicates that subsurface water flows northwest from Spanish Fork drainage and north from Peteetneet and Santaquin Creeks toward Utah Lake.

Subsurface water of best quality comes from the deeper aquifers, which have less total dissolved solids. Chloride, sodium, and potassium show more variation in parts per million along the fault zone than water from surrounding wells.

Warm water flowing from Benjamin Fault near Arrowhead Resort has a hydrothermal gradient of 10.6 degrees per hundred feet. Coarse sediments on the east have been displaced against finer sediments of the upthrown block on the west resulting in the formation of a ground-water dam in the sediments of the east. This fault was traced from Benjamin to Payson by use of differing static levels and similarity of sodium content in the water.

The largest quantities of water used in the area are for culinary and stock purposes. Water obtained from springs and ponds helps supplement reservoir water for irrigation.

*A thesis submitted to the faculty of the Department of Geology, Brigham Young University in partial fulfillment of the requirements for the degree Master of Science, March 9, 1964.

Prospects for development of water supplies are fair in the area north of Santaquin and on the Spanish Fork flood plain and delta.

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INTRODUCTION

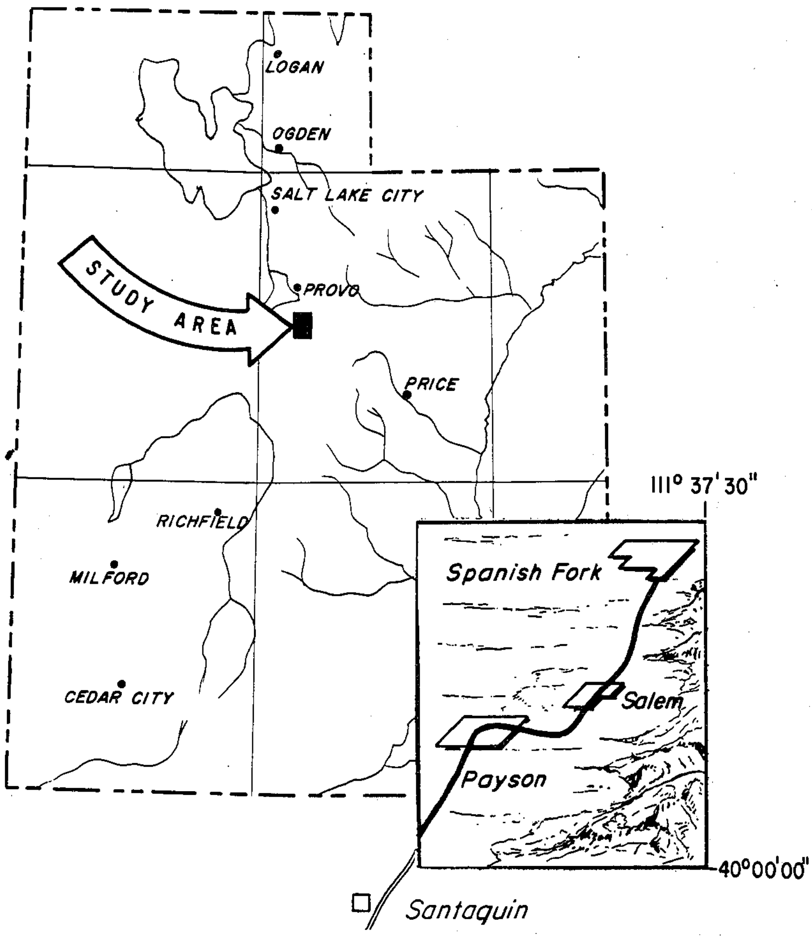
Purpose and Scope of the Investigation

This report was undertaken and completed between March and September of 1959. Its purpose is to determine the source, movement, and physical and chemical properties of subsurface water in Spanish Fork Quadrangle and to determine the particular significance of the Benjamin Fault in relationship to subsurface water of the quadrangle.

Subsurface water, as a natural resource of culinary water, is very important to the 65 square miles included in the Spanish Fork Quadrangle, situated south and east of Utah Lake. Shortage of water presented no problem to early settlers because water sources seemed inexhaustible, and they saw no need to determine occurrence, quantity of water available, quality, movement, temperature, or pressure of their subsurface water supply. It was not until 1935 that people of this area recognized the value of subsurface water as a natural resource. At that time the surface reservoirs diminished in potential shortage because of a drought, and artesian flowing wells ceased to produce the necessary culinary water. The U.S. government recognized the water shortage at that time and established a well-drilling program to search for water to ease the crisis.

Because of a continuing increase in subsurface water being drawn from wells in Spanish Fork Quadrangle, it is important to have an adequate understanding of subsurface water in this area in order to facilitate proper utilization and conservation of this natural resource.

The Spanish Fork 7½-minute quadrangle is in south-central Utah Valley, an intermont in the Eastern Great Basin. (Text-fig. 1). Natural boundaries which encircle the area are the Wasatch Mountains on the east and the south, Utah Lake on the north, and West Mountain on the west.



TEXT FIGURE 1.—Location of area studied.

Previous Investigations

Bedrock surrounding the valley has been described in various publications cited at the end of this report. The Bonneville sediments which extend from the highest gravel terraces to the silts and clays on the valley floor have been described (Bissell, 1963, p. 107-121). A detailed study of the pre-Quaternary rocks was made by Brown (1952, p. 1-51). Up to the time of this report no detailed subsurface water study had been undertaken in Spanish Fork Quadrangle. A reconnaisance report was compiled by Boyden (1951) but no conclusions about subsurface water possibilities of the valley were reached.

Methods of Investigations

Subsurface water investigation was facilitated by the subsurface water law of 1935 which required that all wells drilled within the state must have an application number and complete log filed in the State Engineer's office in Salt Lake City. For this report 154 such well logs were studied and 72 of these wells were selected because of their location and depth for detailed comparison in the construction of the subsurface geologic panel (see Plate 1). Twenty-two of these wells, with varying magnitudes of artesian discharge and varying depths, were chosen for observation wells. These were observed at regular intervals over a three months period for rate of discharge, hydrostatic pressure and temperature changes. Water samples from the 22 wells were analyzed by Prof. John Wing of the Chemistry Department at Brigham Young University. Where conditions permitted, hydrostatic pressure readings were taken from the top of the well casing with a mercury monometer designed and constructed by the writer. The collar elevations of wells were derived from the Geological Survey topographic map of Spanish Fork Quadrangle.

In addition to the wells mentioned above, records of seven U.S. Geological Survey wells covering a period from 1935 to 1958 were studied. These data were compiled into a piezometric surface map (Plate 2).

Pertinent information regarding flowing and non-flowing wells was obtained from talking with local well drillers and well owners in this area.

Information relating to subsurface stratigraphy is based upon well logs of varied depths and locations within the quadrangle. Validity of this material depends upon the accuracy taken by the well driller in recording the logs and the writer's ability to correlate the data.

ACKNOWLEDGMENTS

The writer expresses appreciation to Drs. Harold J. Bissell and George Hansen, advisory committee members who suggested the thesis area and critically read the text.

Acknowledgments are given the Utah County Water Users Association for financial assistance; to Professor John H. Wing of the Brigham Young University Chemistry Department for assistance with water analysis; to Mr. Symore Sibiskue, hydrologist for the U.S. Geological Survey, who aided in obtaining observation well data; and to the personnel of the State Engineer's Office for their cooperation in supplying well log data.

Appreciation is also extended to my wife and parents for their encouragement.

GEOGRAPHY

Topography

Utah valley lies within the eastern edge of the Bonneville Basin located in the northeastern part of the Basin and Range Province. The valley floor is underlain by unconsolidated Tertiary and Quaternary sediments. It gradually rises southward and eastward to the Wasatch Mountains. Spanish Fork Quadrangle, on the east and south, is encircled by the Bonneville Terrace, marking the highest shoreline of ancient lake Bonneville. The slopes extending valleyward from the Bonneville terraces are marked by bay bars, deltas, and minor terraces formed during transgressive and regressive fluctuation of Lake Bonneville.

Spanish Fork and Salem are located upon deltaic material. Payson is located upon a long erosional remnant jutting northward into the valley. Santaquin, in the southern end of this area, is located upon post-Lake Bonneville fan and delta gravels. The largest delta, Spanish, Fork, extends three-fourths the distance across the north end of the Spanish Fork Quadrangle. Spanish Fork River has eroded a large channel through this delta. The degraded material from the channel has been deposited at its base, forming an alluvial fan.

On the east side and south end of the valley, Spanish Fork River, Peteetneet, and Santaquin Creeks have incised into the unconsolidated sediments of the Provo stage deltas and terraces forming alluvial sediment. The streams deposited the sediment into large coalescing fans overlying Lake Bonneville sediments. South of Salem the two largest coalescing alluvial fans of the area extend basinward across the old pre-Lake Bonneville fans cutting terraces and bars of the lower Bonneville sediments and coming to rest upon the Provo sand and silt of the valley floor. The valley slopes north from Spanish Fork, Salem, and Payson to Utah Lake, a fresh-water remnant of ancient Lake Bonneville.

Drainage

Except for Spanish Fork River, all streams entering the area have their headwaters west of the crest of the Wasatch Range and drain the steep west slope of that range. These streams from north to south are Peteetneet Creek and Santaquin Creek.

Average Spanish Fork drainage run-off per year, over a twenty-four-year period, was 149,000 acre feet (Text. fig. 3). Run-off data for Peteetneet Creek was not complete for the twenty-four-year period, but during April of each year, the creek carried as much water as Spanish Fork River; however, this temporary increase was of short duration. During the balance of the year, Peteetneet Creek carried one-eighth to one-sixteenth as much water as Spanish Fork River. The reasons for the low rate of run-off from Spanish Fork and high rate of run-off from Peteetneet Creek are a combination of complex factors, the major ones being size of area, soil types and thickness, vegetation, and slope of topography. Spanish Fork is broader and contains more vegetation on its slopes than does Peteetneet Creek, accounting in large measure for the differing rates of run-off between the two areas.

Richardson (1906, p. 18) states that the run-off is approximately fifteen percent of the precipitation for Spanish Fork drainage. This differs with sixty-three percent run-off of Peteetneet Creek. Much of the eighty-five percent of precipitation that seeps into the ground of Spanish Fork drainage reappears at the surface as springs, seeps or well water. That portion that does not seep into the sediments of the quadrangle flows into Utah Lake as surface run-off.

Climate

The climate of Spanish Fork Quadrangle is semi-arid with precipitation generally low to moderate with greater precipitation during January, February, and March. Mean annual precipitation in the Spanish Fork area ranges from fourteen to eighteen inches (Text fig. 3). Mean annual precipitation, measured in inches of water, is 1½ inches less for Peteetneet Creek than for Spanish Fork River. The snowfall, measured in inches of water, is two inches less for Peteetneet Creek than for Spanish Fork (U.S. Weather Bureau, 1935-1958). Santaquin, in the south end of the area, has a mean annual precipitation ranging from sixteen to twenty-one inches. The area above and immediately adjacent to Utah Lake has an annual precipitation of eight to twelve inches with greater precipitation during February, March, and April. Evaporation from Utah Lake averages sixty-two inches per year,

GEOLOGY

Bedrock in Surrounding Mountains

Mountains adjoining the valley on the east and south present a moderately complete geologic sequence from Precambrian to the Recent (Hintze, 1962).

Southeast of Payson faulting is observed in pre-Quaternary igneous, metamorphic, and sedimentary rocks.

Quaternary Sediments

Most of Spanish Fork Quadrangle is surfaced by sedimentary deposits formed in Lake Bonneville during the Pleistocene. Beneath these beds are old fluviatile gravels and soil formed from material derived in the mountains to the east. Studies by Hunt and others (1953, p. 11) revealed that "Tertiary water-laid volcanic tuffs, muds and agglomerates are also found under Lake Bonneville." Interbedded with the Lake Bonneville beds are deposits of outwash carried to the lake's edge by streams. Post-Lake Bonneville fan deposits overlie Bonneville terraces and deltas and pre-Lake Bonneville fanglomerates.

Several 400-foot wells located toward the valley perimeter show four distinct clay and gravel beds. If a cyclic interpretation is given to this information, an inference can be drawn that the lake had at least four major periods of fluctuation. Deeper wells, close to Utah Lake, show five distinct clay and sand beds, an indication that five cyclic periods of deposition have occurred here.

Structure in Spanish Fork Quadrangle

Spanish Fork Quadrangle is located within the structurally controlled intermontane basin of Southern Utah Valley. The Wasatch Mountains extend north-south except for a large arcuate re-entrant to the east starting at Ironton and ending at Payson where it regains its north-south direction (Gilbert, 1890, p. 10). This arcuate re-entrant forms the eastern boundary of Spanish Fork Quadrangle (Text fig. 1).

Triangular facets and piedmont scarps occur on the east side and southeast corner of this area (Rigby, 1962, pl. 1, p. 83). The recent origin of the latest displacement is inferred from the state of preservation of these features, Gilbert (1890, p. 11) states that "Spanish Fork delta extending across the fault zone has been displaced 150 feet in the upper delta. The lower delta's maximum displacement is 40 feet." Faulting is observed in pre-Quaternary igneous, metamorphic, and sedimentary rocks southeast of Payson.

Gilbert (1928, p. 11) later stated that mountains during Pliocene times were not fully formed; consequently lake bed deposits in the Basin and Range Province have been displaced or tilted. This is evidenced in the area under study by the displacement of Bonneville sediments against Tertiary sediments of the Salt Lake Formation two miles north of Payson at Benjamin Cemetery.

WATER RESOURCES

Springs

Flowing springs in Spanish Fork Quadrangle are found along the toe of fans and deltas, along the Wasatch fault scarp where Lake Bonneville and pre-Lake Bonneville sediments have been displaced by faulting, and from old mine tunnels. At the toe of the fan in Sec. 17, T. 9 S., R. 2 E., near Payson, a small spring occurs, but the flow could not be measured. A spring, in the area of Spring Lake, furnishes a portion of the water for Spring Lake Fish Farm. This spring appears to be coming from the Lake Bonneville sediments. In the same area as the fish farm several springs issue from Lake Bonneville sediments to feed Spring Lake. Location of all springs along the fault scarps is not known by the writer, but those observed are the developed tunnel near the "Leader Mine," Sec. 17, T. 9 S., 3 E., and a piped spring in the "Goose Nest" area. The latter spring furnishes water to several families in Sec. 22, T. 9 S., R. 2 E. The Benjamin Fault is the cause of an interesting hydrothermal spring which originally flowed openly into a pond but is now enclosed and pumped for the source of hot water for Arrowhead Resort. South and east of the Spring Lake Fish Farm, at the Nelson Mine a small spring issues from old mine workings. This spring has not been developed but produces approximately two gallons of water per minute.

Several of these springs increase in flow during spring run-off.

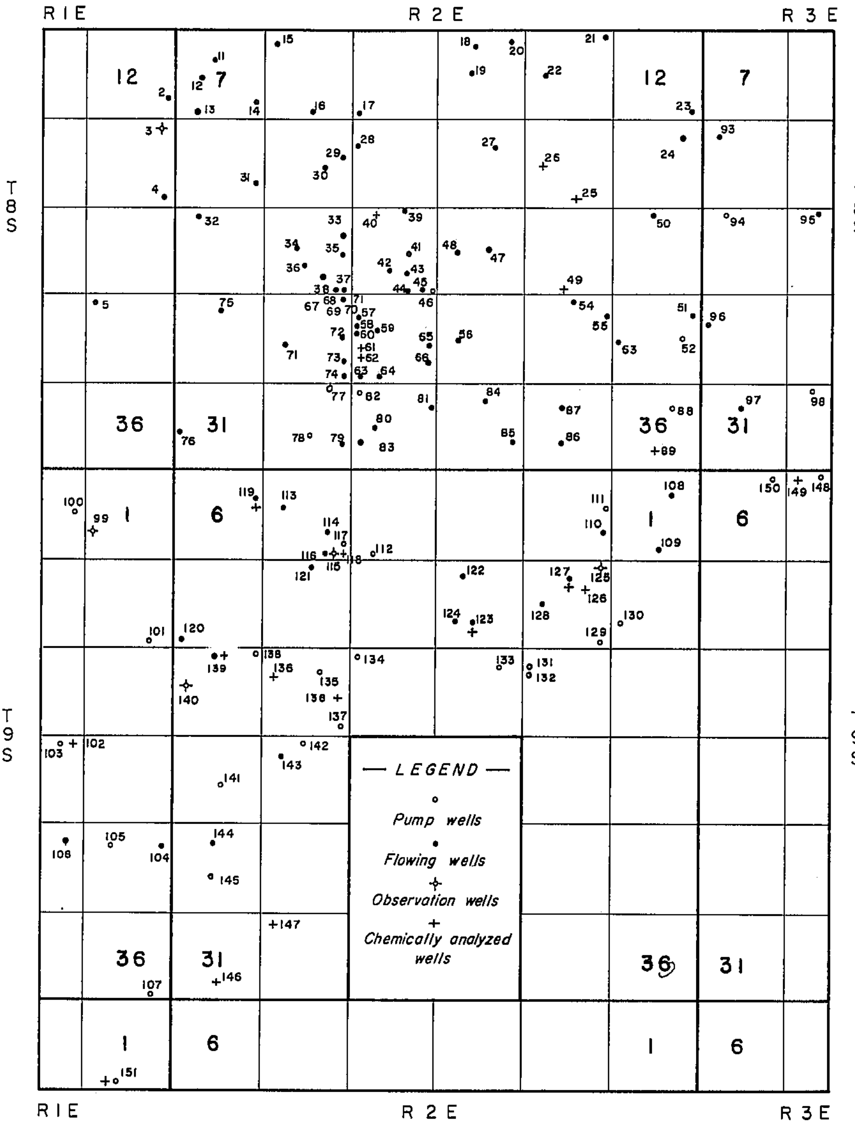
Wells

Development of Wells

Soon after settling in Salt Lake Valley in 1847, Mormon pioneers began systematic settlement of adjacent valleys. In Spring, 1849, a number of Mormon families entered Utah Valley (Richardson, 1906, p. 5). They located their towns on the well-drained Provo deltas and post-Lake Bonneville fans.

The first wells in the area were dug soon after the arrival of these settlers for domestic use where it was impossible to obtain uncontaminated water from springs and streams. These first wells were shallow. Not until several years after settlement of the valley did anyone have a flowing well. The first flowing well in Lehi, drilled in 1885, was obtained by driving a steel-pointed 1¼ inch pipe, 75 feet into the ground. The well flowed four gallons per minute for three years and then stopped. According to Hunt (1953, p. 63) this well was the first flowing well on the northern end of the lake.

In the only subsurface water study made of this area (Boyden, 1951, p. 30) reference is made to 169 wells selected for study. By 1959 there were 300 wells on file at the Utah State Engineer's Office in Salt Lake City. From



TEXT FIGURE 2.—Index map of wells within Spanish Fork Quadrangle.

1951 until 1959 the increase in well development was accelerated by the following: (1) development of farm lands, (2) industry, (3) replacement of old inefficient wells, and (4) better drilling methods.

Well Numbering System

A well numbering system which enables rapid location of wells under study has been adopted by the Utah State Engineer's Office. The system consists of dividing the state into four quadrants using the Salt Lake Meridian as the boundary between the east-west quadrants. These quadrants are lettered ABCD, starting in the upper right hand quadrant and lettering counter clockwise. Each major quadrant is subdivided into townships and ranges which are given numbers. Each township is divided into thirty-six sections of 640 acres. Each section has a number and is divided into four quarter sections containing 160 acres. Each quarter section is divided in four units of 40 acres and each redivided into four ten-acre units. Each of the subdivisions, after the section division, is designated by small letters abcd in the same manner as the major quadrants. Thus, when a well is given a location number, such as (D-8-2) 21-aba-1, the observer will be able to determine how many wells have been drilled in the ten-acre tract by the last numeral; the "a" unit is located with the "b" unit of the 40-acre subdivision; and the "b" unit is located within the "a" unit of a quarter section. The number outside the parentheses states that quarter section a is in Section 21. The first number inside the parentheses stands for Range 2 East within which Section 21 is located. The next number stands for Township 8 South which is a division of Range 2 East. The first figure is capital D which stands for major division of the State within which Township 8 South, Range 2 East is located. For illustrations see Boyden (1951, p. 37).

Well Discharge

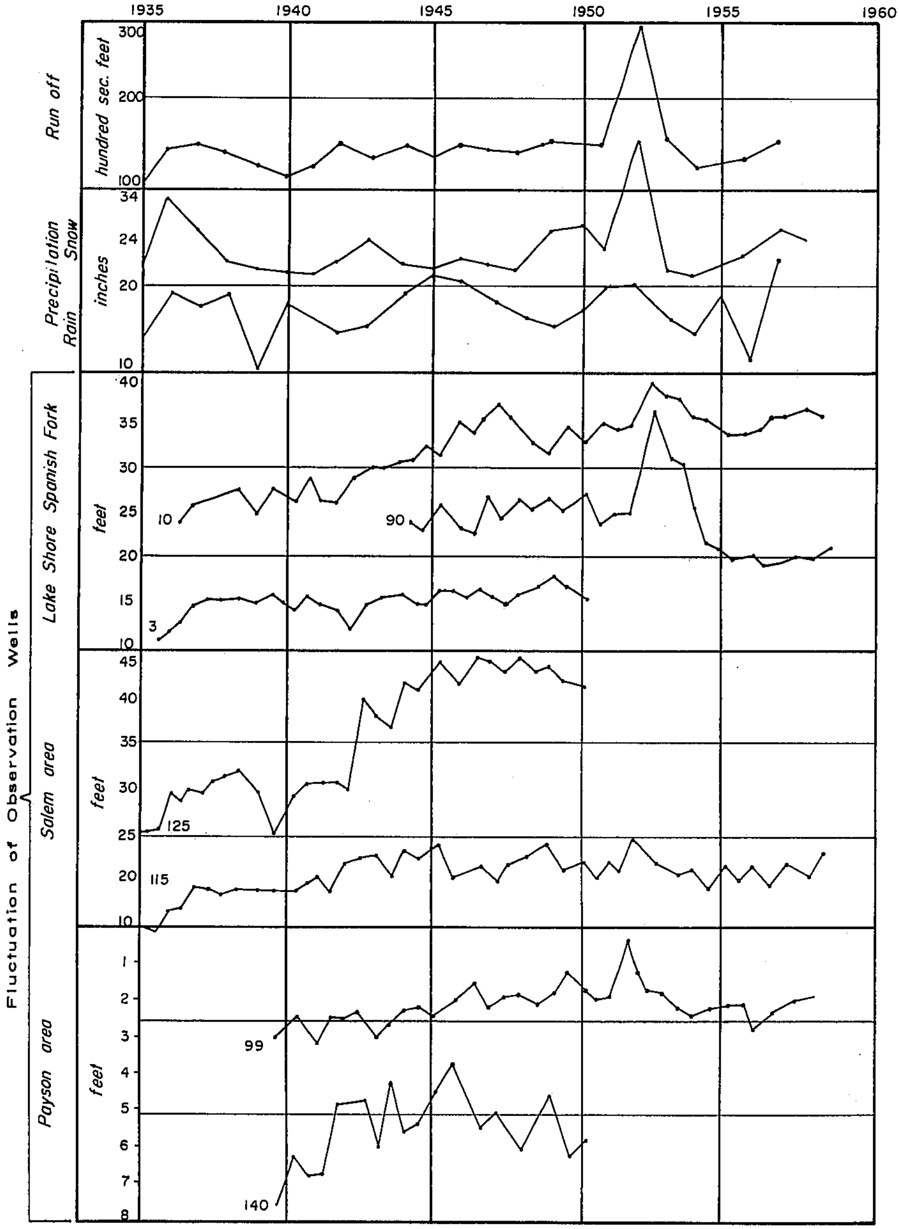
Tabulation of total discharge from wells in the area was not attempted in this report, but records for individual discharging wells were collected from the State Engineer's Office. Twenty-two wells in the area were measured for discharge by the writer. It would be impractical, however, to try to calculate the total discharge from the wells in the area because many of the wells flow continuously, some flow for three or four days at a time, while others flow intermittently throughout the summer months only. In order to obtain an approximate yearly discharge, all wells in the area must be measured over a specific period of time.

Wells in the Spanish Fork Quadrangle do not discharge uniformly. The rate of subsurface water discharge from wells in this area, whether flowing or pumping from independent or combined aquifers, is largely dependent upon transmissibility, thickness, lateral extent, and hydrostatic gradient of the aquifer or aquifers from which the water is taken.

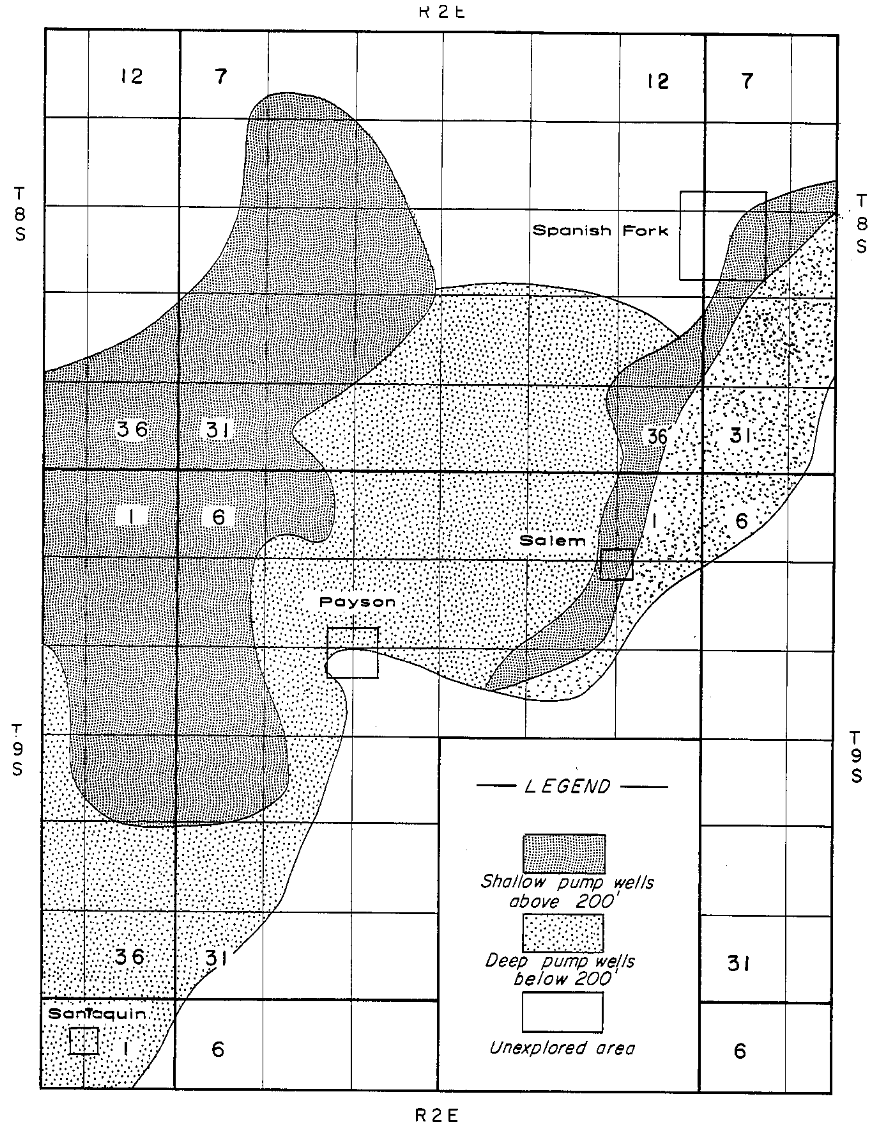
Pumping Wells.—Wells with extremely low hydrostatic pressure do not flow to the surface and are pumped to obtain water. In Spanish Fork Quadrangle many pump wells are flowing wells, but extremely low hydrostatic pressure necessitates the use of a pump to acquire adequate discharge for use in watering lawns, gardens, and stock.

Pump wells of the area are divided into two types: (1) shallow pumping wells less than 200 feet deep (but mostly under 100 feet deep), and (2) deep pumping wells greater than 200 feet deep (Text fig. 4).

The shallow low-pressure pump wells are divided into two types: (1) wells where the water table is near the surface, and (2) perched water table wells that appear on the east side and along the south end of the valley (Text fig. 5). The shallow, low-pressure, pump wells are located in the western half of Spanish Fork Quadrangle where the gradient of the water table intermittently intersects the surface but where the water table, in general, is within

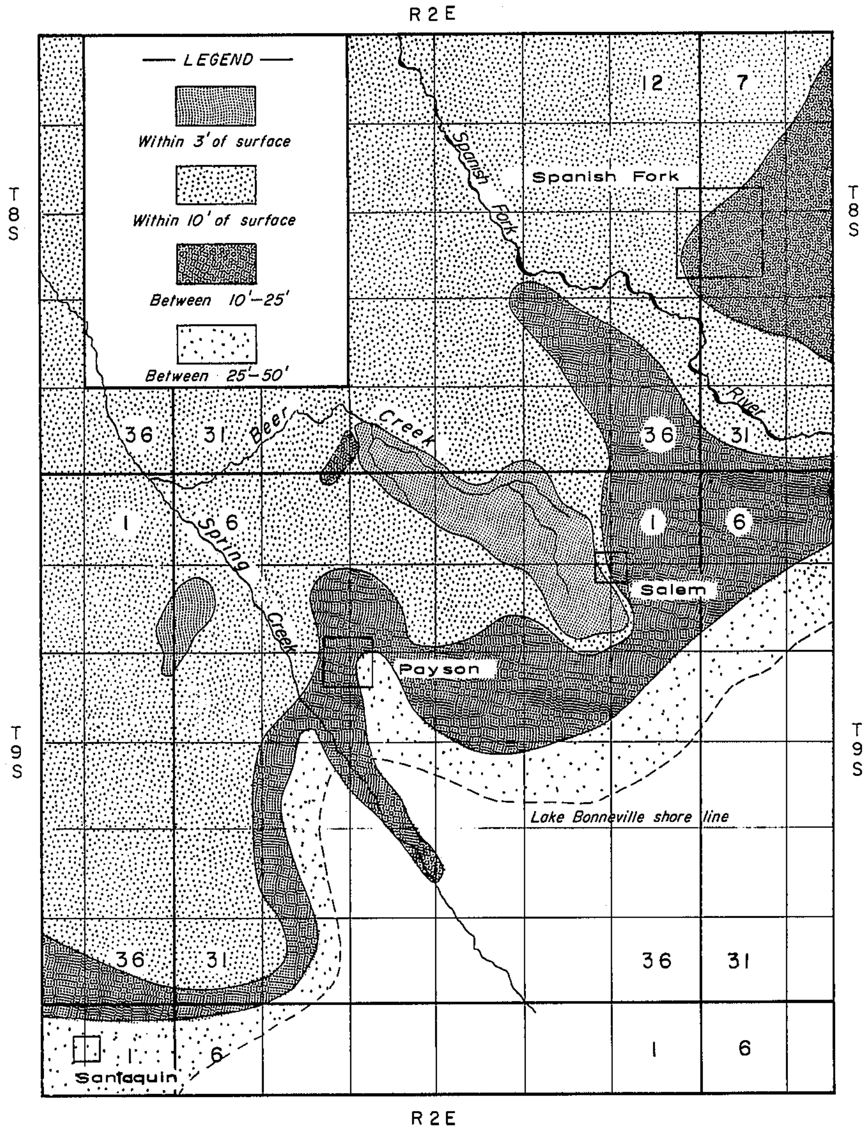


TEXT FIGURE 3.—Hydrographs of the relationship between annual precipitation, run-off and hydrostatic pressure fluctuation of observation wells, numbers 10, 90, 3, 125, 115, 99 and 140.



TEXT FIGURE 4.—Areal distribution of shallow and deep pumping wells.

five to ten feet of the surface (Text fig.5). Shallow wells are also located along a narrow belt that parallels U.S. Highway 91 south from Spanish Fork to Salem and 1½ miles southwest of Salem. This narrow shallow belt is a perched water table underlain by the clay member of the Provo Formation. Shallow pump well discharge varies from 5 gallons per minute from Well No. 141 to 110 gallons per minute from Well No. 105 (see Table 1). Most deep pumping wells in the quadrangle are over 200 feet deep and are pumping



TEXT FIGURE 5.—Areal distribution of water tables of differing depths.

their water from pre-Lake Bonneville or Lake Bonneville sand aquifers. Deep pumping wells are divided into two types: (1) wells which penetrate the thick sand and clays of Lake Bonnebille sag pond, and (2) wells high up on the pediment slopes of the east side and south end of the area, where the water table is as low as 80 feet below the surface (Text fig. 5).

Deep pumping wells that penetrate the thick sands and clays which encompass Salem, Grimes, Dixon and Duck Creek ponds and other areas in

Sec. 25, 26, 27, 33, 34, 35, and 36, T. 8 S., R. 2 E. and Sec. 1, 2, 3, and 4, T. 9 S., R. 2 E. are of low hydrostatic pressure. These areas appear on the piezometric surface map as subsurface water depressions (see Plate 2). The original depression in this area is believed to have been caused when faulting left the down-thrown block dipping toward the Wasatch Mountains along the fault zone. The writer believes that deposition of sediments in this area occurred contemporaneous with the deposition of the Spanish Fork Delta during a standstill of the Provo Stage. Extension of the Payson Spit restricted this bay area from extreme wave action from the south, and Spanish Fork River deposited fine sand, silts, and clays off the left flank of the delta into the restricted bay. It is the writer's belief that the thick accumulation of fine, thin interbedded sediments is of low transmissibility; thus, high hydrostatic pressures are not present in this thick sequence. Where effluent transmissibility is greatest, ponds and swamps appear.

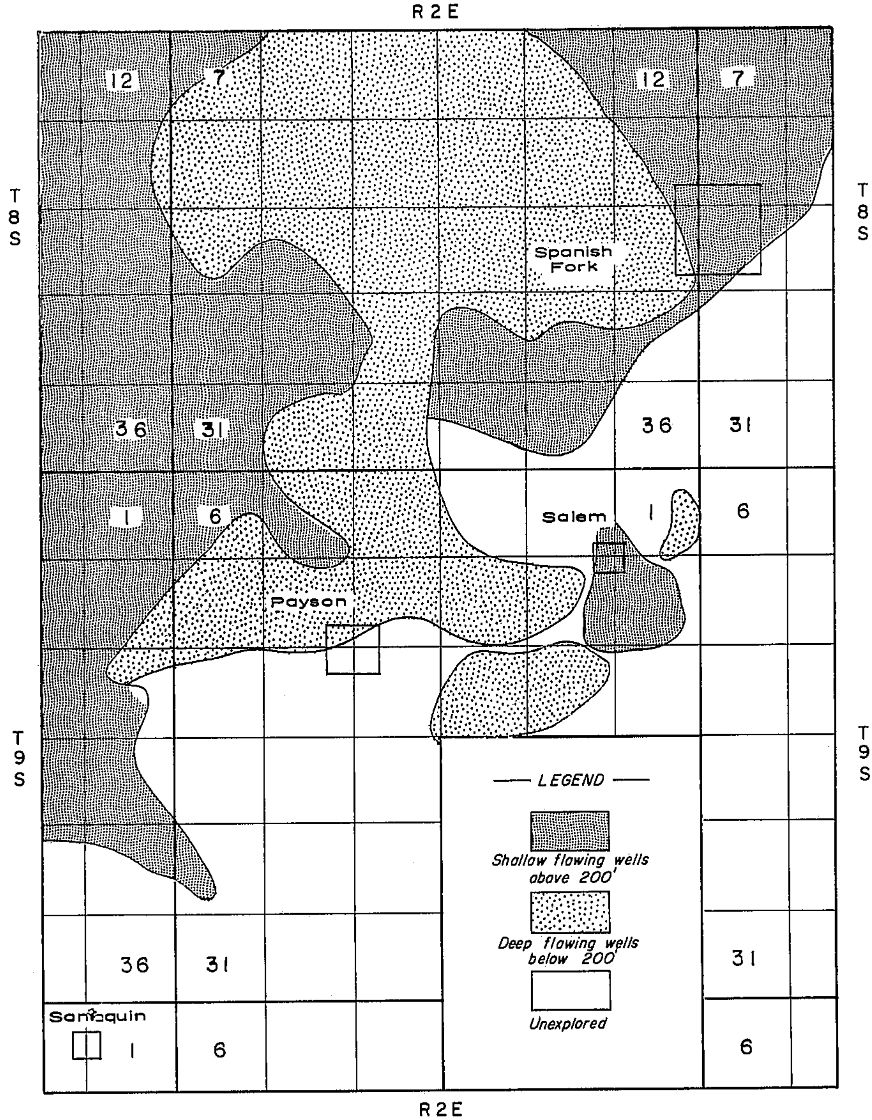
Deep pumping wells, located high on the pediment slopes of the valley, do not have the underlying and overlying clays necessary to produce hydrostatic pressures. Thus, these wells have to depend upon the regional water table for their water sources. This water table varies from 50 to 80 feet below the surface (Text fig. 5). When placed under pump, Well No. 132 discharges 10 gallons of water per minute; Well No. 149 discharges 75 gallons per minute. The majority of wells in the Santaquin area are of this type (Text fig 4). Deep pumping wells in the quadrangle vary in discharge from 45 gallons per minute from Well No. 46 to 925 gallons per minute from well No. 151 (Table 1).

Flowing Wells.—Flowing wells of Spanish Fork Quadrangle, both deep and shallow, constitute more than half of the wells of the area. Flowing wells are of two types: (1) shallow wells less than 200 feet deep, and (2) deep wells greater than 200 feet deep (Text fig. 6).

Shallow flowing wells are mainly concentrated in the northeast corner of Spanish Fork Quadrangle and along the west side of the quadrangle with small additional areas at Salem and in the southeast corner of Sec. 17, and in the northeast corner of Sec. 20, both in T. 9 S., R. 2 E. The shallow wells in these areas produce from sands and gravels near the surface with pressures confined by underlying and overlying clay. Shallow wells in these areas flow from two aquifers of differing depths. The first aquifer lies between 85 and 110 feet below the surface; the second aquifer lies between 150 and 180 feet below the surface. These two aquifers are localized zones and generally appear together where shallow flowing wells are found. Discharge from the two aquifers varies from 3 to 35 gallons per minute (Table 1). Deviation in depth, between 85 and 110 feet and between 150 and 180 feet, is due to variation in thickness between the overlying sediments of the upper slopes and the shallower overlying sediments of the valley floor on the west side of the quadrangle.

Deep flowing wells are limited in the Santaquin area to Sec. 25 and 26, T. 9 S., R. 1 E., where recharge from Santaquin Canyon is confined by overlying clay. This zone extends farther north possibly coalescing with recharge from Payson Canyon moving northward toward Utah Lake (Plate 2).

Deep flowing Well No. 120 near Payson flows from subsurface pre-Lake Bonneville fan gravels that extend valleyward from Payson Canyon to connect with deep aquifers of the northern part of the quadrangle. Deep



TEXT FIGURE 6.—Areal distribution of shallow and deep flowing wells.

wells in the northern end of the quadrangle near Utah Lake produce water from layers of sand interbedded with clay. These deposits extend from the surface downward at least 600 feet, the depth of the deepest flowing well in the area, Sec. 20, T. 8 S., R. 2 E. Discharge from deep flowing wells varies from 6 gallons per minute from Well No. 127 to 200 gallons per minute from Well No. 126 (Table 1).

TABLE 1
Record of wells in Spanish Fork Quadrangle

Number in Thesis	*State Application Number*	*Location*	*Depth*	*Pump or Flowing*	*Gallons per Minute*	*Temperature*
1†‡	29942	(D-7-2) 35-cad	256	F	5	----
2	14698	(D-8-1) 12-dda	188	F	6	----
3*	14076	(D-8-1) 13-aaa	385	F	8	----
4	14794	(D-8-1) 13-ddd	291	F	5	----
5	16093	(D-8-1) 25-bbb	193	F	----	----
6†‡	29369	(D-8-2) 1-ccd	187	F	10	----
7†	26003	(D-8-2) 3-bab-1	147	F	6	53°
8†	23305	(D-8-2) 3-caa-1	377	F	----	----
9†	21701	(D-8-2) 4-abc-1	230	F	----	----
10†*	10844	(D-8-2) 4-cba	200	F	----	----
11	17904	(D-8-2) 7-bda-1	108	F	4	----
12	17404	(D-8-2) 7-cab-1	263	F	3	----
13	17682	(D-8-2) 7-dcc-1	290	F	25	----
14	28160	(D-8-2) 7-dda-1	276	F	15	62°
15	13638	(D-8-2) 8-bb	361	F	15	----
16	17267	(D-8-2) 8-dcc	295	F	8	----
17	25786	(D-8-2) 9-ccc-2	98	F	10	51°
18	28737	(D-8-2) 10-bad-1	420	F	15	56°
19	27542	(D-8-2) 10-bdd-1	411	F	----	56°
20	12987	(D-8-2) 10-aa	159	F	25	----
21	26745	(D-8-2) 11-aaa-1	210	F	3	52°
22	28672	(D-8-2) 11-bcd-2	420	F	12	56°
23	27822	(D-8-2) 12-ddd-1	173	F	30	52°
24	29989	(D-8-2) 13-aac	183	F	----	54°
25‡	12786	(D-8-2) 14-dcc-1	377	F	30	----
26‡	25594	(D-8-2) 14-bcd-1	424	F	7	60°
27	17232	(D-8-2) 15-aca-1	403	F	25	60°
28	20531	(D-8-2) 16-bcb-1	459	F	44	61°
29	14467	(D-8-2) 17-add-3	514	F	8	56°
30	17776	(D-8-2) 17-dba-2	399	F	12	60°
31	25913	(D-8-2) 18-dda-1	336	F	10	56°
32	25813	(D-8-2) 19-bba-1	109	F	8	52°
33	17221	(D-8-2) 20-ada-2	164	F	7	56°
34	10832	(D-8-2) 20-bdd	600	F	----	----
35	16927	(D-8-2) 20-daa	105	F	7	----
36	12446	(D-8-2) 20-dbc	407	F	19	----
37	19140	(D-8-2) 20-ddd	413	F	18	----
38	27446	(D-8-2) 20-ddd-3	207	F	3	55°
39	29248	(D-8-2) 21-aba-1	360	F	5	56°
40‡	26777	(D-8-2) 21-bab-2	346	F	35	56°
41	14044	(D-8-2) 21-dba	325	F	15	56°
42	10747	(D-8-2) 21-dbc	200	F	----	52°
43	17182	(D-8-2) 21-dca	278	F	----	54°
44	19842	(D-8-2) 21-dcd	236	F	10	54°
45	28210	(D-8-2) 21-ddd-3	110	F	6	53°
46	9932	(D-8-2) 21-ddd-1	347	P	45	58°
47	19640	(D-8-2) 22-acc-1	394	F	5	58°
48	---------	(D-8-2) 22-cba	434	F	----	----
49‡	C-15930	(D-8-2) 23-cdd	391	F	5	62°
50	26259	(D-8-2) 24-baa	330	F	80	53°
51	29107	(D-8-2) 25-ada-4	135	F	2	54°
52	1310	(D-8-2) 25-dab	400	P	270	61°
53	26088	(D-8-2) 25-cbb-2	338	F	5	60°
54	15669	(D-8-2) 26-abb-3	371	F	12	61°
55	25859	(D-8-2) 26-aad-2	223	F	10	54°

TABLE 1 (Continued)

56	20064	(D-8-2) 27-cba-2	180	F	12	52°
57	15925	(D-8-2) 28-bbc	175	F	....	53°
58	17429	(D-8-2) 28-bcb	189	F	10	56°
59	18027	(D-8-2) 28-bcd-4	240	F	8	56°
60	23285	(D-8-2) 28-bcc-5	160	F	8	56°
61‡	15854	(D-8-2) 28-cbb	300	P	50	95°
62‡	15854	(D-8-2) 28-cbb-2	336	P	....	83°
63	20131	(D-8-2) 28-ccc	168	F	9	....
64	18050	(D-8-2) 28-cdc-3	240	F	1	57°
65	12978	(D-8-2) 28-daa	120	F	5	56°
66	12891	(D-8-2) 28-dda	242	F	30	54°
67	28881	(D-8-2) 29-aaa	390	F	....	60°
68	15951	(D-8-2) 29-aaa	176	F	6	53°
69	14444	(D-8-2) 29-aaa	174	F	9	53°
70	15928	(D-8-2) 29-aaa	168	F	35	53°
71	18687	(D-8-2) 29-cab	168	F	35	53°
72	14980	(D-8-2) 29-daa	153	F	8	52°
73	12820	(D-8-2) 29-dda	189	F	6	53°
74	20327	(D-8-2) 29-ddd	171	F	6	....
75	16097	(D-8-2) 30-bad	92	F	7	54°
76	16123	(D-8-2) 31-cbb	96	F	....	....
77	82	(D-8-2) 32-aab-1	585	no water	....	....
78	20004	(D-8-2) 32-caa-1	247	P	7	....
79	27814	(D-8-2) 32-dad-1	247	F	....	55°
80	C-16970	(D-8-2) 33-bdc-1	185	F	....	53°
81	10703	(D-8-2) 33-aad	450	P	....	61°
82	1628	(D-8-2) 33-bbb	140	F	....	52°
83	20004	(D-8-2) 33-cbc	247	P	100	58°
84	....	(D-8-2) 34-abc	80	F	3	56°
85	21974	(D-8-2) 34-dda-1	110	F	8	50°
86	29942	(D-8-2) 35-cad-1	256	F	7	54°
87	C-23044	(D-8-2) 35-abc-1	162	F	....	53°
88	27015	(D-8-2) 36-aac-1	230	P	....	60°
89‡	27217	(D-8-2) 36-dcb-1	280	P	7	56°
90†*	11830	(D-8-3) 4-cad	231	F	....	56°
91†	C-21434	(D-8-3) 17-abc-1	200	F	15	56°
92†	25654	(D-8-3) 17-dda-1	125	F	8	60°
93	25315	(D-8-3) 18-bbd-1	157	F	5	52°
94	30029	(D-8-3) 19-bba-1	200	P	8	52°
95	23269	(D-8-3) 20-bab-1	80	F	4	52°
96	29837	(D-8-3) 30-bcb	180	P	....	....
97	18059	(D-8-3) 31-abc-1	225	F	....	53°
98	23088	(D-8-3) 32-bba-1	275	P	25	60°
99*	3344	(D-9-1) 1-cba	....	P	....	....
100	1063	(D-9-1) 2-add-1	356	P	7	61°
101	....	(D-9-1) 12-dcd	40	P	250	58°
102‡	30511	(D-9-1) 23-aab-3	322	P	900	60°
103	30511	(D-9-1) 23-aba	290	P	....	58°
104	176	(D-9-1) 25-ada-5	124	F	70	54°
105	176	(D-9-1) 25-bac-1	79	P	110	43°
106†‡	30511	(D-9-1) 26-aac	340	P	500	58°
107	....	(D-9-1) 36-ddc	325	P	....	62°
108	28701	(D-9-2) 1-aac-1	250	F	20	58°
109	29088	(D-9-2) 1-ddc-1	288	F	20	58°
110	27882	(D-9-2) 2-dad-2	227	F	35	54°
111	12289	(D-9-2) 2-add-1	188	P	45	54°
112	14758	(D-9-2) 4-cdc-1	310	F	12	62°
113	28423	(D-9-2) 5-bcd	142	F	6	60°
114	19837	(D-9-2) 5-dac	64	F	10	54°
115*	1139	(D-9-2) 5-ddc	176	F	8	54°

TABLE 1 (Continued)

116	19500	(D-9-2) 5-dcd	90	F	....	52°
117	7647	(D-9-2) 5-ddc	200	F	10	54°
118‡	25416	(D-9-2) 5-ddd-4	85	F	5	52°
119‡	19498	(D-9-2) 6-ada-5	208	F	20	59°
120	25661	(D-9-2) 7-ccc-1	310	F	45	60°
121	28416	(D-9-2) 8-abb-2	163	F	10	59°
122	28048	(D-9-2) 10-bac-1	360	F	4	52°
123‡	....	(D-9-2) 10-cad	410	F	6	60°
124	15162	(D-9-2) 10-cbd-3	180	F	....	54°
125*	3364	(D-9-2) 11-aac	320	F	....	60°
126‡	28363	(D-9-2) 11-aca-3	285	F	200	57°
127‡	16905	(D-9-2) 11-abc-1	410	F	6	60°
128	24951	(D-9-2) 11-bcd-2	243	F	8	57°
129	13713	(D-9-2) 11-ddd-1	150	P	5	54°
130	542	(D-9-2) 12-cbc	205	P	460	56°
131	19045	(D-8-2) 14-bcb	135	P	....	54°
132	16682	(D-9-2) 14-bcb	110	P	10	54°
133	22418	(D-9-2) 15-aac	102	P	....	54°
134	14277	(D-9-2) 16-bbb	362	P	5	58°
135	1243	(D-9-2) 17-aca	251	P	12	56°
136‡	26047	(D-9-2) 17-daa	225	P	640	56°
137	35827	(D-9-2) 17-ddd-1	184	P	10	56°
138	13177	(D-9-2) 18-aaa	91	P	3	53°
139‡	28416	(D-9-2) 18-abb-2	333	P	....	59°
140*	8357	(D-9-2) 18-bcd	....	F	....	58°
141	....	(D-9-2) 19-dbb	158	P	5	53°
142	100	(D-9-2) 20-baa	108	F	....	53°
143	....	(D-9-2) 22-bbd	834	no water	....	....
144	541	(D-9-2) 30-bad	166	F	1	54°
145	574	(D-9-2) 30-caa	197	P	....	54°
146‡	24859	(D-9-2) 31-cda	150	P	....	53°
147‡	....	(D-9-2) 32-bbb	200	P	15	58°
148	23934	(D-9-3) 5-bab-1	262	F	5	58°
149‡	30484	(D-9-3) 5-bbb-2	276	P	75	56°
150	29069	(D-9-3) 6-aaa-1	260	P	....	56°
151‡	27809	(D-10-1) 1-cdc-2	461	P	925	61°
152†	C-14517	(D-10-1) 6-bdb-1	150	P	30	56°
153†	24878	(D-10-1) 17-cca-1	102	P	75	54°
154†	17065	(D-10-1) 22-dcc	110	P	....	56°

* Refers to U. S. Geological Survey observation wells.

‡ Refers to wells upon which water analysis was made.

C Refers to claim wells.

† Wells Number 1, 6, 7, 8, 9, 10, 90, 91, 92, 106, 152, 153 and 154 are outside of area.

Fluctuation of Free Water Table.—In Spanish Fork quadrangle the free water table lies at different levels. On the upper slopes above Bonneville benches and Provo deltas the free water table is as deep as 80 feet below the surface. Near benches, the free water table is as low as 50 feet below the surface. Below the Bonneville benches and on the Spanish Fork Delta is a narrow strip of land where the free water table is between 10 and 25 feet below the surface. In places on the valley floor, the free water table lies between 5 and 10 feet below the surface. There are areas around Salem Pond and northwest around Dixon and Grimes Ponds where the free water table varies from the surface to five feet below. The free water table in the extreme northern part of the quadrangle is also near the surface (see Fig. 5).

Level of the free water table in any one area is not constant, changing from day to day according to the amount of water taken into or given up by the upper zone of saturation. The writer found by measuring the fluctuating free water table in the vicinity of a flowing well that no noticeable change in hydrostatic pressure occurred when the free water table dropped approximately one foot. Previous evidence from the drought period in 1935 showed that under extreme lack of precipitation both the water table and hydrostatic pressures decreased (personal communication, T. Woodhouse, 1959).

Fluctuation of Hydrostatic Pressures.—Hydrostatic pressures vary, changing from day to day according to the amount of water taken into or given up by the underground reservoir. Combined water levels in an area are dependent upon the hydraulic gradient. If hydrostatic pressure is increased due to additional recharge water, the level of water in a well rises above the point where water was previously encountered; and if pressures are extremely high, due to additional recharge, water will flow above the elevation of the surface.

Water fluctuation data for seven wells in Spanish Fork Quadrangle and surrounding area were obtained covering the period from 1935 to 1958. These measurements were made periodically by hand, except when a hydrographic pressure recorder was used. Hydrographs for these wells (Text fig. 3) show seasonal and annual fluctuations of the well levels as compared to the snow course, run-off, and total precipitation of the Spanish Fork recharge area (Text fig. 3).

Observation wells located adjacent to different recharge areas are of varying depths. Hydrographs of these wells compared to the snow course, run-off, and total precipitation of the recharge area show that the greatest direct influence in fluctuation of wells is illustrated by those wells located closest to the recharge area.

Well No. 10, located in the Spanish Fork recharge area and adjacent to the north boundary of the quadrangle, indicates that when seasonal run-off increases over the previous year, well levels rise. In 1952 Well No. 10 rose four feet higher than the previous year since run-off for the area in 1952 was $1\frac{1}{2}$ times that of the previous year's flow. In Well No. 10 the run-off for the area was low for 1953-55 and during this time the well level dropped, but remained above the 1952 level (Table 1).

During May and June of 1959, data obtained from Wells No. 3, 10, 90, 99, 115, and 140, by recording instruments, showed periods of maximum subsurface water recharge as sharp rises in water levels and hydrostatic pressures. Hydrographs (see Fig. 3) show that since 1935, the year Utah ended a severe drought cycle, a rise in water levels occurred in all of the above mentioned observation wells.

It is apparent that the deeper the well the higher the hydrostatic pressure will be if confining clay beds are present and penetrated. Well No. 115 is 176 feet deep and has hydrostatic pressures of 11 to 17 feet, depending upon the time of year measurements are taken and the run-off conditions for that year. Well No. 90 is 231 feet deep and has hydrostatic pressures of 18 to 35 feet. Well No. 125 is 320 feet deep and has hydrostatic pressures of 25 to 45 feet. Calculations show that if the aquifer at the point of discharge is gravel, the hydrostatic pressure increases approximately seven feet for every fifty feet of increased depth. Sediments with differing transmissibility will vary from the proposed seven feet of hydrostatic head (Text fig. 3).

Data from U.S. Geological Survey observation wells indicate that during years of increased total precipitation due to meltwater of snow and rain all observation wells increased in hydrostatic pressure or static level. Not all wells showed the same increase due to the differing permeability of the aquifer from which the water was being drawn, but increased in pressure or static level where wells were located nearer their recharge areas. Thus, from study of these data, the writer believes that the subsurface water supply of the Spanish Fork Quadrangle fluctuates as one independent subsurface unit (Text fig. 3).

Sources of Subsurface Water

Practically all the subsurface water used in Spanish Fork Quadrangle, whether from wells or springs, is derived from unconsolidated valley fill of Quaternary age. Along the Wasatch Range small amounts of water are acquired from springs and mine tunnels in consolidated rock. These springs help furnish water for Salem Pond and Spring Lake but are relatively unimportant in the total subsurface water picture. Little importance is given to springs in this report.

The surface geology (Bissell, 1963, geologic map, Plate 5) shows several water-bearing formations of post-Provo alluvial deposits and sand and gravel members of the Lake Bonneville Group. From post-Provo alluvial sediments water flows from shallow depth along the eastern and southern boundaries of the area. Water from these shallow aquifers is utilized for domestic and stock purposes. Lake Bonneville sediments flow water from aquifers of intermediate depth and are of much significance to the subsurface water structure of the quadrangle. Because of the permeability and high discharge rate of the pre-Lake Bonneville sediments, these sediments are of major importance as water-bearing sediments in the Spanish Fork Quadrangle, but only a few of them crop out in the area.

Pre-Lake Bonneville Sediments

Pre-Lake Bonneville Pleistocene sediments underlie Lake Bonneville sediments in the Spanish Fork Quadrangle and it is probable that these sediments underlie the entire Utah Valley. Well logs, however, show that lithology of these sediments varies greatly and correlation from well to well is extremely difficult. Several conditions have added to the complexity of differentiating Lake Bonneville from pre-Lake Bonneville sediments in sub-crop. Logs of the deepest wells indicate that during the Pleistocene sediment deposited in Utah Valley from Spanish Fork River and Peteetneet Creek interfingered with different units of lake sediment. Extremely thick deposits of sand and clay are found in the Salem area and north from Benjamin to Utah Lake. Another condition adding to the complexity of correlation is a north-south fault which extends across the western edge of the quadrangle.

Deeper wells in the area penetrating pre-Lake Bonneville sediments between 300 and 400 feet beneath the surface obtain higher hydrostatic pressures than do wells of the Lake Bonneville Group.

Permeability.—Plate 1 shows that beds of pre-Lake Bonneville sediments in the northeastern part of the quadrangle grade from permeable coarse boulders, gravels, and sands into progressively finer and thinner less permeable sediments toward the west. In the southern part of the area highly permeable gravels and sands, separated by thick clay beds, extend four to five miles northwest, with a gradient of 30 to 40 feet per mile, before pinching out.

Hydrostatic Pressure.—Throughout the area where wells have been drilled, Pleistocene pre-Lake Bonneville sediments consist of four major units (Hunt, 1953, p. 82). In Spanish Fork Quadrangle, these four units may be observed in Well No. 50 (see Plate 1). These units are not as thick as those of Northern Utah Valley, but exist as four separate aquifers which are separated by clay beds furnishing water for Spanish Fork area. The first aquifer is 35 feet thick, with a depth of 165 feet and is called the shallow Pleistocene artesian aquifer. Water in this unit has a hydrostatic pressure between one and ten feet above the surface, sufficient enough to produce flowing wells in the vicinity of Spanish Fork.

The second gravel aquifer lies 180 feet below the surface and is composed of 15 feet of permeable gravel. This unit has no specific name, but is one of the intermediate zones between the shallow and deep artesian aquifers which produce flowing wells. These wells in July of 1959 had head pressures ranging between 10 and 15 feet.

The third Pleistocene artesian aquifer lies approximately 250 feet below the surface. This permeable gravel member is 20 feet thick and grades basinward into sands that become progressively thinner and less permeable. Hydrostatic pressures from this aquifer are not known.

The fourth aquifer is located at a depth of 310 feet below the surface. The total thickness of this deep aquifer has not been penetrated by wells, but its observable thickness in Well No. 98 is 80 feet. Wells flowing from this aquifer had hydrostatic pressures in July, 1959 of between 15 and 20 feet. These four units, observable in well logs of the area, are coarse permeable zones separated by impervious clay layers. Thus, these zones, when penetrated, yield wells of high hydrostatic pressures.

Movement and Disposal.—Influent seepage from Spanish Fork River enters deep subsurface aquifers composed of pre-Lake Bonneville sediments. This seepage flows northeast toward the lake and discharges its flow effluently into Utah Lake. The deep pre-Lake Bonneville aquifers extend northeast from Payson and north from Santaquin discharging their subsurface flow effluently into Utah Lake.

Lake Bonneville Sediments

Water-bearing properties of Lake Bonneville sediments in the Spanish Fork Quadrangle differ from water-bearing Lake Bonneville sediments of northern Utah Valley. Lake Bonneville sediments in the Spanish Fork Quadrangle are thicker because of the restricted bay that existed in the southern end of the quadrangle and the tremendous amount of coarse to fine sediments deposited by Spanish Fork River during the Pleistocene. Because of the varying sizes and rates of deposition that occurred, water-bearing strata in the area vary widely depending upon their topographic position and composition of sediment.

Permeability.—Coarse permeable sands and gravels of the Bonneville Group readily carry vertically seeping and laterally percolating water. These sediments on the high slopes are above the regional water table and, therefore, are not saturated. Extending toward the high water table of the valley floor, sand and gravels of the Bonneville Group become pressure-charged aquifers when overlain by impermeable clays. Silt and clay sediments of the Alpine and

Provo formations, covering the lower parts of the valley floor, are poor aquifers because of poor transmissibility. These poor aquifers generally lie within the zone of saturation and constitute the shallow pumping wells. Where clays of the Provo Formation are not thick, seepage occurs through the almost impervious clay. This effluent seepage helps furnish Salem Pond and the surrounding areas with water. Large quantities of water are discharged into Utah Lake by effluent seepage of water from the underlying aquifers.

Since the gravel member of the Bonneville Formation is limited to distribution high on the valley slopes, the principal aquifers of the Bonneville Group are the coarse permeable, interbedded sands and gravels of the Alpine and Provo formations. These formations are interbedded with silts and clays and are extensive where they interfinger with the Spanish Fork Delta and underlie and outer portion of the alluvial fan extending from the toe of the delta.

Water Table.—The water table gradient for Spanish Fork Delta is approximately 25 feet below the surface and dips uniformily with the slope of the land except in the valley where the table emerges to within 10 feet of the surface. Th water table gradient in the northwesterly direction from Spanish Fork Canyon is approximately 50 feet per mile. Water tables in the area of Payson and Santaquin are higher than that of Spanish Fork Delta. Because of lack of wells the exact depth to the water table is not known, but it is believed to be generally less than 25 feet below the surface. Below the Santaquin bench, wells have been drilled 80 feet deep before water was reached (Richardson, 1906, p. 54).

Movement and Natural Disposal.—Regional movement of the subsurface water in the Lake Bonneville sediments is in a northwest direction, roughly perpendicular to the slope of the land surface and approximately at right angles to the piezometric surface contours (see Plate 2). Water moves from the high Spanish Fork Delta down into the flood plain of the northwest trending Spanish Fork River.

Post-Provo Alluvial Sediments

Post-Provo sediments in the area are Recent fluvial sands, silts, and gravels that have been deposited along the flood plains of such streams as Spanish Fork, Peteetneet, and Santaquin Creeks.

Permeability.—The thickest deposits of post-Provo alluvial sediment are well-rounded, permeable gravels and boulders at the mouth of Spanish Fork River. These deposits grade into smaller size material of lower permeability shown by Wells No. 50, 25, 39, 98, 88, and 85 (see Plate 1). This Recent alluvial material may be as thick as 80 feet as shown by Well No. 98.

Recent alluvial fans are composed of poorly sorted angular to sub-rounded gravels mixed with silt and clay which have fair to poor permeability and occur along the eastern side of the quadrangle and in the southern end of the area.

Water Table.—Because of lack of wells in the vicinity of the flood plain, determination of the horizon of the water table was based on only one or two wells found in the area. The water table of the Spanish Fork River flood plain is approximately 20 to 25 feet lower than that of the delta area through which the river flows. It is possible that through influent seepage conditions, the river and irrigation waters have added to the water table of the delta area. The water table of the alluvial fans, south of Salem, is somewhat deeper than that of Spanish Fork River because of lack of influent seepage from surface streams of rivers. The depth to the water table in the area of these fans is below 50 feet.

Movement and Natural Disposal.—Most surface waters empty into Utah Lake. It is generally believed that the subsurface waters also flow toward the lake and discharge their flow by effluent seepage. Alluvial fans, south of Payson, and, in particular, the Santaquin Creek fan are far from Utah Lake and lose their water by seepage into the Lake Bonneville sediments.

Characteristics of Developed Aquifers

The town of Spanish Fork, situated on the general lowland at the base of Mapleton bench, produces its shallowest well water from about 15 to 30 feet below the surface, but the water from this horizon has a bad taste that might be due to a high sulfate content; second flow is obtained at 285 to 300 feet, and the third between 350 and 400 feet. The water from the second and third horizons is of good quality in that it contains less than the allowable 500 ppm for total ionized solids and less than 250 ppm of chlorides (see Table 2). These aquifers are diagrammed in Plate 1. The first and third horizons may be traced westward from Spanish Fork for three miles, while the second gravel aquifer pinches out one and one-half miles west of Spanish Fork. The wells at the packing plant, south of Spanish Fork, are

TABLE 2
Chemical constituents in parts per million of subsurface water
Spanish Fork Quadrangle, Utah
Professor John H. Wing, analyst

Well Number	*Reported Depth of Wells*	*Total Ionized Solids*	*pH*	*Na*	*K*	*Ca*	*Mg*	*Cl*	*Temp.*
1	256	369	7.47	43.7	0	120	380	15.75	59
6	187	540	7.55	53.0	2	350	500	53,37	58
25	377	315	7.83	10.0	0	300	380	10.91	59
26	424	360	7.70	10.7	0	200	380	12.73	59
40	346		7.88	28.8	4.7	90	290	10.91	
49	391	360	7.59	9.5	0	300	100	12.13	62
61	300	549	7.62	47.5	15.5	120	290	114.02	95
62	336	468	7.53	51.0	14.3	120	290	26.96	82
89	280	612	8.35	40.0	2.5	230	600	27.90	59
102	322	495	7.72	16.6	0	450	500	26.68	
106	290	450	7.95	10.7	0	450	390	24.26	
118	85	540	7.75	14.0	1.7	450	390	21.83	54
119	208	342	8.23	12.0	1.2	120	290	18.80	
123	410	382	7.62	7.0	0	350	380	19.41	60
126	285	540	7.72	29.2	0	520	500	41.24	
127	410	517	7.80	23.0	0	500	500	41.85	60
136	225	360	7.52	42.5	3.0	350	390	16.37	
139	333	324	8.42	30.0	5.0	120	290	86.12	59
146	150	720	7.72	47.5	0	860	700	173.46	55
147		427	7.80	11.6	0	400	500	18.19	
149	276	726	7.60	18.0	0	580	700	41.24	
151	461	300		8.0	8.0	61	100		

300 and 400 feet deep and perforated from near the surface to the bottom of the wells. These two wells, when pumping at capacity, have an influence on wells within the Spanish Fork area and on the deep artesian aquifers as far south and west as Salem, for when the wells are pumping at capacity the piezometric surfaces on the deep aquifers drop as much as five feet. The writer believes these packing plant wells are the primary reason some of the shallow aquifer wells on the Spanish Fork Delta have discontinued flowing.

The town of Salem is located south of Spanish Fork and is situated upon Provo sand and silts of the lower Provo bench. The water table in this area may be reached within five to ten feet of the surface. The first water horizon is approximately 160 feet below the surface, the second at 265 feet, and the third at a depth of 410 feet. The water from the first aquifer is of fair quality being 40 ppm above the maximum limit of total ionized solids for good water. The wells of this first flow have low hydrostatic pressures between five and ten feet. The second and third flows are of good quality by being under maximum ppm allowable. Hydrostatic pressures in this area vary from 10 to 44 feet of hydrostatic head. The area of these two flows extends northwest from Salem for a distance of approximately four miles.

Payson is located west of Salem upon the Lake Bonneville spit and delta formed by Peteetneet Creek. Flowing wells are not found in Payson. The Payson City Well obtains water of good quality from gravel 200 feet below the surface that furnishes water to a static level of 40 feet. The water table in this area is irregular, fluctuating between 15 and 100 feet below the surface. The main source of water for Payson City comes from reservoir storage and the Payson City Well No. 117 (see Table 1).

Spring Lake is located south of Payson near the base of Dry Mountain. The water table in this area is within 10 feet of the surface. Flowing wells are absent along the entire axis of the Lake Bonneville spit which extends north from Payson. Flowing wells are found east and west from this topographic high. The depth to the deep pre-Lake Bonneville aquifer in the Spring Lake area is approximately 200 feet, with hydrostatic pressures ranging from 10 to 20 feet above the surface.

The town of Santaquin is farther south and is located upon a former delta of Santaquin Creek; the main water supply is obtained from the Santaquin well which is a pump well 460 feet deep. Water from this well is obtained from four water-bearing aquifers, 165, 277, 375, and 413 feet deep respectively. In the area of Santaquin, shallow wells obtain water from a perched water table 15 to 25 feet below the surface.

West Mountain has several high-yield pump wells drilled along its lower slopes. Two of these wells, Nos. 102 and 106, are approximately 300 feet deep (see Table 1). From Well No. 102, 600 to 900 gallons of water per minute can be produced with a 28-foot draw-down and recovering 25 feet in 15 seconds. The static level of this well is approximately 49 feet.

Benjamin, Palmyra, and Lake Shore are small towns located north of Payson and west of Spanish Fork. Flowing wells are obtained throughout this area from every sand bed 50 to 600 feet below the surface. Most of the wells range from 300 to 400 feet deep and have low hydrostatic pressures under ten feet. This area is mainly farm land and very limited quantity of water from wells supplements the irrigation water received from canal systems.

Piezometric Surface

The piezometric surface is not the same for wells of different depths and different aquifers. The piezometric surface of the deep Pleistocene artesian aquifers (see Plate 2) is generally higher than that of the shallow artesian aquifers, as shown by measurements of 80 wells in July, 1959 (see Plate 2).

Shallow Pleistocene artesian aquifers in the quadrangle have pressure sufficient to cause water flow at the surface. These pressures are produced by the overlying Lake Bonneville Group which is relatively impermeable and confines most of the water within the aquifer. Lower pressures are found near Lake Shore and Utah Lake and rise to the east and south with increasing gradient.

The higher pressure zones maintain pressures of 40 to 50 feet except along the Benjamin Fault where shallow wells have pressures of 20 to 30 feet which is abnormally high. The general shallow hydrostatic pressures range between one and ten feet. The high-pressure zones are spotty and obtain their pressure from differing depths. Highest pressures were measured from two wells located on the west side of the town of Salem at depths of 285 and 410 feet. Gravel aquifers from which these pressures are derived start at the valley perimeter and pinch out valleyward within three miles. Hydrostatic pressures from these wells range from 40 to 50 feet. Well No. 28 is 459 feet deep, located in Sec. 16, T. 8 S., R. 2 E., and has a hydrostatic head of 44 feet, while surrounding wells of the approximate same depth have pressures of three to ten feet. The writer believes this hydrostatic pressure is caused by water embankment along the fault zone. High hydrostatic pressures at Leland are found where the depth to deep Pleistocene aquifers is 385 feet. A hydrostatic head of 10 to 20 feet is obtained from wells of this depth.

The northwest movement of water in the artesian aquifer is generally shown at right angles to the piezometric contour lines. Thus, influent seepage of water moving along the axis of the river and streams recharges the subsurface water aquifers. From the piezometric high along the delta near Leland, the piezometric surface has the form of a sloping ridge, and water appears to move in a southwest to northeast direction off the flanks of the delta. Water from Peteetneet Creek moves northwest, southwest, and southeast off the axis of the ridge in the same direction as the recharge of Spanish Fork River. The piezometric surface map suggests that Santaquin Creek discharge moves north toward Utah Lake. The general movement of the water is toward a topographic low west of Payson, and Benjamin (see Plate 2.

Chemical Quality of Water

A partial analysis made on 22 wells from the area of the subsurface water study indicates that waters of Spanish Fork Quadrangle contain 300 to 700 micro-moles of dissolved solids, and have a hardness ranging from 120 to 860 parts per million of calcium. The calcium is derived from the limestones which are present in the drainage basins of the Wasatch Range (see Table 2).

Water analysis of shallow artesian aquifers show water from 100 to 200 feet below the surface to contain more magnesium, chloride, and calcium than the deeper aquifers which were sampled. Calcium and sodium content increase in parts per million where water samples were taken nearer the recharge area. Chloride, sodium, and potassium show more variation in ppm along the fault zone than samples taken from areas near the eastern side or along the southern end of the quadrangle. These minerals also increase in ppm where water samples were taken closer to the recharge area. In general, the chemical analysis leads the writer to believe that the concentration of mineral constituents in different gravel aquifers varies where they are separated by confining clay and where upward movement of water from deep aquifers does not intermix to dilute or add new chemical constituents to these shallower aquifers. Thus, the best quality of water comes from the deeper aquifers.

The Benjamin Fault and Its Effect on Subsurface Water

The most interesting of the springs in the area is a hydrothermal one that originally appeared near the Benjamin Cemetery. This spring was formed by the post-Lake Bonneville Benjamin fault which displaced the Bonneville sediments at the Benjamin Cemetery.

The Benjamin fault acts as a conduit along which the deep hydrothermal water flowed to the surface in the past. Since that time, a well has been drilled to a depth of 300 feet. Woodhouse, driller of the 300-foot-deep well, (1959, personal communication) stated that for every 25 to 30 feet of penetration, a new gravel bed containing hotter water was encountered. Drilling was continued until temperature sufficient for swimming purposes was encountered. The temperature of this water has dropped slightly since the well was drilled with a temperature now ranging between 90 and 95 degrees fahrenheit. Constant use of the well for swimming facilities at Arrowhead Resort during the summer months has caused the original spring to cease to flow. Since installation of a 300-foot pump well to obtain water, the surrounding wells on the downthrown side of the fault were influenced. Water levels near the resort dropped sufficiently to cause the surrounding wells to cease flowing. Fortunately, this drawdown is limited to a small area whose radius to the east of the fault is less than a one quarter-mile. After summer use of the resort well is discontinued, Well No. 83, adjacent on the south, takes two weeks to recover normal flowing status. The writer's measurement of recovery showed it to rise approximately 55 feet. Recovery is slow because the water must regain its previous status by seepage through the overlying sands and gravel and near-impermeable clays which, because of their low transmissibility, restrict flow.

A study of water temperatures indicates that water from the hot spring has greater influence on the downdropped block and little influence on the other side of the fault zone. Well No. 63, north along the fault zone, is 168 feet deep and has a water temperature of 80 degrees. Well No. 83, south along the fault zone, is 140 feet deep and has a water temperature of 80 degrees. Another well, farther south along the fault, is 130 feet deep with a temperature of 80 degrees. The writer assumes that hot water seepage along the fault zone for at least one-fourth of a mile in each direction penetrates the upthrown block 150 feet westward, one-fourth of a mile north to one-fourth of a mile south, and one-half mile east in the downthrown block. Wells having an average depth of 140 feet have water temperatures of approximately 80 degrees F., while the 300-foot well, drilled at Arrowhead Resort, has a temperature of approximately 95 degrees F. Comparison of these wells shows that the hydrothermal gradient at this point is 10.6 degrees per hundred feet of depth.

The mineral content of the water from Wells No. 61 and 62 differ from the water of the surrounding aquifers (see Table 2). This suggests the water source is (1) deep, (2) that shallow subsurface water is circulated through hot deep formations of differing composition, and (3) that warmer water dissolves more parts per million of solids than does colder water.

Water from Arrowhead Resort Well was high in sodium compared to most surrounding wells. Five other wells, four lying along the projected strike of the fault, also have high sodium contents. These are Payson City Well No. 136 and Tharvelson Gravel Pit Well No. 146 located in the southwest part of the quadrangle. Two other wells with high sodium content are No. 1 and No. 6, located in the northern part of the area. Well No. 139, located west of Payson near faulted Paleozoic sandstones, has a relatively high sodium content and exactly the same content of calcium and magnesium as resort wells No. 61 and 62. These three wells are approximately 300 feet deep. The calcium content for Well No. 1 is the same as the resort wells and the well near the sandstone outcrops. The Payson City Well's calcium content is 230 parts per million higher and its magnesium 100 parts per million higher than in the resort wells. The Gravel Pit Well's content of calcium is 740 ppm higher and its magnesium 600 ppm higher than in the resort wells. Wells No. 6 and 140, as well as the Gravel Pit Well south of Payson, have high calcium and magnesium contents. The writer believes that the similarity of chemical content suggests that this water is chemically influenced along a fault zone and that similarity of content aids in projecting the trace of the fault.

Wells in the vicinity of the fault vary in depth to the water source. Those wells on the upthrown block, near the cemenery, are pumpers or wells which obtain little or no water, such as Well No. 74. A well-cemented conglomerate was penetrated before water could be obtained. This is a localized condition in the area of the Benjamin Fault and exists one-half of a mile north and one-half a mile south of the cemetery along the fault zone with a width on the upthrown block of one-third of a mile.

Richardson (1906, p. 54) states that one well in Payson obtained water at 18 feet, while on the opposite east side of the street, a well was dug 90 feet without encountering water. It is the writer's belief that this is the result of faulting, possibly an extension of the Benjamin Fault.

Another result of this Recent displacement along the Benjamin Fault is that the coarse, more permeable aquifers that are encountered within 200 feet on the east side of the fault have been displaced on the west against the fine sediments of the west. Coarse more permeable aquifers that were on the west side of the fault have been displaced against finer sediments on the east side. Thus, to the west shallower wells are needed to reach water-bearing aquifers. These aquifers which have been partially cut-off from the eastern recharge area by the fault and water removed from them are replenished more slowly than in the case wells east of the fault.

Hydrostatic pressures of these wells have been altered by the fault displacement. A general low-pressure zone from aquifers along the fault is caused by pressure escaping along the fault zone. Other aquifers that have been totally displaced against an impervious material, such as clay, have hydrostatic pressures between 15 and 35 feet because of water embankment, which formed a ground water dam on the downthrown block. This ground-water dam, along the Benjamin Fault, is indicated by considerable difference of static levels in wells of comparable depths only a few hundred yards apart (see Plate 2). Wells on the upthrown block have hydrostatic pressure of one to five feet. Where the fault released pressure to the surface or other aquifers, the wells must be pumped. The total extent of the fault is not known, but through projection of pressure studies, the fault was traced beyond Benjamin to the north and possibly as far as Payson to the south.

The effect of faulting upon the movement of subsurface water through the unconsolidated sediments is shown by contours of the piezometric surface (see Plate 2). The contours show a distinct ground-water dam in the vicinity of the fault.

Recharge

The primary source of water entering Spanish Fork Quadrangle is precipitation derived from annual snow-fall and rain-fall in the Wasatch Mountains to the east of the area. Of this total precipitation, only the portion not evaporated, or that which does not enter Utah Lake as run-off, influently seeps into the subsurface aquifers to become subsurface water. This recharge by influent seepage is accomplished by surface run-off being absorbed by surface sediments and by means of stream contact with its channel. The major streams carrying meltwater and rain water into the quadrangle are Spanish Fork River and the Peteetneet and Santaquin Creeks.

Influent seepage of irrigation water and water lost through seepage beneath canal systems adds an unknown quantity to the subsurface water supply. Springs along the base of the mountains undoubtedly contribute some water through influent seepage to the subsurface water supply. The exact quantity that this spring water adds is also unknown.

The total influent seepage from above mentioned means constitutes the subsurface water supply that flows through the unconsolidated sediments of pre-Lake Bonneville, Lake Bonneville, and post-Lake Bonneville sediments. These sediments include the primary water-bearing aquifers throughout Spanish Fork Quadrangle.

An example of natural recharge is illustrated through the gravel of the Bonneville Formation south of Salem. Where the Bonneville bar passes across the mouth of two northward extending gullies to form the area called the Goose Nest, a natural dam was formed. The farmers in the area had hopes of diverting excess flow from streams and creeks into this supposedly natural reservoir for use later in the season when other sources had been depleted. This embankment is constructed of gravel and could not retain all the water, thus as water entered the reservoir, influent seepage through the permable gravel carried water underground to the Lake Bonneville and pre-Lake Bonneville aquifers. Thereby, some of the subsurface water supply of Spanish Fork Quadrangle was replenished. This was unfortunate for the farmers in one respect, but the water was not going to waste. This water added to the subsurface water supply helped recharge the subsurface aquifers.

Consumptive Use

The deep artesian aquifer is the source of most of the water yielded by wells in Spanish Fork Quadrangle. Only 63 wells of 154 studied were above 200 feet. The remaining wells ranged in depth from 200 to 800 feet. A limited amount of water flowing from wells in the quadrangle is used for irrigation. Three row-crop farms are irrigated with water from wells. The largest use is for domestic and stock watering purposes. Several wells have ceased to flow because of lack of pressure. The major cause of flow stoppage in the quadrangle is caused by silting and caving from extracting sand and fine silts from flowing and pumping wells. At low pressure many wells have been placed on pump in order to gain sufficient water pressures for domestic needs. These wells are generally the first to cease flowing because of the tendency of the pumping to pull fine sands and silts from the well in large quantities. This happens where wells are producing from thin beds of sand and fine gravel.

Potential Development of Water Resources

Conditions for further economic development of the subsurface water in the area are limited but locally are favorable. Since the 1934 drought, the water table has been gradually rising (see Fig. 3).

Since 1950 approximately 200 wells, both deep and shallow, have been drilled in this area without any drastic decrease occurring to the free water table or confined water levels.

The best prospect for development of additional water supplies in the area for industry and irrigation are as follows: (1) Drilling a number of widely spaced wells below 200 feet along the drainage route from Santaquin towards Utah Lake. Wells in this area have the greatest yield from pump discharge of any wells in the area. The reason for this is that this area accumulates water from Spanish Fork, Salem, Payson, and Santaquin. Thus, withdrawal from wells in this lower level would have much less effect on the wells of Benjamin and Payson than wells placed between them and their recharge areas. (2) Drilling a number of widely spaced wells between 250 feet and 400 feet deep adjacent to the Spanish Fork River flood plain and adjacent to this area on the Spanish Fork delta.

Wells of low yield needed for stock and domestic use can be obtained from 100 feet to 250 feet below the surface in all areas of the quadrangle except those near the Benjamin Cemetery, Salem pond area, and the high slopes in the southeast corner of the area.

The wells for industry, irrigation, stock and domestic use should be drilled until their presence on adjoining wells shows a detrimental effect. If such development of wells shows a constant decrease in the subsurface water supply, the previously mentioned artificial recharge method of adding to the subsurface water by diverting spring meltwaters into the subsurface aquifers could be attempted. Such development requires an adequate knowledge of hydrology and wise management of the supply by the State Engineer's Office. This would require continued enforcement of the 1935 subsurface water law and adoption of proper conservation techniques.

It is possible that the key to needed subsurface water reserves in the quadrangle lies in the possibility that several deep water-bearing aquifers might exist below the deepest of the present water-bearing aquifers.

REFERENCES CITED

Bissell, H. J., 1963, Lake Bonneville: Geology of southern Utah Valley, Utah: U. S. Geol. Survey Prof. Paper 257-B, p. 101-130.

Boyden, T.A., 1951, Ground-Water Geology of the Payson-Benjamin, Utah, Area: unpub. M. S. thesis, Brigham Young University, 50 p.

Brown, R. S., 1950, Geology of the Payson Canyon-Picayune Canyon Area, Southern Wasatch Mountains, Utah: unpub. M. S. thesis, Brigham Young University, 51 p.

Gilbert, G. K., 1890, Lake Bonneville: U. S. Geol. Survey Mon. 1, 438 p.

———, 1928, Studies of Basin-Range Structure: U. S. Geol. Survey Prof. Paper 153, 92 p.

Hintze, L. F., and others, 1962, Geology of the Southern Wasatch Mountains and vicinity, Utah: Brigham Young University, Geology Studies, v. 9, pt. 1.

Hunt, C. B., Varnes, H. B., and Thomas, H. E., 1953, Lake Bonneville: Geology of northern Utah Valley, Utah: U. S. Geol. Survey Prof. Paper 257-A, 99 p.

Richardson, G. B., 1906, Underground Water in the Valley of Utah Lake and Jordan River, Utah: U. S. Geol. Survey Water-Supply Paper 157, 81 p.

Rigby, J. K., 1962, Some Geomorphic Features of the Southern Wasatch Mountains and Adjacent Areas: Brigham Young University, Geology Studies, v. 9, pt. 1, p. 80-84.

Thomas, H. E., 1941, Ground-Water Dams Created by Faulting of Alluvial Sediments in the Hurricane Fault-Zone, Utah: American Geophysical Union Transactions, v. 22, 775-778.

U. S. Weather Bureau, 1935-1958, Annual Climatological Reports for Utah, v. 32-68.