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DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TEST WELLS IN CENTRAL WASHINGTON, 1977 TO 1979: DESCRIPTION AND RESULTS

W. E. Lum II and D. R. Cline

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GEOLOGICAL SURVEY

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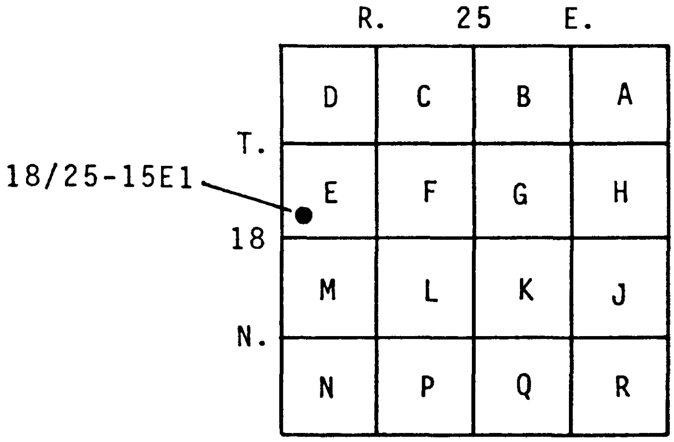
WELL-NUMBERING SYSTEM

In this report wells are designated by symbols that indicate their locations according to the official rectangular public-land survey. For example, in the symbol 18/25-15E1, the number for the George test well, the part preceding the hyphen indicates, successively, the township and range (T.18 N., R.25 E.) north and east of the Willamette base line and meridian. Because the report area lies entirely north and east of the base line and meridian, the letters indicating the directions north and east are omitted. The first number following the hyphen indicates the section (sec. 15), and the letter "E" gives the 40-acre subdivision of the section, as shown in the figure below. The numeral "1" indicates that this well is the first one listed in the subdivision.



Section 15

CONVERSION FACTORS, INCH-POUND TO METRIC

Multiply inch-pound units	By	To obtain SI units
inches (in.)	25.40	millimeters (mm)
feet (ft)	0.305	meters (m)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
pounds per square inch (psi or lb/in^2)	0.07031	kilograms per square centimeter (k/cm^2)
gallons per minute (gal/min)	0.063	liters per second (L/s)
gallons per minute per foot [(gal/min)/ft]	0.207	liters per second per meter [(L/s)/m]
feet squared per day	0.093	meters squared per day (m^2/d)
degrees Fahrenheit (°C)	°C = 5/9 (°F-32)	degree Celsius (°C)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

TEST WELLS IN CENTRAL WASHINGTON, 1977-79: DESCRIPTION AND RESULTS

By W. E. Lum II and D. R. Cline

ABSTRACT

During the period October 1977-March 1979, three test wells were drilled and a test well near George was deepened and equipped with piezometers in central Washington. The work was done to provide supplemental ground-water data for aquifers in the Columbia River Basalt Group. Two wells were drilled to 602 feet and 1,019 feet respectively, in the Yakima River canyon near the mouths of Burbank Creek and Umtanum Creek. A third well was drilled to 725 feet in the Badger Pocket area of the Ellensburg-Kittitas valley. A test well near the town of George was deepened from 975 to 1,610 feet, and three piezometers were installed in this interval.

The Burbank Creek, Umtanum Creek, and George test wells are completed in basalts and associated interflow zones of the Yakima Basalt Subgroup of the Columbia River Basalt Group. The Badger Pocket well penetrated more than 725 feet of unconsolidated materials without reaching the basalt.

Specific capacities calculated from pumping tests of the Umtanum Creek and George wells after at least 20 hours of pumping were 190 and 160 to 190 gallons per minute per foot of drawdown, respectively. The specific capacity of the Burbank Creek well after flowing for 24 hours was calculated to be 32.5 gallons per minute per foot of drawdown. The Badger Pocket well was not tested for yield.

INTRODUCTION

Purpose and Scope

During the period 1977 to 1979, three test wells were drilled and a well near George was deepened in central Washington; piezometers were installed in the latter well in 1979. These wells were constructed and tested with federal drought relief funds; all were added to a network of wells drilled as part of a continuing cooperative program begun in 1970 between the U.S. Geological Survey and the State of Washington Department of Ecology. This report describes the construction, testing, and geohydrologic conditions of these wells. Locations of all the test wells drilled under this program since 1970 are shown in figure 1. The information gathered from these wells is used to provide (1) hydrologic information in areas where little is known of local conditions, and (2) supplemental information to be used for water-management decisions made by the Department of Ecology and others.

Two drilling sites were selected between Ellensburg and Yakima, one near the confluence of Umtanum Creek and the Yakima River and the other near the confluence of Burbank Creek and the Yakima River. The purpose of drilling in this largely undeveloped area was to determine if large-yield flowing wells could be developed to supplement the flow of the Yakima River during low-flow periods.

A third drilling site was located in the Badger Pocket area near Ellensburg, where ground water could be used to supplement the existing surface-water irrigation system in that area. A well at the site would also provide hydrologic information that could be used in regional studies of basalt aquifers.

A fourth well near the town of George, originally drilled to 975 feet in 1975, was deepened to obtain information about basalt aquifers at greater depths than existing irrigation wells in that area could provide. East of George, the deeper aquifers have been tapped for irrigation supplies, and development of comparable supplies in the area around George can be expected in the near future.

During drilling operations, samples of drill cuttings were collected at frequent intervals and a lithologic log was compiled for all four wells. Following the completion of drilling operations, the Burbank Creek, Umtanum Creek, and George test wells were geophysically logged by personnel of Washington State University. Practical and economic considerations halted drilling at 725 feet in the Badger Pocket well before basalt was penetrated. The borehole below the casing was allowed to collapse, and the well was capped and not tested further.

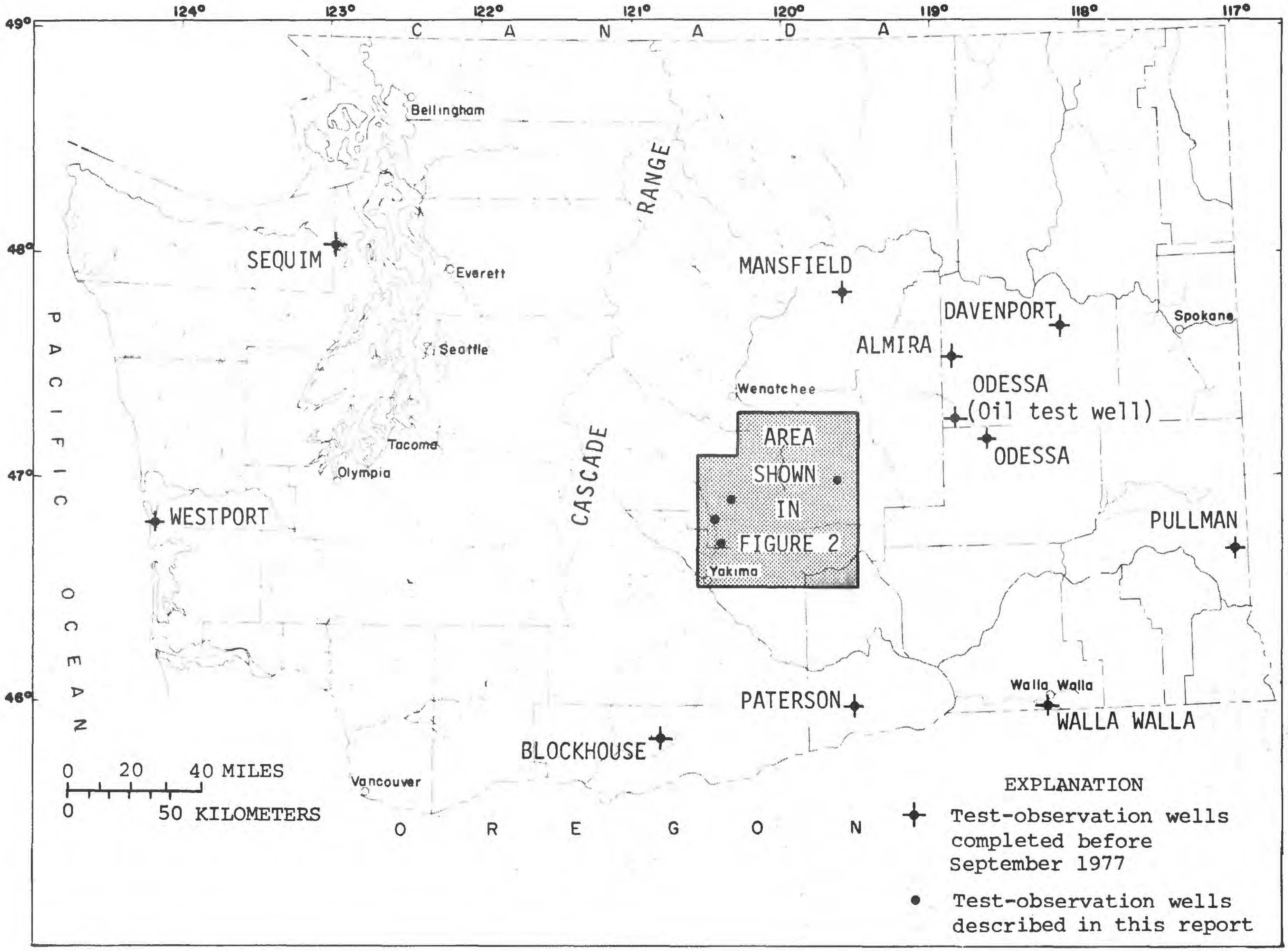


FIGURE 1.--Location of test-observation wells in Washington.

The water-yielding characteristics of aquifers tapped by three of the wells were tested in 1978; the Umtanum Creek and George wells by pumping water from the wells, and the Burbank Creek well, a flowing well, by controlling and measuring the rate of flow of the water from the well. After the testing, three piezometers were installed in the George test well that enabled the measurement of water levels in several separate aquifers.

The Burbank Creek, Umtanum Creek, and George test wells are now (1980) part of the statewide network of wells in which water levels are measured periodically to assess changes in local hydrologic conditions.

Description of the Area

The four test wells discussed in this report are located in central Washington, east of the Cascade Range (fig. 1). The climate of the area is generally arid to semiarid, with an average annual precipitation of less than 10 inches (U.S. Department of Commerce, 1965).

Central Washington has an economy based primarily on agriculture, with related service and manufacturing businesses. Irrigation has placed large demands on the ground- and surface-water resources from this and other areas of Washington.

Acknowledgments

The authors thank the drillers employed by Holman Drilling Corp.[1] of Spokane, Wash., and Leo Kay of Tully Drilling Co., Yakima, Wash. (subcontractor to Adcock Air Drilling, Lewiston, Idaho) for their cooperation during the drilling of the test-observation wells, and Marlatt Well Drilling, Milton-Freewater, Oreg., during the installation of piezometers in the George well. The authors also thank property owners Emile L. Robert, Jr. and Victor E. Robert of Yakima, Wash., and Albert DeKoning of Ellensburg, Wash., for their cooperation.

[1] Reference to companies or other proprietary names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

GENERAL HYDROGEOLOGIC FEATURES OF THE AREA

The area surrounding the test wells described in this report is underlain to great depths (maximum thickness probably more than 5,000 feet; Don Ford, Washington Division of Geology and Earth Resources, oral commun., 1981) by the Yakima Basalt Subgroup of the Columbia River Basalt Group (Bingham and Grolier, 1966). The Yakima Basalt Subgroup is described as a series of flood basalts and associated interflow (between basalt flows) deposits (Grolier and Bingham, 1978). This subgroup, deposited during the Miocene age, is divided into the Grande Ronde (oldest), Wanapum, and Saddle Mountain (youngest) Basalts (Swanson and others, 1979). Some flows have great lateral extent; the Frenchman Springs Member of the Wanapum Basalt is known to extend over an area of about 28,000 square miles (Swanson and others, 1979). Flows generally range from about 10 to 200 feet in thickness. In part of central Washington the basalt has been deformed into a series of ridges (anticlines) and valleys (synclines) (fig. 2).

The basalt is mostly dark gray to black and fine textured. The upper part of basalt flows is commonly vesicular and well jointed, whereas the center part of individual flows tends to be dense, with fewer joints and in places almost impermeable. The lower part of flows has a thin zone of jointing or a zone of "pillows." The pillows occur where the basalt flowed into lakes or rivers.

Overlying and sometimes interfingered with the Yakima Basalt in some locations are continental sedimentary deposits of the Ellensburg Formation (Bingham and Grolier, 1966; Mackin, 1961). These deposits were penetrated to a depth of 725 feet by the Badger Pocket well.

Interflow deposits that occur in central Washington, mostly part of the Ellensburg Formation of Miocene age (Swanson and others, 1979), consist mainly of gravel, sand, silt, and clay, generally of granitic origin and transported onto the basalt flow surface by streams and rivers (Mackin, 1961); some peat and diatomite also occur in these deposits. The beds of diatomite were deposited in lakes, and commonly contain layers of silt and clay and nodules of opal. The fine-grained layers were generally flat-lying when they were deposited and have relatively low permeability.

The Vantage Member of the Ellensburg Formation is a sedimentary interbed that commonly separates the Grande Ronde and Wanapum Basalts (Swanson and others, 1979) over a large part of central Washington. The Vantage Member (which was penetrated by the George and Burbank Creek test wells) and (or) the uppermost flows of the Grande Ronde Basalt commonly have a low permeability and may act as ground-water confining layers in many parts of central and east-central Washington.

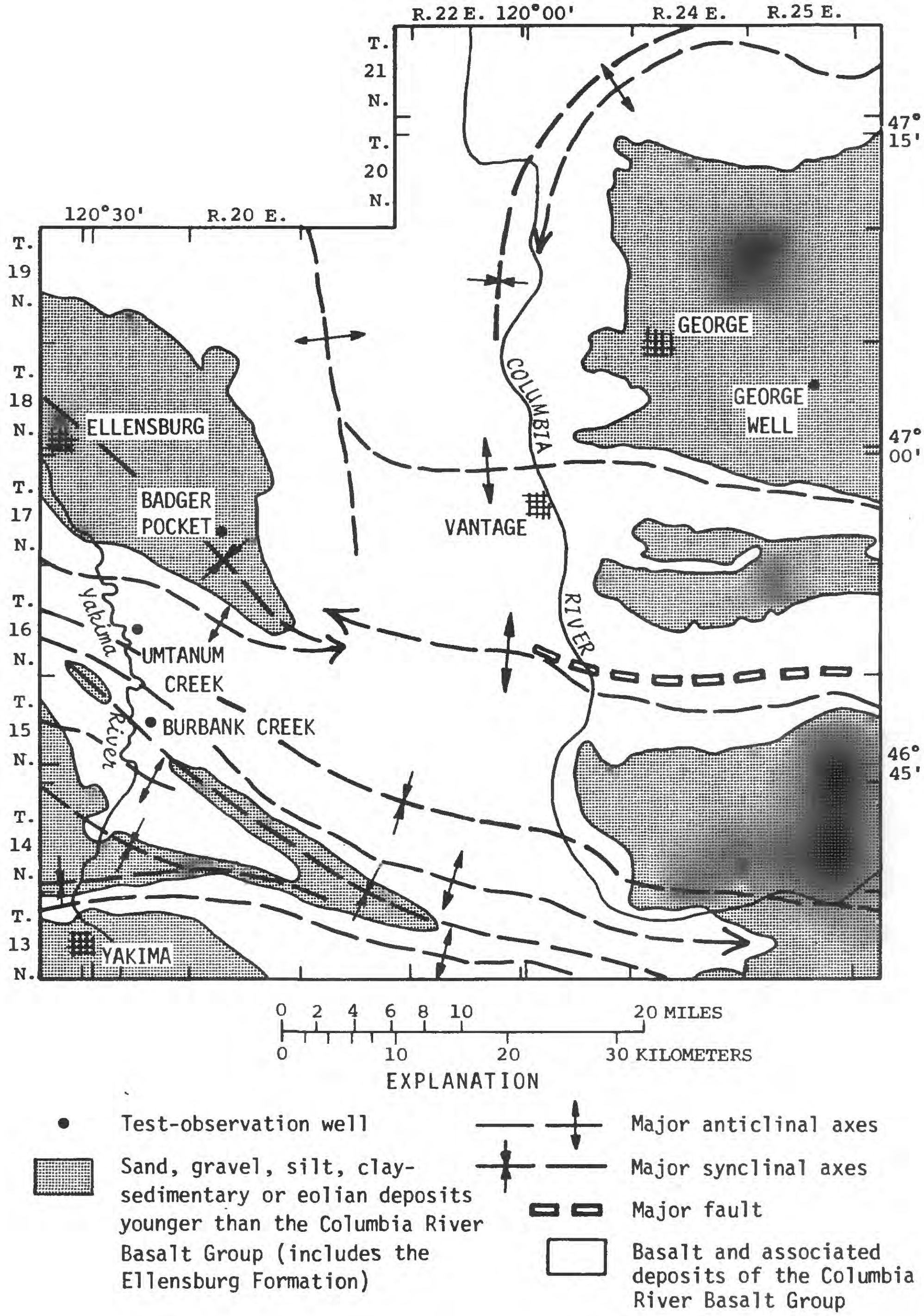


FIGURE 2.--Generalized geology and structure of part of central Washington, and locations of four test wells.

The principal water-bearing zones in central Washington occur between flows in the Yakima Basalt Subgroup, and are composed of the porous, rubbly, and well-jointed tops and adjacent jointed and (or) pillowed zones at the bottoms of the flows. The interflow zones that contain permeable sand or gravel or both, although usually not as productive, can also produce substantial quantities of water to wells. Wells open to a series of basalt flows commonly yield more than 1,000 gal/min.

The Ellensburg Formation also yields more than 500 gal/min to individual wells in some locations. The most productive water-bearing zones are well-sorted gravel strata that occur throughout the formation, but in many areas the entire saturated thickness yields water to properly constructed wells.

Water in the Burbank, Umtanum Creek, and George test wells is clear, of good quality, and generally similar to water from wells of the same depths in surrounding areas (Van Denburgh and Santos, 1965). The water from all three wells is moderately hard (table 1), but is suitable for most uses, including irrigation of all crops currently (1980) grown in the area.

TABLE 1.--Chemical quality of water from three test wells

Constituent (in milligrams per liter, except as noted)	Burbank Creek well	Umtanum Creek well	George well
Date	8-16-78	3-02-78	2-17-78
Time	11:45 a.m.	8:15 a.m.	10:00 a.m.
Discharge (gal/min)	975	960	1,050
Specific conductance (umho/cm at 25°C)	260	195	330
pH (units)	8.0	8.5	7.0
Temperature, water (°C)	22.8	26.8	25.6
Color (units)	--	1	1
Hardness as $CaCO_3$	80	56	68
Noncarbonate hardness	0	0	0
Calcium, dissolved (Ca)	17	14	16
Magnesium, dissolved	9.2	5.2	6.7
Sodium, dissolved (Na)	22	22	50
Percent sodium	36	45	59
Sodium absorption ratio	1.1	1.3	2.6
Potassium, dissolved (K)	4.5	2.6	6.6
Bicarbonate (HCO_3)	--	120	160
Carbonate (CO_3)	--	0	0
Alkalinity, total as $CaCO_3$	120	98	130
Sulfate, dissolved (SO_4)	1.5	1.9	25
Chloride, dissolved (Cl)	4.3	3.3	11
Fluoride, dissolved (F)	0.5	0.6	1.2
Silica, dissolved (SiO_2)	51	48	67
Dissolved solids, residue at 180°C	175	150	251
Dissolved solids (ton/acre-ft)	.24	.20	0.34
Iron, total (ug/L)	120	30	100
Manganese, total as Mn (ug/L)	20	0	10

LITHOLOGIC AND GEOPHYSICAL LOGS

Lithologic and geophysical logs of the test wells were used to delineate aquifers in each well. Lithologic logs were obtained by observing drill cuttings during all drilling operations. Geophysical logs of the Burbank Creek and Umtanum Creek test wells were made shortly after the completion of drilling operations (figs. 4 and 6). The George well was logged in June 1975 (Eddy, 1976), after initial drilling to a depth of 975 feet (fig. 10), and again after the well was deepened to 1,610 feet (fig. 11). All geophysical logs were made by Washington State University. The Badger Pocket well was not logged geophysically.

Several characteristics of the geophysical logs indicate where aquifers, shown on the left side of the figures, may occur. Enlargements in hole diameter, as indicated by the caliper log, indicate vesicular and (or) broken basalt or interflow zones that may produce water. Shifting of the neutron-neutron log to the left indicates increasing porosity and, thus, zones where water may be found. Assuming no changes in well diameter, changes in the flowmeter log (below the bottom of the casing) indicate zones where water is entering or leaving the well bore. Note that the recorded (apparent) water velocity can decrease with an increase in flow when the flowmeter and the water are moving in the same direction. Zones where the gamma-gamma log shifts to the left indicate areas of decreased density, and thus may indicate the location of aquifers or vesicular zones or both. Changes in the resistivity log may indicate where broken or vesicular basalt and potential water-bearing zones occur.

DESCRIPTION OF THE WELLS AND HYDROLOGIC TEST DATA

Burbank Creek Test Well

The Burbank Creek test well (15/19-22L1) was drilled in the Yakima River Canyon area of central Washington. The well site is 14 miles north of Yakima and 17 miles south of Ellensburg. The land-surface altitude at the well head is about 1,390 feet above sea level in an area of locally high relief; the altitude of the Yakima River, about 3,000 feet west of the well site, is 1,245 feet. Burbank Creek, a small, perennial, spring-fed stream, flows nearby. This drilling site was selected because many geologic structures in the area suggested the possibility of an appreciable artesian flow (see fig. 2). Such a flow could supplement the Yakima River during periods of low flow in the irrigation season.

The well was drilled between October 18 and October 28, 1977, to a depth of 602 feet, penetrating the first of numerous flows of Wanapum Basalt at about 190 feet below land surface, the Vantage Member of the Ellensburg Formation at 492 feet, and the Grande Ronde Basalt at 557 feet (see table 2). The well is cased with 12-inch casing to a depth of 50 feet and 8-inch casing to a depth of about 200 feet (fig. 3). Both casings were grouted in the well bore with concrete before drilling below 200 feet. The potentiometric surfaces (water levels) in the several aquifers penetrated between 200 and 602 feet were above land surface. The estimated flow and measured temperature of the water discharging from the well at various well depths were as follows.

Date	Time	Well depth (ft)	Estimated flow (gal/min)	Water temperature (°C)
10-20-77	2:55 p.m.	200	[a]20	—
	3:20 p.m.	200	[a]70	—
	5:20 p.m.	200	[a]100	21.6
10-21-77	9:30 a.m.	[b]200	[a]130	21.8
	5:10 p.m.	[b]200	[a]200	22.4
10-24-77	8:00 a.m.	[b]200	[a]200	—
	4:40 p.m.	[b]296	[c]500	22.8
10-25-77	9:30 a.m.	[b]296	[a]1,500	23.0
10-27-77	8:00 a.m.	[b]375	[c]500	22.8
10-28-77	8:00 a.m.	[b]500	[c]600	22.8
	5:30 p.m.	[b]602	[c]600	22.8
11-01-77	4:00 p.m.	[b]602	[a]1,600+	22.8

[a]Drilling tools (bit and rods) were removed from the borehole.
[b]Well cased to about 200 ft.
[c]Drilling tools in borehole causing restricted flow of well.

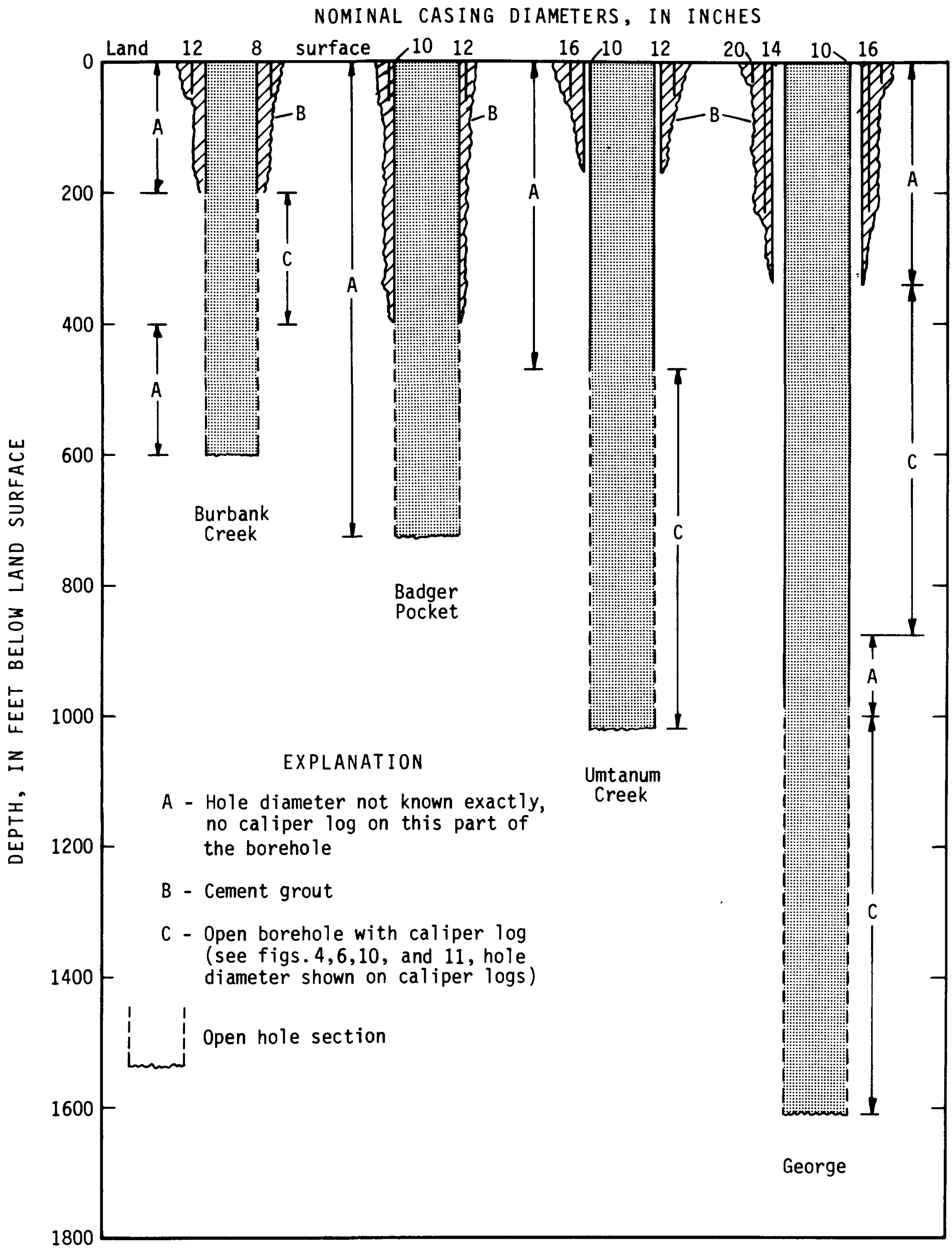


FIGURE 3.--Diagrammatic sketch of well construction for four test wells.

At the completion of drilling operations the top of the 8-inch casing was fitted with a measuring port and an 8-inch gate valve to control the flow. The shut-in pressure was monitored periodically for 10 months, and in August 1978 an automatic recording device was installed to continuously record the pressure at the well. Pressures measured (and calculated water level) for the first year after completion were as follows.

Date	Pressure (pounds per square inch)	Calculated water level (feet above land surface)
11-03-77	16.1	39
11-18-77	25.1	60
2-27-78	32.6	77
4-24-78	34.0	81
7-11-78	35.2	83
8-15-78[a]	33.0	78
10-28-78	30.2	72

[a]Flow testing of the well was done August 15-23, 1978.

Geophysical logging of the Burbank Creek test well was completed on February 27, 1978. However, due to the blockage in the well at about 425 feet, logging was limited to the upper 400 feet. A suite of 10 geophysical logs of this well was made (fig. 4).

On the basis of the geophysical logs and information obtained during drilling, the principal aquifers were identified and are described as follows.

Depth (feet (below land surface)	Material
	Wanapum Basalt
190-200	Basalt, broken, black.
256-261	Basalt, broken, black.
294-308	Basalt, broken, and coarse, well-rounded sand and gravel.
324-333	Basalt, broken, vesicular.
375-406	Basalt, vesicular, black and brown.

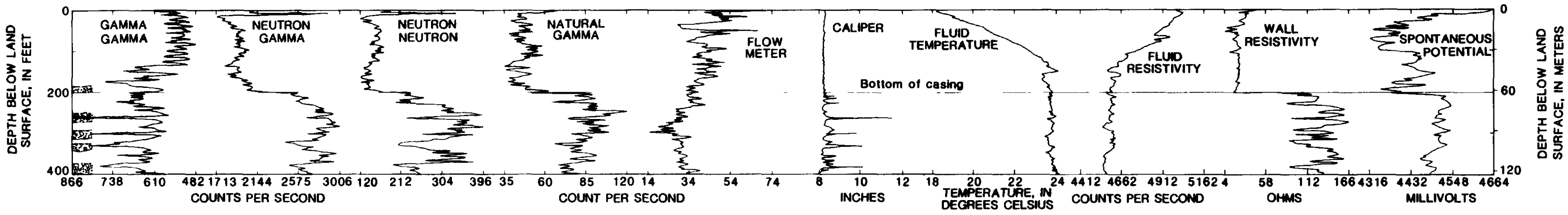


FIGURE 4.--Borehole geophysical logs of the Burbank Creek test well.

Flow testing of the Burbank Creek test well was conducted from August 15 to 23, 1978. The well head was fitted with a saddle-type meter to measure the rate of flow from the well, and a pipe was installed to direct the flowing water away from the well to nearby Burbank Creek. The artesian pressure was measured with a pressure transducer and associated recorder at a point immediately in front of a permanently mounted 8-inch gate valve used to control the rate of flow. A standard pressure gage and a mercury manometer were used to assure accurate calibration of the pressure transducer. Artesian head, flow rates, and water temperatures were measured during the tests (table 3), and a water sample was collected and analyzed (table 1). A graphical representation of the water-level data collected during testing is shown in figure 5.

The first test (test 1) was started at 10:47 a.m. on August 15, 1978. A rate of flow of 1,000 gal/min was maintained for about 69.5 hours. The specific capacity calculated for the first 24 hours of the test was 32.5 gal/min per foot of drawdown. This constant rate was maintained by progressively opening the gate valve as the test advanced. At 69.5 hours into the test, the gate valve was about 70 percent open to maintain 1,000 gal/min. The gate valve was then fully opened to allow the well to flow at a higher rate. The flow rate increased to about 2,600 gal/min immediately after the gate valve was opened. The rate of flow decreased to about 2,500 gal/min at 70.5 hours, when the gate valve was closed.

The second flow test (test 2) was started at 1:15 p.m. on August 21, 1978. The rate of flow was adjusted almost immediately to about 2,000 gal/min, and was maintained there for about 4.3 hours. (To maintain this flow the gate valve had to be opened slightly about every 5 minutes.) The rate of flow was then reduced to about 1,750 gal/min, and maintained with frequent adjustments for about 6 hours. At that time, the well was allowed to flow with no additional adjustments for about 6 hours. During that period the rate of flow decreased from 1,750 to 1,550 gal/min. To increase the flow to 1,700 gal/min the gate valve was opened a significant amount. The flow was maintained with adjustments at about 1,700 gal/min for 14.5 hours. By this time the gate valve was nearly all the way open to maintain the flow, as indicated by the measured head of only 3.8 feet. The gate valve was fully opened at 32 hours into the test, and the flow increased to about 1,850 gal/min. When the gate valve was closed at the completion of the test (44 hours of discharge) the discharge had decreased to 1,700 gal/min.

The recovery from test 2 was monitored manually for about 1 hour by recording the shut-in pressure at intervals ranging from 0.5 to 10 minutes. After this time the automatic pressure recorder was used.[1]

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[1] The pressure is now recorded at intervals ranging from 15 to 60 minutes. The U. S. Geological Survey plans to maintain this recorder for at least several years. This installation will provide data on any water-level changes that may occur because of development of ground-water supplies for irrigation and domestic use in nearby areas.

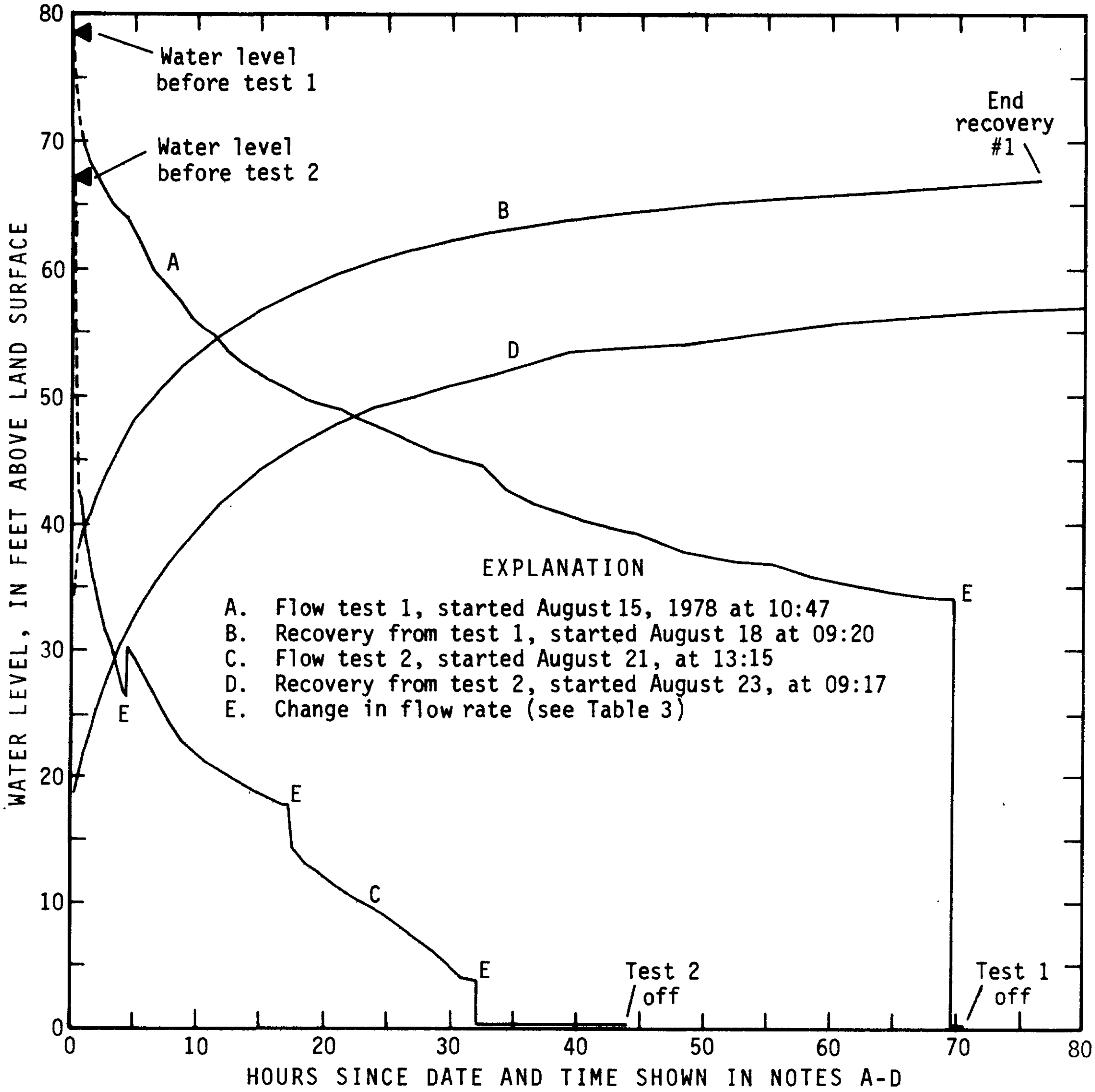

FIGURE 5.--Water-level fluctuations during flow test of the Burbank Creek test well.

The data collected during and after the two flow tests were analyzed to determine the transmissivity (T) of the aquifers tapped by the well. Three methods of analysis were used: (1) a modified nonequilibrium formula (after C. E. Jacob), (Ferris and others, 1962, p. 98-100); (2) the Theis recovery formula (Ferris and others, 1962, p. 100-102); and (3) a single-boundary solution (Stallman, 1963). The transmissivities are tabulated below.

Method of analysis	Part of flow test used for analysis	Transmissivity (ft^2/day)
Modified nonequilibrium formula	Flow test 1	1,300
	Flow test 2	2,700
Theis recovery formula	Recovery from flow test 1	2,000
	Recovery from flow test 2	2,600
Single boundary solution	Flow test 1	2,600

These T values are supported by other studies conducted in surrounding areas. Luzier and Burt (1974) calculated that the basalt and associated interflow zones in east-central Washington had T's ranging from about 1,600 to 4,000 ft^2/day and averaging 3,200 ft^2/day. Tanaka and others (1974) calculated values of T in the Yakima Basalt Subgroup ranging from about 500 to 7,400 ft^2/day, with an average value of 2,600 ft^2/day. Thus, based on the calculated T, the Burbank Creek well appears to be about average for wells tapping the Yakima basalt. However, during the analysis of the data it was noted that boundary conditions within the aquifers may exist.

The boundary effect that was detected in the flow-test data indicates that there may be a discontinuity of aquifer transmissivity in one or more of the aquifers tapped by the well. This discontinuity appears to be an area of significantly lower transmissivity. The distance, direction, and extent of the low transmissivity area cannot be calculated from the data presently available. The area of low transmissivity could have a significant effect on the long-term yield of water from this or any nearby well.

Badger Pocket Test Well

The Badger Pocket test well (17/20-29R1) was drilled about 10 miles southeast of Ellensburg. The land-surface altitude at the well head is about 1,830 feet above sea level. This is an area of low relief, where intensive agricultural development has taken place. Most of the nearby land is irrigated, primarily by water diverted from the Yakima River or its tributaries.

The well was drilled between November 3 and November 17, 1977, to a depth of 725 feet. The entire well is apparently in the Ellensburg Formation, which consists of unconsolidated to partially consolidated deposits of clay, silt, sand, and gravel (table 2). The well has 12-inch casing from the surface to 62 feet, 10-inch casing to 400 feet, and is uncased from 400 to 725 feet. The casing is grouted in the well bore (fig. 3).

During drilling operations, the first water was found at a depth of about 80 feet in the unconsolidated deposits. Changes in water level with depth of the well are shown below.

Depth of well bore	Depth of casing	Depth to water
(All in feet below land surface)		
80	62	about 80
400	62	58
580	400	66
725	400	71

The Badger Pocket well did not penetrate basalt and was not geophysically logged nor test pumped, because the primary interest in drilling the well was to obtain information about the basalt aquifers. Some observations made during drilling were that (1) almost all the materials deeper than 80 feet below land surface were saturated with ground water, and (2) large amounts of water (more than 500 gal/min) were discharged from the borehole during the drilling operations. The borehole below the bottom of the casing collapsed when the drilling tools were removed at the completion of drilling operations.

Umtanum Creek Test Well

The Umtanum Creek test well (16/19-28C1) was drilled between November 18, 1977, and February 10, 1978, in the Yakima River Canyon, 6 miles north of the Burbank Creek well and 11 miles south of Ellensburg. The land-surface altitude at the well head is 1,425 feet above sea level, and the Yakima River, 1,100 feet to the west, is about 1,310 feet. The area has locally high relief.

The 1,019-foot well penetrates layers of the Grande Ronde Basalt (Diery, 1967) and associated interflow zones below a depth of 50 feet (table 2). The well is cased as follows: 16-inch to 54 feet, 12-inch to 169 feet, and 10-inch to 474 feet. The 16- and 12-inch casings were grouted into place (fig. 3). Well 28C1, as finished, is open to the rock formation from 474 feet to 1,019 feet. The annular space between the 12- and 10-inch casings is open and allows measurement of the water level that is representative of the interval from 169 to 474 feet; it is designated well 28C2.

Water-level measurements taken at various depths during the drilling operations in well 28C1 are tabulated below. They show that water levels were higher with depth.

Depth of well bore	Depth of casing	Depth to water
(All in feet below land surface)		
70	54	[a]70
200	54	55 to 60
349	169	33.6
386	169	36.14
476	169	34.23
476	474	34.06
503	474	27.10
508	474	27.49
568	474	26.95
622	474	26.76
652	474	27.5
696	474	26.55
698	474	26.43
761	474	26.5
863	474	25.73
918	474	24.51
1,002	474	24.28
1,019	474	23.25

[a]Water table (?).

A suite of 10 geophysical logs was made for this well on February 8, 1978, for its entire depth of 1,019 feet (fig. 6). On the basis of the geophysical logs and information obtained during drilling, the principal aquifers were identified and are described below.

Depth (feet below land surface)	Material
	Grande Ronde Basalt
220-235	Basalt, broken and(or) vesicular, with some volcanic ash (?) and charcoal (?).
457-466	Volcanic ash (?) and broken basalt.
504-525	Basalt, broken and vesicular.
548-567	Basalt, broken and vesicular.
599-632	Basalt, broken, with palagonite (?).
749-840	Basalt, broken and vesicular.
911-955	Basalt, broken and vesicular.
975-990	Basalt, broken.

The Umtanum Creek test well was pumped at an average rate of 960 gal/min for about 20 hours on March 2-3, 1978, to determine its water-yielding characteristics. The specific capacity of the well was calculated to be 190 gal/min per foot of drawdown at that time. Water levels, pumping rates, and water temperature data were measured (table 4), and a water sample was collected and analyzed (table 1). A graphical representation of the water-level data is shown in figure 7. On the basis of the data collected, this well has a large potential yield. However, the average pumping rate of 960 gal/min did not produce sufficient stress on the aquifers tapped by the well for a determination of their transmissivities. Water levels in well 28C2, the upper, cased off part of the well, were unaffected by the pumping.

Water levels in well 28C1 are about 20 feet higher than in the shallower 28C2 (fig. 8), and show that ground water is moving upward in this area.

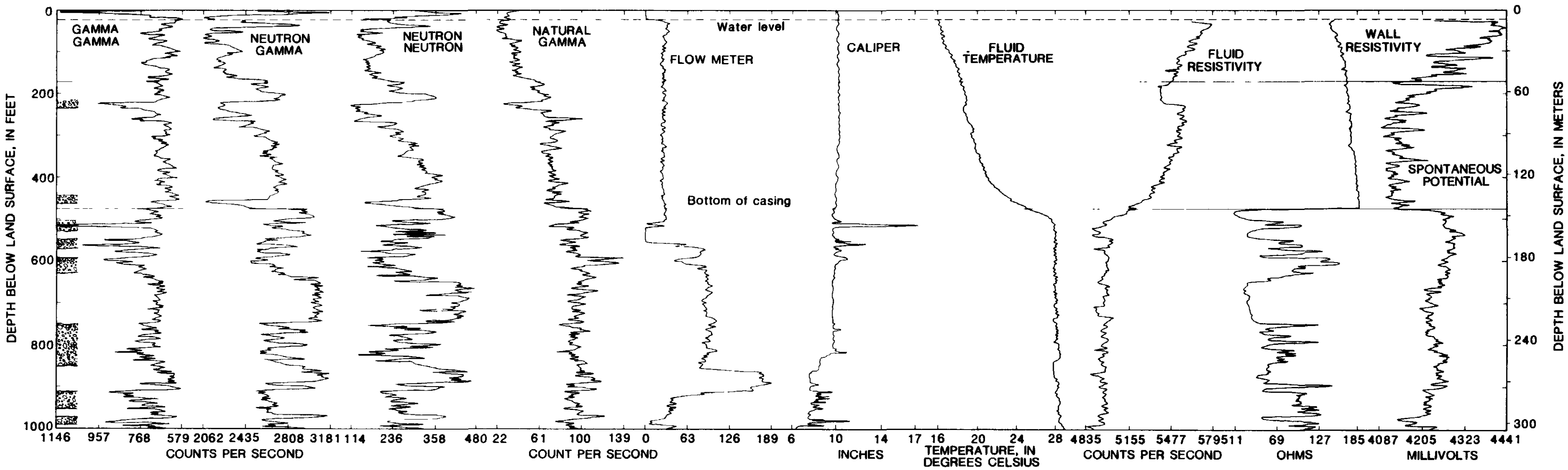

FIGURE 6.--Borehole geophysical logs of the Umtanum Creek test well.

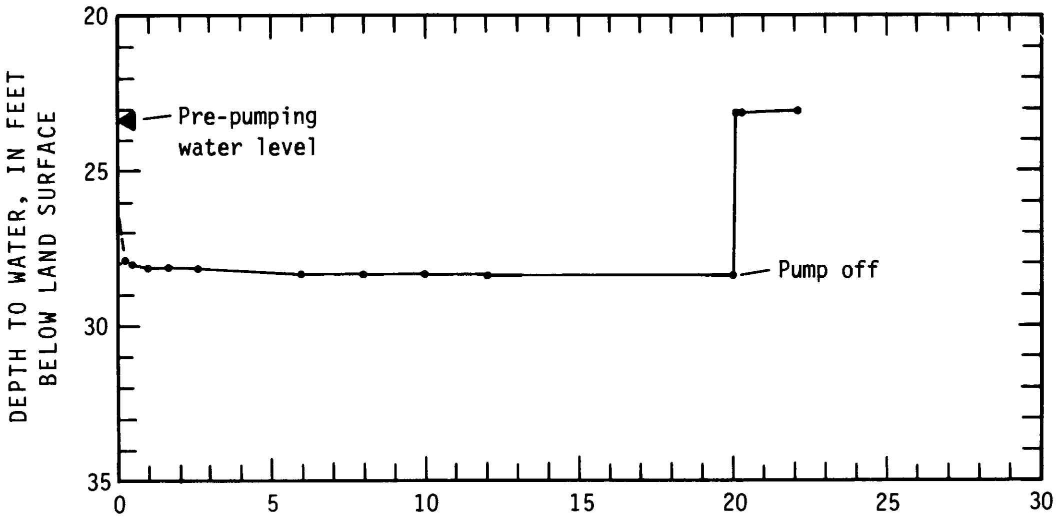

FIGURE 7.--Water-level fluctuations during test pumping of the Umtanum Creek test well.

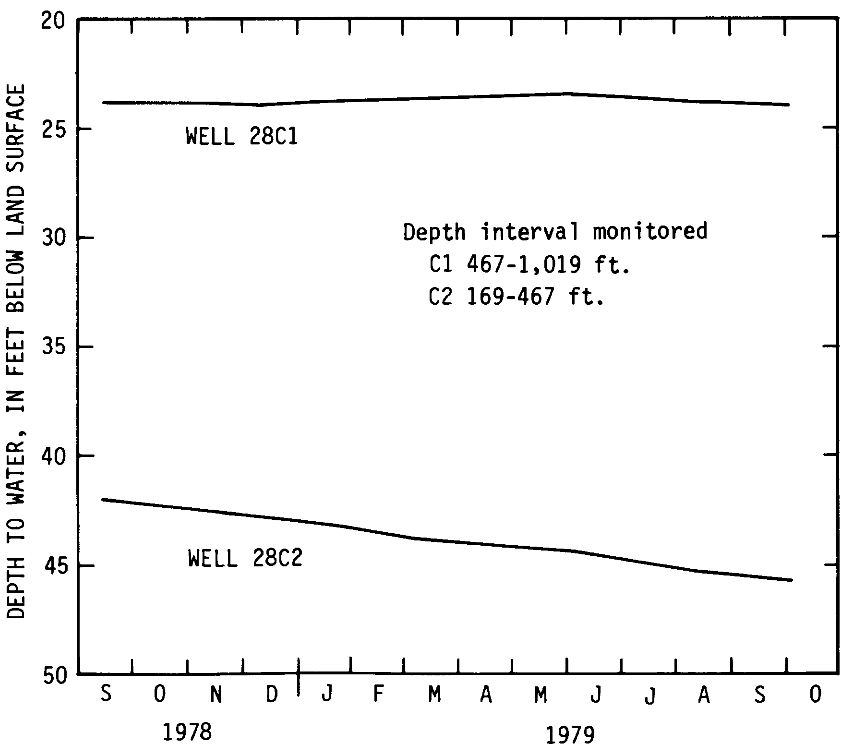

FIGURE 8.--Water-level fluctuations in the Umtanum Creek test well, September 1978-October 1979.

George Test Well

The George test well (18/25-15E1) is located 8 miles southeast of George on relatively flat-lying land that is 1,157 feet above sea level. The surrounding area is undergoing intensive agricultural development, and much of the land is being irrigated with ground water.

The George test well was originally drilled to a depth of 975 feet in May 1975 (Eddy, 1976). At that time, the well was cased as follows (all casing was grouted): 20-inch casing to 30 feet, 16-inch to 228 feet, and 14-inch to 343 feet. Below 343 feet, the well was left uncased. The uncased part of the well was open to the water-bearing zones in the Wanapum Basalt and penetrated into the Vantage Member of the Ellensburg Formation (Eddy, 1976). Water levels, representative of the aquifers open to the uncased part of the well, were measured in the well for 2-1/2 years (fig. 9) before the well was deepened.

The well was deepened in January 1978 to tap aquifers in the Grande Ronde Basalt below the Vantage Member (table 2). Because the Vantage Member was caving, the well was cleaned out, deepened to 986 feet, and cased with 10-inch casing to that depth. The well was then further deepened to 1,610 feet (see fig. 3 for a diagrammatic sketch of the well construction).

Large water-level changes occurred during drilling below 975 feet. At a well depth of 975 feet, the water level in the well was about 80 feet below land surface. At a well depth of 1,157 feet, the water level was 395 feet below land surface, and at a completed depth of 1,610 feet (on February 17, 1978) the water level was 384.0 feet below land surface. A drop in water levels in wells that penetrate into deeper aquifers is generally typical of conditions in the basalt aquifers in much of east-central Washington, where ground water is moving downward from shallow zones to deeper zones.

Nine geophysical logs were made for the George test well on June 6, 1975, to a depth of 887 feet; caving blocked any deeper logging of the 975-foot well. The logs (fig. 10) show the casing to 343 feet and some characteristics of the hole, surrounding rock and water before additional casing was installed to 986 feet and the well was deepened. The deepened well was geophysically logged on March 1 and March 7, 1978. Nine logs, all to a depth of 1,601 feet, are shown in figure 11. The well bore was also inspected by a down-hole video camera to a depth of 1,600 feet.

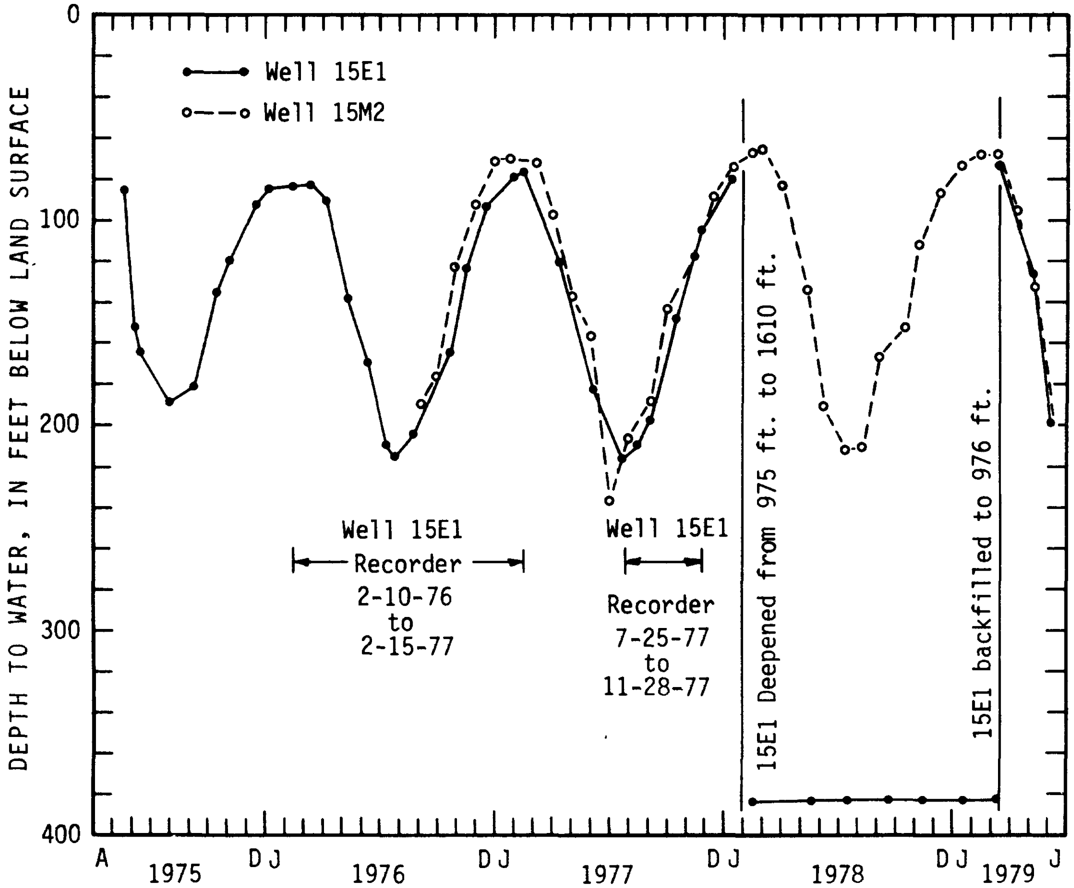

FIGURE 9.--Water-level fluctuations in the George test well and well 18/25-15M2, 1975-79.

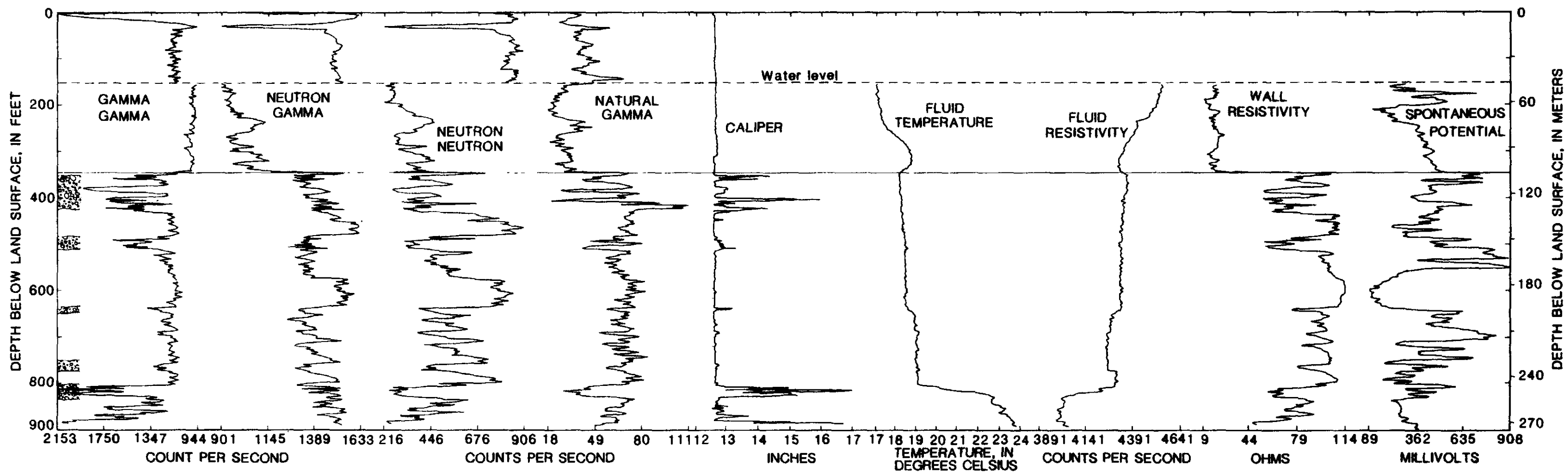

FIGURE 10.--Borehole geophysical logs of the George test well, 975 feet deep.

On the basis of the geophysical logs, video tape, and data collected during all drilling operations, the principal aquifers were identified and shown in figures 10, 11, and 13. A description of the aquifers is given below.

Depth (feet below land surface)	Material
	Wanapum Basalt
350-425	Basalt, vesicular, red and black, with clay and opal.
485-505	Basalt, vesicular.
635-645	Basalt.
752-772	Basalt.
802-830	Basalt (broken), vesicular.
Vantage Member of the Ellensburg Formation	
880-900	Clay, basalt, and pillow basalt.
	Grande Ronde Basalt
1,085-1,120	Basalt, broken.
1,150-1,190	Basalt, broken (vesicular?).
1,320-1,350	Basalt (slightly broken?).
1,380-1,445	Basalt, vesicular.
1,530-1,560	Basalt (slightly broken?).

A pumping test of the 1,610-foot George well was made on February 16-17, 1978, and a water sample was collected and analyzed (table 1). The well was pumped for about 23.5 hours at an average rate of 1,150 gal/min, but pumping rates ranged from a few hundred to more than 1,700 gal/min (table 5). Because water levels measured during the test (table 5 and fig. 12) were not accurate enough (due to technical difficulties) to use in an analysis of the data, aquifer transmissivity was not determined.

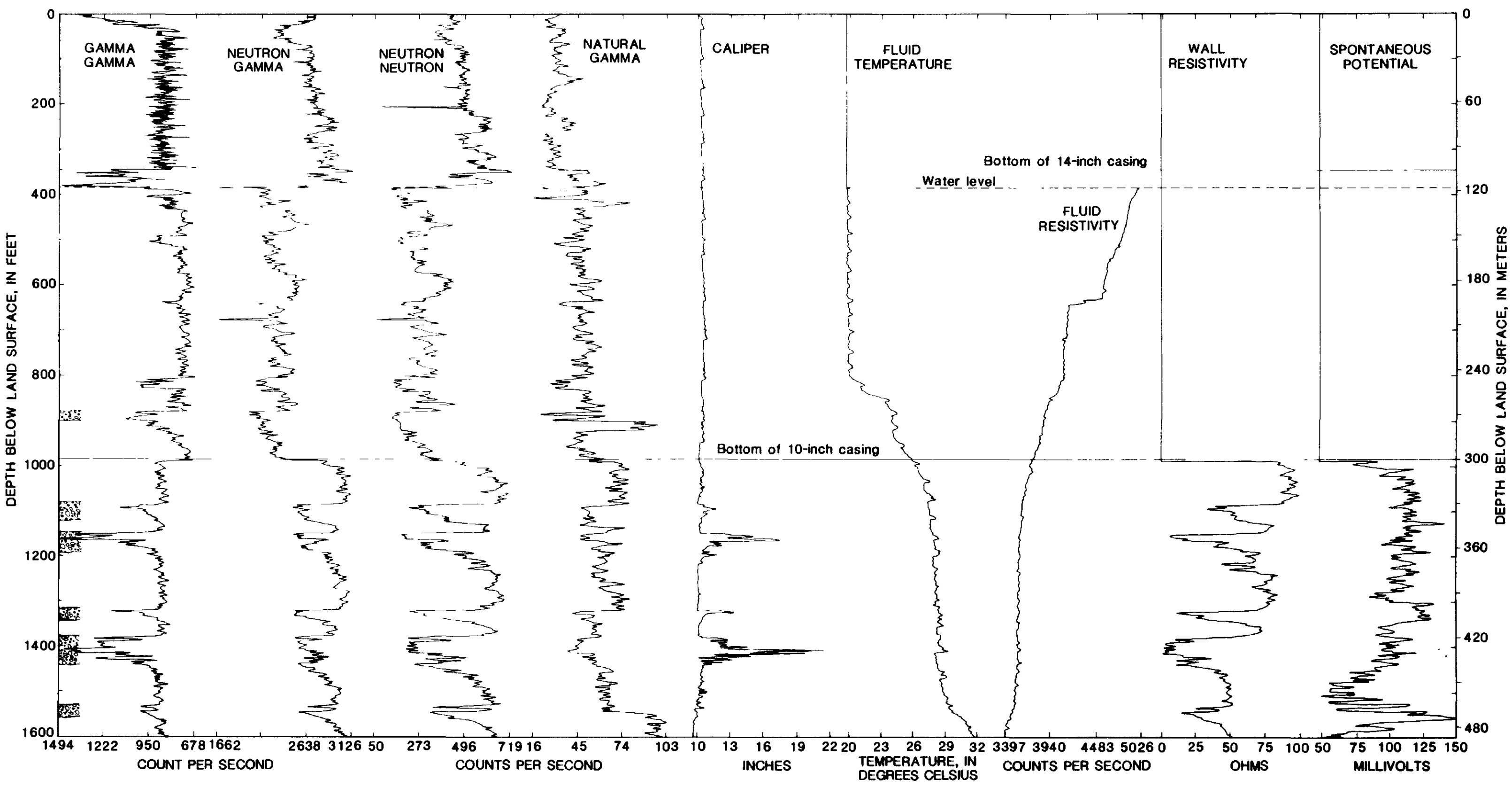

FIGURE 11.--Borehole geophysical logs of the George test well, 1,610 feet deep.

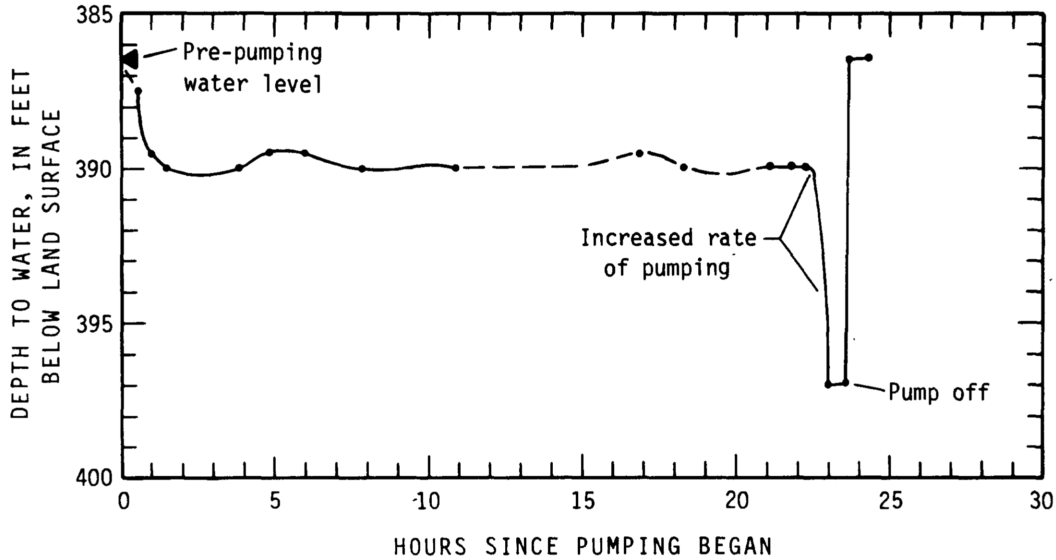

FIGURE 12.--Water-level fluctuations during test pumping of the George test well.

The specific capacity of the well as calculated from the test data was about 190 gal/min per foot of drawdown at a discharge of 1,150 gal/min, and 160 gal/min per foot of drawdown at a discharge of 1,700 gal/min. The lower specific capacity value at a higher discharge was probably caused by a reduction in the efficiency of the well due to turbulence and other factors, and possibly because of an undefined hydrologic boundary in the area. The specific capacity of the original 975-foot well tapping only Wanapum Basalt was about 113 gal/min per foot of drawdown after 24 hours of pumping at a discharge of about 2,200 gal/min (Eddy, 1976). Although the specific capacity of the Grande Ronde Basalt is larger than that of the Wanapum Basalt, depths to water are much greater for wells tapping the former.

In March 1979, the 10-inch casing was perforated in a number of places opposite the water-bearing zones in the Wanapum Basalt between 350 and 900 feet (fig. 13 and table 6). The perforations allowed water in that interval to enter the well and flow downward and into the deeper water-bearing zones in the Grande Ronde Basalt. Perforating the casing did not affect the water level, indicating that the deep zones are very permeable.

Three piezometers were installed in the uncased lower part of the well (Grande Ronde Basalt), and the well was backfilled with pea gravel and cement plugs to isolate the deep water-bearing zones (fig. 13). Data from the three piezometers, which are 1-1/4 inches in diameter and have 5-foot-long, 0.060-inch slot screens, are as follows.

Piezometer identification number	Screened interval	Backfilled gravel interval between cement plugs	Aquifer
	(All in feet below land surface)		
18/25-15E6	1,163-1,168	1,145-1,225	1,150-1,190
18/25-15E7	1,406-1,411	1,379-1,463	1,380-1,445
18/25-15E8	1,541-1,546	1,520-1,610	1,530-1,560

Depths to water in all three piezometers were about 383 feet, the same as the water level in the well (15E1) before backfilling (fig. 14).

The depth of well 15E1 after backfilling was 976 feet, or basically the same depth as before the well was deepened in January 1978. As the successive water-bearing zones were blocked off, the water level in the well rose (fig. 15). With the completion of backfilling, the water level had risen to the level it had been at prior to deepening of the well (fig. 9).

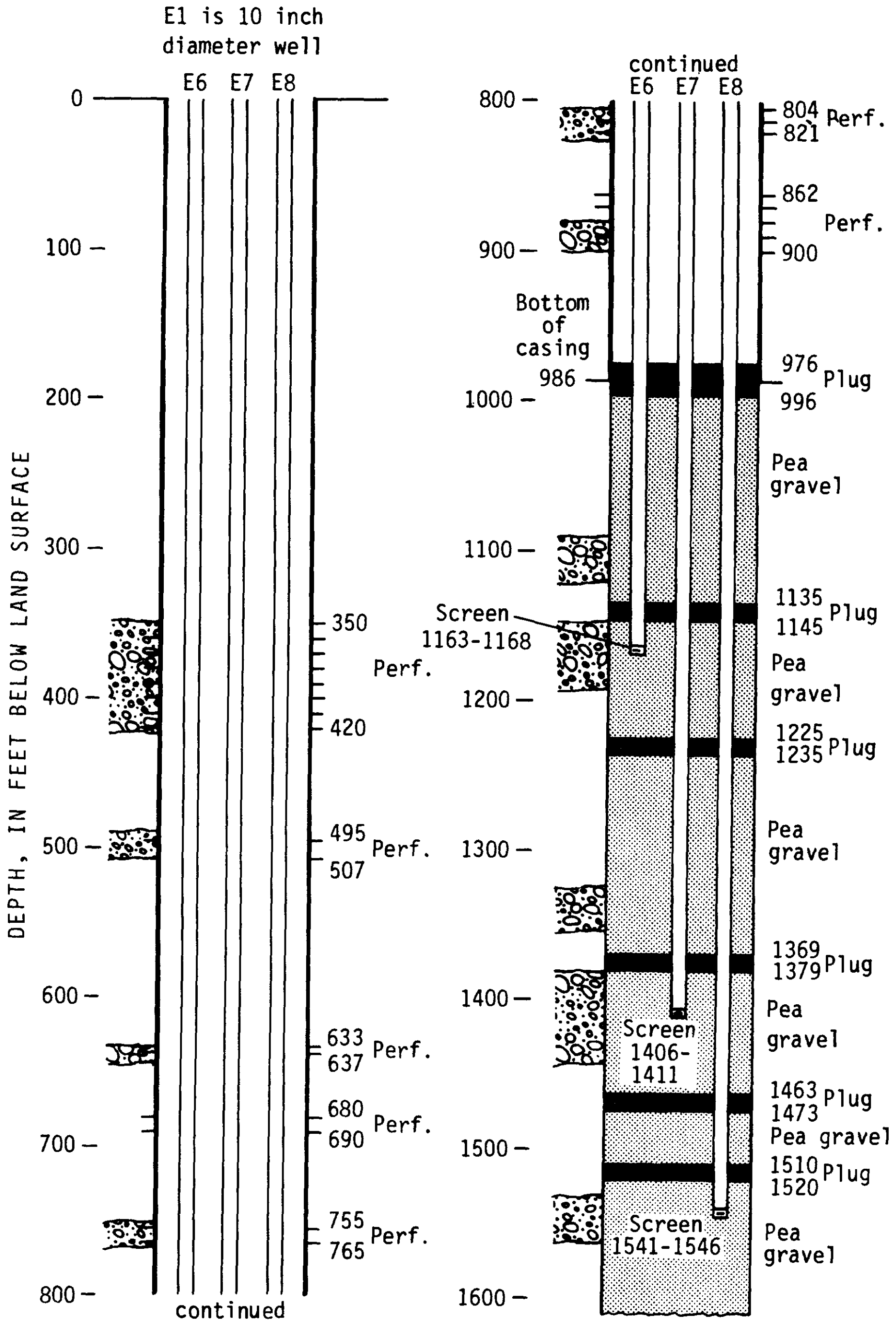

FIGURE 13.--Construction of the George test well, E1, including piezometers E6, E7, and E8.

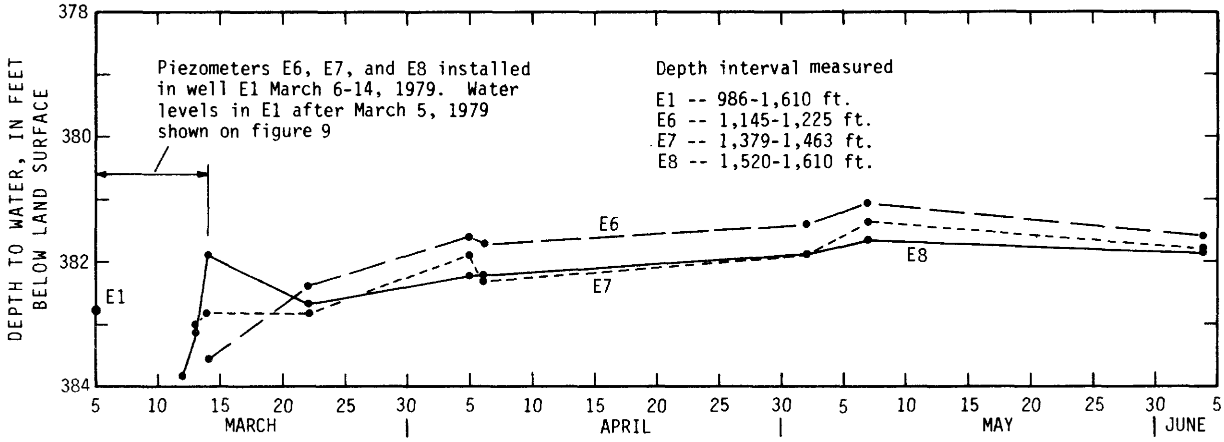

FIGURE 14.--Water levels in piezometers in the George test well, E1, March-June 1979.

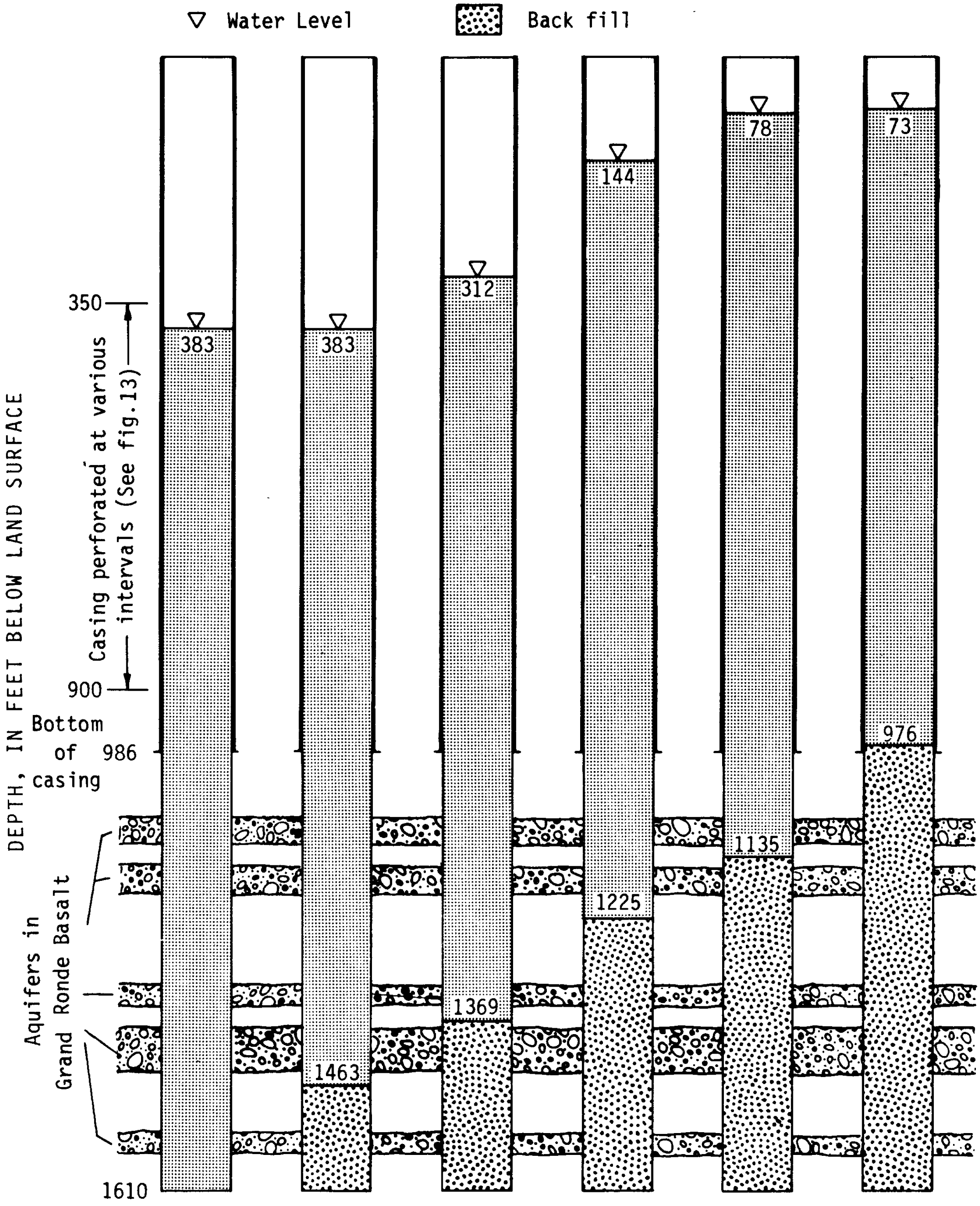

FIGURE 15.--Water levels in the George test well as it was backfilled, March 8-14, 1979.

Water levels in aquifers in the Grande Ronde Basalt below the Vantage Member of the Ellensburg Formation are completely different from those in the basalt aquifers in the overlying Wanapum Basalt. Water levels in the Wanapum Basalt are represented in figure 9 by the water levels in well 15M2 and in well 15E1 from May 1975 to January 1978 (before deepening) and after March 1979. Water levels in the Grande Ronde Basalt (below the Vantage Member) are shown by the water levels in well 15E1 from January 1978 to March 1979 (fig. 9) and in piezometers 15E6, E7, and E8 since March 1979 (fig. 13). The difference in water levels in the two units during winter is more than 300 feet (fig. 9).

Fluctuations of the water levels in the two units are also markedly different. Although the water level in the Wanapum Basalt drops to more than 200 feet below land surface in the summer (a seasonal change of more than 100 feet), the water level in the Grande Ronde Basalt remains nearly constant. The large water-level fluctuations in the Wanapum Basalt are caused by pumping from several irrigation wells in the area that tap it.

The unconsolidated deposits and uppermost basalt flows overlying the Wanapum Basalt that are tapped by the test well form a shallow aquifer. Although several irrigation wells in the area tap this uppermost aquifer, the pumping of these wells has little effect on water levels in the Wanapum Basalt, as shown by an earlier pumping test (Eddy, 1976).

In 1979, 11 active irrigation wells tapped the Wanapum Basalt within T.18 N., R.25 E. (fig. 16). No wells in the area tapped the Grande Ronde Basalt at that time. The theoretical drawdown of the water level in the Wanapum Basalt at the George well (15E1) that was caused by the pumping of these wells was calculated for each well and, although not exact, gives an approximation of the drawdown expected (table 7). The drawdown was calculated using a transmissivity value of 21,400 ft^2/day and a storage coefficient of 0.0008, based on a pumping test analysis by H. H. Tanaka, Washington State Department of Ecology (written commun., 1977). (This high transmissivity value, nearly nine times that of the Burbank Creek well, is in part due to the many aquifers that were open to the well during this test.) The length of time of pumping used in the calculation was 100 days (approximate length of local irrigation season). The total calculated drawdown of the water level in well 15E1 from wells tapping the Wanapum Basalt in T.18 N., R.25 E. is about 62 feet (table 7), less than one-half the observed drawdown. This is larger than expected and indicates that wells farther away are probably also affecting the water level in 15E1. Changes in aquifer transmissivity and (or) storage coefficient could also be causing larger drawdowns than were expected.

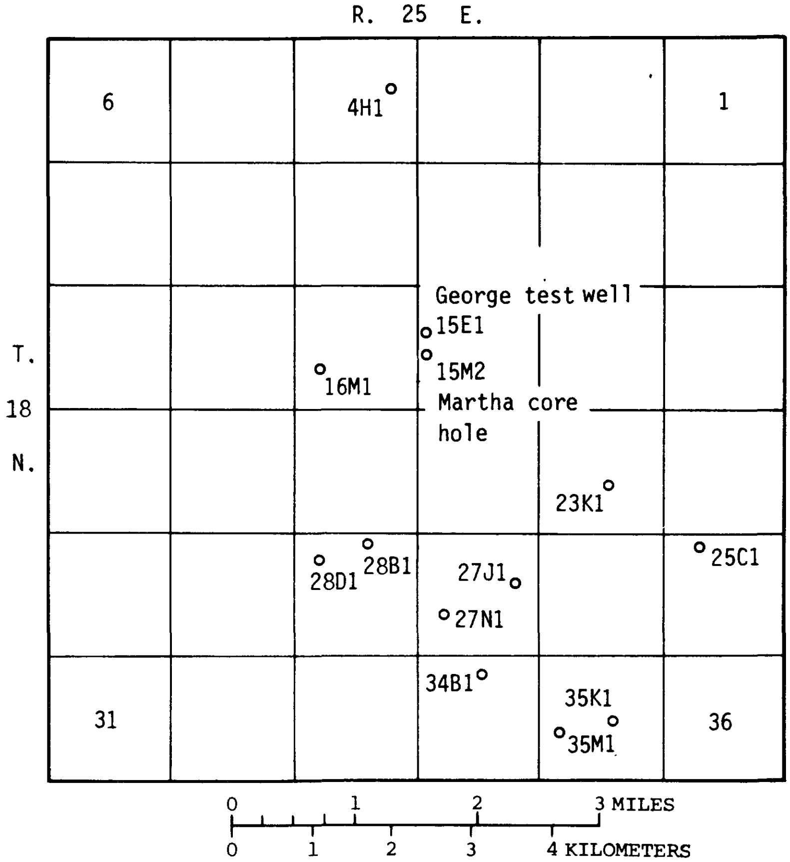

FIGURE 16.--Locations of the George test well, well 18/25-15M2, and irrigation wells tapping the Wanapum Basalt in T. 18 N., R. 25 E.

WATER-LEVEL MEASUREMENTS

The George well is in a good location to measure water levels in the Wanapum Basalt, from which water is pumped for irrigation. The three deep piezometers tapping the Grande Ronde Basalt in the well should indicate whether any significant water-level changes occur in these deep zones due to pumping.

The Badger Pocket well will be temporarily left in its present condition, but in the future it may be extended into the Yakima Basalt Subgroup. It would then provide water-level and water-yield information for the presently little-used basalt aquifers in that area.

Water levels in the Umtanum Creek well are currently being measured bimonthly. The water level that is representative of the aquifers between 474 and 1,019 feet (the open-hole portion of the well) is measured inside the 10-inch casing. The water level for the aquifers open to the annular space between the 12- and 10-inch casings (about 169 to 474 feet below land surface) is measured through a hole at the top of the well that is open to the annular space. There are no plans to install piezometers in this well.

The Burbank Creek well is equipped with a pressure recorder that now (1982) provides a record of shut-in pressure at discrete (15-minute to 1-hour) intervals. Ground-water development has begun in the area near the well. The information from the well will become more significant as more irrigation and domestic wells penetrate into the same aquifers.

SELECTED REFERENCES

Bingham, J. W. and Grolier, M. D., 1966, The Yakima Basalt and Ellensburg Formation of south-central Washington: U. S. Geological Survey Bulletin 1224-G, 15 p.

Diery, H. D., 1967, Stratigraphy and structure of Yakima Canyon between Rosa Gap and Kittitas Valley, central Washington: Seattle, Wash., University of Washington, Ph.D. thesis, 117 p.

Eddy, P. A., 1976, Description, preliminary results, and pumping tests of test-observation well 13 near George, Washington: State of Washington Department of Ecology, Water Resources Information System Technical Bulletin 19, 43 p.

Ferris, J. G., Knowles, D. B., Brown, R. H., and Stallman, R. W., 1962, Theory of aquifer tests: U. S. Geological Survey Water-Supply Paper 1536-E, 105 p.

Grolier, M. J., and Bingham, J. W., 1971, Geologic map and sections of parts of Grant, Adams, and Franklin Counties, Wash.: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-589, 6 plates.

-----1978, Geology of parts of Grant, Adams, and Franklin Counties, east-central Washington: Washington Department of Natural Resources Bulletin 71, 91 p.

Keys, W. S., and MacCary, L. M., 1971, Application of borehole geophysics to water-resources investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 2, Chap. E1, 126 p.

Luzier, J. E., and Burt, R. J., 1974, Hydrology of basalt aquifers and depletion of ground water in east-central Washington: Washington Department of Ecology Water-Supply Bulletin 33, 53 p.

Mackin, J. H., 1961, A stratigraphic section in the Yakima Basalt and the Ellensburg Formation in south-central Washington: Washington Division of Mines and Geology, Report of Investigations 19, 45 p.

Newcomb, R. C., 1970, Tectonic structure of the main part of the basalt of the Columbia River Group, Washington, Oregon, and Idaho: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-587, 1 sheet.

Stallman, R.W., 1963, Type curves for the solution of single boundary problems, <u>in</u> Bentall, Ray (compiler), Shortcuts and special problems in aquifer tests: U. S. Geological Survey Water-Supply Paper 1545-C, p. C45-C47.

Swanson, D. A., Wright, T. L., Hooper, P. R., and Bentley, R. D., 1979, Revisions to stratigraphic nomenclature of the Columbia River Basalt Group: U.S. Geological Survey Bulletin 1457-G, 59 p., 1 plate.

Tanaka, H. H., Hansen, A. J., and Skrivan, J.A., 1974, Digital-model study of ground-water hydrology, Columbia Basin Irrigation Project area, Washington: Washington Department of Ecology Water-Supply Bulletin 40, 60 p.

U.S. Department of Commerce, U.S. Weather Bureau, 1965, Climatological data, Washington: v. 69, no. 6.

U. S. National Oceanic and Atmospheric Administration (formerly U.S. Weather Bureau), 1978, Climatological data, Washington, annual summary 1977: V. 81, No. 13, 17 p.

Van Denburgh, A. S., and Santos, J. F., 1965, Ground water in Washington, its chemical and physical quality: Washington Department of Conservation, Water-Supply Bulletin 24, 93 p.

TABLE 2.-- Geologic logs of four test wells

Material	Thick-ness (feet)	Depth to bottom (feet)
Burbank Creek Well		
Soil zone	3	3
Basalt, broken and weathered, brown and black, some sand and gravel (subangular to subrounded) with silt and (or) clay	77	80
Sand, and gravel, subangular black basalt pebbles and cobbles, some vesicular, water-bearing	58	138
Clay, silt and (or) ash, brown, white, green, blue, blue green, laminations (1-2 mm thick) of differing colors	30	168
Basalt, broken, black, angular and subangular	3	171
Sand and gravel, fine to medium, gravels 2-6 cm, partially cemented	1	172
Basalt, vesicular, black with some gray and green clays	3	175
Basalt, broken, vesicular, greenish-black	4	179
Clay and (or) ash, gray-white, laminations 1-2 mm thick	10	189
Basalt, broken, black, with some blue-green clays	1	190
Basalt, broken (hackly ?) black, water-bearing, artesian head, well flowing 150-200 gal/min	10	200
Basalt, hard, black	56	256
Basalt, broken, black, with blue-green quartz and iron pyrite (?) as vein-filling material, water-bearing, artesian head	5	261
(Water-bearing zones not easily distinguishable below this point.)		
Basalt, hard, black	33	294
Basalt, broken, (hackly ?), black (free flow of well 1200-1600 gal/min at 296 foot depth)	3	297
Gravel and sand, coarse, well rounded pea size and subrounded coarse sand, well washed, poorly sorted, 30 to 50 percent light-colored minerals	1	298
Basalt, broken, black	9	307
Gravel and sand, thin layer (?), well rounded, fair sorting	.5	307.5
Basalt, hard, black	16.5	324
Basalt, broken, vesicular, black	2	326
Basalt, hard, black	58	384
Basalt, vesicular, black-brown	20	404
Basalt, broken (vesicular ?), black	2	406
Basalt, hard, black	7	413
Basalt, broken, black and brown, iron pyrite and and quartz (?) as vein-filling material	5	418
Basalt, broken (hackly ?), slightly vesicular(?), black	7	425
Basalt, slightly broken, vesicular at top, black	51	476
Basalt, broken (hackly ?), slightly vesicular, black, iron pyrite as vein-filling material	16	492
Ash (or siltstone ?), fine-grained, green	6	498
Basalt, vesicular, black and brown	6	504
Sandstone and (or) ash, fine-grained, green, light gray, with green clay, some pieces of brown vesicular basalt (?)	44	548
Carbonized wood (?), black-brown, possibly tree stump	8	556
Clay, brown, gray	1	557
Basalt, broken, brown	6	563
Basalt, vesicular, brown	1	564
Basalt, hard, black	38	602

TABLE 2.-- Geologic logs of four test wells--continued

Material	Thickness (feet)	Depth to bottom (feet)
Badger Pocket Well		
Topsoil	3	3
Sand, medium, tan, with clay and basaltic gravel	25	28
Sand, medium, brown, and some silt and basaltic gravel	53	81
Gravel, basaltic, and sand	11	92
Sand, medium, brown	9	101
Gravel, basaltic, rounded and weathered	84	185
Gravel, basaltic, and brown coarse sand	25	210
Gravel, basaltic, with some pebbles of brown siltstone and clay	205	415
Sand, medium, brown, silt, and basaltic gravel	100	515
Sand, medium, brown, with white grains of soapstone, and basaltic gravel	7	522
Silt, brown, and sand	33	555
Sand, medium, tan, with arkosic pebble fragments	40	595
Silt, semi-hard, brown	26	621
Sand, brown, and silt with basaltic gravel	104	725
Umtanum Creek Well		
Sand, gravel, boulders, clay and silt, river deposits and possibly landslide material	50	50
Basalt, broken, black (large boulders with some sand and gravel between them?)	20	70
Basalt, hard, black	35	105
Basalt, broken, black, with light colored vein filling material	20	125
Basalt, hard, black	95	220
*Basalt, broken, black, some vesicular basalt, some subrounded black basalt gravels, some light gray volcanic ash (?)	9	229
*Carbonized wood, black	2	231
*Basalt, broken, black	4	235
Basalt, slightly broken, black	25	260
Ash (?), brown to gray	1	267
Basalt, broken, black	20	287
Basalt, hard, black	164	451
Basalt, broken, black	4	455
Basalt, hard, black	2	457
*Ash(or clay), brownish-gray	4	461
Basalt (or volcanic glass?), aphanitic, (vitreous luster), blue-green	1	462
*Basalt, broken, black to brownish-black	4	466
Basalt, hard, black	38	504
*Basalt, broken, black, some sand and subrounded black basaltic pebbles	5	509
Basalt, broken, black to dark brown, some light-colored vein-filling material	2	511
Basalt, hard, black to dark brown	2	513
*Basalt, broken, highly vesicular, black to reddish-brown (scoria?)	12	525

(continued)

TABLE 2.-- Geologic logs of four test wells--continued

Material	Thick-ness (feet)	Depth to bottom (feet)
Umtanum Creek Well--continued		
Basalt, vesicular, reddish-brown to black	23	548
*Basalt, highly vesicular, broken, brown to black	19	567
Basalt, broken, slightly vesicular black to reddish brown	10	577
Clay (or ash?), brown, and black sand	1	578
Basalt, broken, slightly vesicular, black	7	585
Basalt, broken, black	2	587
Basalt, hard, black, some light-colored vein-filling materials	5	592
Ash (?), yellowish-white to light brown	7	599
*Basalt, broken, black, some lighter-colored material (palagonite ?)	33	632
Basalt, broken, black, some thin layers (6-12 inches) of slightly (?) vesicular basalt	16	648
Basalt, hard, black	101	749
Basalt, broken, black	14	763
Basalt, broken, vesicular, black	10	773
Basalt, hard, dark gray	5	778
*Basalt, broken, vesicular, black to reddish-brown	76	854
Basalt, hard, black	9	863
Basalt, broken, black	8	871
Basalt, hard, black to dark gray	11	882
Basalt, slightly-broken, dark green-black, some green vein-filling material	5	887
Basalt, hard, dark gray	7	894
*Basalt, broken, black, vesicular in places	9	903
Basalt, hard, black	8	911
*Basalt, very broken, vesicular, black to reddish-brown	6	917
*Basalt, moderately broken, black	7	924
*Basalt, broken, vesicular, black, with some blue-green vein-filling material	18	942
Basalt, broken, black, vesicular in places	27	969
Basalt, moderately hard, black	2	971
Basalt, hard, black	4	975
Basalt, broken, black, vesicular in places, some flint (?) nodules	44+	1,019+

*Water-bearing zones; zones that were noted during drilling. It is not possible to note every water-bearing zone during drilling operations. However, major aquifers sometimes are easily distinguished due to changes in discharging water temperature, a large and immediate increase in air pressure during drilling, or a change in potentiometric head in the well (usually not noticeable until the following day).

TABLE 2.-- Geologic logs of four test wells--continued

Material	Thick-ness (feet)	Depth to bottom (feet)
George Test Well (original well, modified from Eddy, 1976)		
Sand, gravel, clay and silt------------------------	130	130
Sand, medium to fine, clear quartz, white (feldspar) grains, some mica with a small amount of basalt fragments--	20	150
Sand, medium to fine, basaltic, subangular to angular, also clear quartz and some white (feldspar) grains--	20	170
Sand, very fine, basaltic, subangular to angular, with quartz and feldspar, some mica; tends to pack-------	10	180
Basalt, angular, black, very few inclusions-----------	20	200
Basalt, angular, black, few inclusions, relatively small grains (very dense flow)---------------------	10	210
Sand, medium to fine, basaltic, subangular to angular, black, with quartz---------------------------------	20	230
Basalt, angular, black--------------------------------	34	264
Basalt, vesicular, medium to coarse, angular, black, red-brown inclusions-------------------------------	6	270
Basalt, vesicular, coarse, angular, black, with secondary reddish-yellow clayish material-----------	10	280
Basalt, coarse, angular, black------------------------	10	290
Basalt, vesicular, coarse, angular, black, rounded secondary material, yellow to green, inclusion reddish-orange to green-----------------------------	10	300
Basalt, medium, angular, black, very few red inclusions--	10	310
Basalt, medium, angular, black, with red to yellow inclusions--	10	320
Basalt, vesicular, coarse, changing with depth to medium, angular, black; red, yellow and green inclusions, vesicular-------------------------------	20	340
Basalt, vesicular, coarse, angular, reddish; red, yellow and green inclusions------------------------	40	380
Clay, wood, and a few basalt fragments----------------	10	390
Opal, coarse, brown to tan, some quartz crystals, a few fragments of medium angular basalt-------------	10	400
Basalt, coarse, angular, black; with brown to tan cryptocrystalline quartz material-------------------	10	410
Basalt, medium coarse to coarse, angular, black-------	10	420
Basalt, medium coarse, angular, black; green, tan and clear inclusions----------------------------------	10	430
Basalt, coarse, angular, black------------------------	10	440
Basalt, coarse, angular, black; white, green and clear inclusions--	10	450
Basalt, coarse, angular, black------------------------	40	490
Basalt, medium to coarse, angular, black, some small vesicles---	10	500
Basalt, medium, angular, black, some small vesicles, with dark red and tan inclusions--------------------	10	510
Basalt, very coarse, angular, black, with tan, green and reddish inclusions	20	530
Basalt, medium, angular, black------------------------	20	550
Basalt, medium, angular, black, with yellow and tan inclusions--	10	560
Basalt, medium, angular, black, with many yellow, tan, reddish-brown, gray and green inclusions------------	10	570

(continued)

TABLE 2.-- Geologic logs of four test wells--continued

Material	Thick-ness (feet)	Depth to bottom (feet)
George Test Well--continued		
Basalt, medium, angular, black	10	580
Basalt, medium to coarse, angular, black, with tan and green inclusions	10	590
Basalt, medium to coarse, angular, black, with tan inclusions	10	600
Basalt, fine, angular, black; a few tan and greenish-yellow inclusions	10	610
Basalt, fine, subrounded to angular, gray; a few tan and reddish inclusions	10	620
Basalt, fine, angular, gray; a few tan inclusions	10	630
Basalt, fine, angular, black; a few red and yellow inclusions, larger and more numerous below 660 ft	40	670
Basalt, fine, angular, black; a few dark red inclusions, coarser below 720 ft	60	730
Basalt, medium, angular, black; with large tan inclusions, a few below 740 ft	20	750
Basalt, small to medium, angular, black	30	780
Basalt, medium to coarse, angular	10	790
Basalt, broken, vesicular, medium, with a white impurity (possible solution precipitate)	10	800
Basalt, vesicular, very coarse, angular, phenocrysts; small vesicles below 810 ft	20	820
Basalt, medium to coarse, vesicular (smaller pores)	10	830
Basalt with phenocrysts, few vesicles	10	840
Basalt, vesicular, medium to coarse, angular, less vesicular below 840 ft, dark, a few phenocrysts	20	860
Basalt, medium, angular, few vesicles	10	870
Basalt, medium, angular, dark, cryptocrystalline	10	880
Clay, and angular to somewhat rounded basalt, 50-percent clay, increasing below 890 ft, some palagonite	20	900
Clay, greenish-gray, very plastic, intermingled with peat granules	10	910
Palagonite and angular fine basalt	60	970
Peat, dark, greatly decomposed, and palagonite	5	975
Deepening of the well		
Clay, greenish-gray	21	996
Basalt, medium, black	99	1,095
Basalt, porous, broken, black	42	1,137
Basalt, medium, black	20	1,157
Basalt, porous, broken	34	1,191
Basalt, medium, black	137	1,328
Basalt, porous, vesicular	22	1,350
Basalt, medium, black	37	1,387
Basalt, porous, vesicular	42	1,429
Basalt, medium, black	181	1,610

TABLE 3.--Data from flow test of Burbank Creek test well, August 1978

Time since flow or recovery started (minutes)	Head (feet of water above land surface)	Rate of flow (gal/min)[a]	Temperature (°C)	Remarks
147	78.4	0	--	Before flow test
17	78.5	0	--	Do.
0	78.5	b/	--	Test started: 1:10:47 a.m., 8-15-78
2	75.9	b/	--	
4	74.5	b/	--	
5	71.0	1,000	--	
6	71.0	c/	--	
7	70.8		--	
8	70.8		--	
9	71.0		--	
10	70.8		--	
12	70.8		--	
14	70.8		--	
15	70.8		--	
18	70.3		--	
20	70.3		22.8	
25	69.9		--	
30	69.9		--	
35	69.9		--	
40	69.4		--	
45	69.2		--	
50	68.9		--	
55	68.7		--	
60	68.5		22.8	
80	68.0		--	
100	67.3		--	
120	66.8		--	
140	66.6		--	
160	65.6		--	
180	65.0		--	
200	65.0		--	
220	64.3		--	
240	64.1		--	
260	63.6		23.0	
280	62.9		--	
300	62.2		23.0	
350	61.8		--	
358	60.0		--	Flow rate increased slightly
373	59.7		--	
388	59.4		--	
433	58.7		--	
493	57.7		--	
553	56.1		--	
613	55.4		--	
673	54.9		--	
733	53.6		--	
793	52.8		--	
853	52.1		--	
913	51.4		--	
973	50.9		--	
1033	50.4		--	
1093	49.8		--	
1153	49.4		--	
1213	49.1		--	
1273	48.9		22.8	
1333	48.2		--	
1393	47.9		--	
1440	47.7		--	10:47 a.m., 8-16-78
1573	46.6		23.0	
1693	45.7		--	
1813	45.2		--	
1933	44.5		--	
2053	42.7		--	

(continued)

TABLE 3.--Data from flow test of Burbank Creek test well, August 1978--Continued

Time since flow or recovery started (minutes)	Head (feet of water above land surface)	Rate of flow (gal/min)[a/]	Temperature (°C)	Remarks
2173	41.6		--	
2293	40.9		--	
2413	40.2		--	
2533	39.8		--	
2653	39.2		23.0	
2773	38.6		--	
2880	37.8		--	10:47 a.m., 8-17-78
2953	37.6		23.0	
3133	37.0		--	
3313	36.8		--	
3493	35.8		--	
3673	35.2		--	
3853	34.7		--	
4033	34.3		--	
4153	34.1		22.8	
4171	34.1	1,000	--	
4173	0	[d]2,600	22.8	Flow rate increased to maximum.
4233	0	[e]2,500	22.8	Valve closed at 9:20 a.m., 8-18-78.
0.25	35.2	0	--	Test 1 recovery started: 9:20 a.m., 8-18-78
.75	35.9		--	
1.0	36.1		--	
1.5	36.3		--	
2	36.5		--	
2.5	36.5		--	
3	36.6		--	
3.5	36.6		--	
4	36.7		--	
5.5	36.8		--	
6	36.9		--	
7	36.9		--	
8	37.2		--	
10	37.3		--	
13	37.5		--	
15	37.7		--	
20	38.1		--	
25	38.4		--	
40	39.4		--	
55	39.9		--	
70	40.8		--	
85	41.6		--	
100	42.3		--	
160	44.5		--	
220	46.5		--	
280	48.1		--	
400	50.5		--	
520	52.6		--	
700	55.0		--	
880	56.9		--	
1060	58.4		--	
1240	59.7		--	
1420	60.7		--	
1600	61.5		--	
1780	62.2		--	
1960	62.8		--	
1120	63.8		--	
2680	64.6		--	
3040	65.2		--	
3400	65.6		--	
3760	66.0		--	
4120	66.4		--	

(continued)

TABLE 3.--Data from flow test of Burbank Creek test well, August 1978--Continued

Time since flow or recovery started (minutes)	Head (feet of water above land surface)	Rate of flow (gal/min)[a/]	Temperature (°C)	Remarks
4480	66.8		--	
4555	67.1		--	Test 2 started: 1:15 p.m., 8-21-78.
0.5	42.6	2,000	--	
1	44.0	[f/]	--	
1.5	43.8		--	
2	43.8		--	
3	43.6		--	
4	43.8		--	
5	43.6		--	
6	43.6		--	
11	43.1		--	
12	42.8		23.0	
14	42.8		--	
15	42.6		--	
18	42.4		--	
20	42.4		--	
25	41.8		--	
29	42.0		--	
30	41.8		23.0	
36	41.0		--	
44	40.0		--	
52	38.9		--	
55	38.0		--	
59	38.3		23.0	
70	37.2		--	
75	36.5		--	
90	35.8		--	
104	34.9		--	
110	34.3		--	
120	33.4		--	
130	32.5		23.0	
140	31.8		--	
150	31.4		--	
160	31.0		--	
179	30.3		--	
200	29.0		--	
220	27.3		--	
240	26.7		23.0	
254	26.6		--	
260	26.2	2,000	--	
264	30.1	1,750	--	Decreased rate of flow.
270	29.8		--	
280	29.6		--	
300	29.3		--	
315	28.6		--	
330	28.2		--	
345	27.7		--	
360	27.3		--	
375	26.8		--	
390	26.6		23.0	
405	26.1		--	
465	24.3		--	
525	22.7	1,750	--	
585	21.9	1,800	--	
645	21.0	1,750	--	
765	19.9	1,700	--	
885	18.7	1,650	--	
1005	17.8	1,670	--	
1035	17.8	1,550	--	
1050	14.2	1,700	22.8	Increased rate of flow.
1065	14.0		--	
1095	13.6		--	
1125	12.9		--	
1185	12.2		--	

(continued)

TABLE 3.--Data from flow test of Burbank Creek test well, August 1978--Continued

Time since flow or recovery started (minutes)	Head (feet of water above land surface)	Rate of flow (gal/min)[a]	Temperature (°C)	Remarks
1245	11.5		23.0	
1305	10.7		--	
1365	10.4		--	
1440	9.5		23.0	
1485	9.0		--	
1605	7.4		23.0	
1725	6.0		23.0	
1845	4.0		--	
1920	3.8	1,700	--	
1922	[d]0	1,850	--	Increased rate of flow.
1965			--	
2085		1,800	--	
2265			--	
2445		1,750	--	
2625			23.0	
2640	0	[g]1,700	0	Valve closed 9:17 a.m., 8-23-78. Test 2 recovery started.
0.5	17.0	0	--	
.75	17.2		--	
1	17.2		--	
1.25	17.2		--	
1.5	17.3		--	
1.75	17.3		--	
2	17.3		--	
2.5	17.5		--	
3	17.5		--	
3.5	17.5		--	
4	17.5		--	
6	17.9		--	
7	18.0		--	
8	18.1		--	
9	18.1		--	
11	18.3		--	
12	18.4		--	
15	18.8		--	
17	18.9		--	
20	19.1		--	
25	19.6		--	
28	19.7		--	
30	20.0		--	
35	20.3		--	
40	20.7		--	
50	21.5		--	
60	22.2		--	
73	22.9		--	
88	23.7		--	
103	24.6		--	
118	25.4		--	
135	26.1		--	
180	28.3		--	
225	30.4		--	
285	32.5		--	
345	34.1		--	
405	35.6		--	
465	37.1		--	
525	38.4		--	
705	41.6		--	
885	44.2		--	
1065	46.1		--	
1245	47.7		--	
1425	49.1		--	
1605	49.8		--	
1785	50.9		--	
1965	51.6		--	

(continued)

TABLE 3.--Data from flow test of Burbank Creek test well, August 1978--Continued

Time since flow or recovery started (minutes)	Head (feet of water above land surface)	Rate of flow (gal/min)[a]	Temperature (°C)	Remarks
2145	52.3		--	
2325	53.4		--	
2865	54.7		--	
3585	55.8		--	
4305	56.7		--	
5040	57.2		--	
5760	57.9		--	
6480	58.4		--	
7200	58.9		--	
8600	59.9		--	
10100	60.6		--	
13000	61.7		--	
15800	62.4		--	
20200	63.5		--	
25900	64.4		--	
32000	65.3		--	
40300	66.7		--	
50000	67.9		--	
62000	69.2		--	
79000	70.6		--	
91000	71.3		--	
100000	71.7		--	

a/Accuracy of flow rate is ± 2 percent, as reported by manufacturer (McCrometer Corporation; Hemet, Calif.) of flow-rate indicator.

b/Flow less than 1,000 gal/min.

c/No noticeable change in discharge until 0820 hr on 8-18-78.

d/The gate valve on the well head was opened to its maximum position.

e/Average flow rate was 1,030 gal/min for 4,233 minutes (70.55 hrs).

f/Flow maintained at 2,000 gal/min.

g/With valve fully open for about 6 hrs flow rate decreased from about 1,950 to about 1,700 gal/min.

TABLE 4.--Data from pumping test of the Umtanum Creek test well, March 1978

Time since pumping or recovery started (min)	Depth to water (ft below land surface)	Pumping rate (gal/min)	Temperature (°C)	Remarks
--	23.36	--	--	
--	23.38	--	--	
0	--	--	--	Pump on 1:54 p.m., 3-2-78.
1	28.00	960	--	
2	27.85	960	--	
3	27.85	960	--	
4	27.90	960	--	
5	27.85	960	26.4	
7	27.80	960	--	
10	27.85	960	26.6	
13	27.85	960	26.6	
18	27.90	960	--	
21	27.95	960	27.0	
24.5	27.95	960	--	
25	27.95	960	--	
28	--	960	26.8	
28.5	28.00	960	--	
30	--	960	--	
40	28.01	960	27.0	
51	28.01	960	27.0	
61	28.11	960	--	
80	28.09	960	27.0	
100	28.10	960	27.0	
156	28.17	960	27.0	
201	28.16	960	27.0	
276	28.22	960	27.0	
346	28.29	960	27.0	
360	28.37	960	26.8	
395	28.36	960	--	
420	28.40	960	--	
450	28.33	960	26.6	
452	28.37	960	26.6	
480	28.35	960	27.0	
510	28.33	960	27.0	
540	28.37	960	27.0	
570	28.32	960	27.0	
600	28.38	960	27.0	
660	28.30	960	27.0	
730	28.38	960	27.0	
800	28.29	960	27.0	
886	28.33	960	27.0	
900	28.36	960	27.0	
956	28.37	960	27.0	
976	28.37	960	27.0	
996	28.35	960	27.0	
1016	28.36	960	27.0	
1036	28.36	960	27.2	
1056	28.37	960	27.3	
1076	28.37	960	27.2	
1096	28.37	960	27.2	
1116	28.36	960	27.2	
1136	28.35	960	27.2	
1156	28.37	960	27.2	
1176	28.37	960	27.2	
1196	28.37	960	27.2	
1203	--	--	--	Pump off, 9:56 a.m., 3-3-78.
0	--	0	--	Recovery.
1.1	23.15	--	--	
2.3	24.32			
3.4	23.33			
4.6	23.28			
5.6	23.27			
9.0	23.25			
10.6	23.21			
12.5	23.19			
14	23.19			
18	23.19			
20	23.16			
30	23.13			
128	23.05			

TABLE 5.--Data from pumping test of the 1,610-foot George test well, February 1978

Time since pumping or recovery started (min)	Depth to water (ft below land surface)[a]	Pumping rate (gal/min)	Temperature (°C)	Remarks
--	384.0	--	--	
	384.0	--	--	Pump on 11:10 a.m., 2-16-78.
4	--	500	--	
35	384.0	1,100	--	
39	385.0	1,100	25.4	
51	387.0	1,100	--	
60	387.0	1,100	--	
65	--	1,100	25.2	
83	387.0	1,100	25.4	
93	387.5	1,150	--	
135	387.5	1,150	25.4	
180	387.5	1,150	25.6	
232	387.5	1,150	--	
290	387.0	1,150	25.5	
359	387.0	1,150	25.4	
457	387.5	1,150	25.2	
560	387.5	1,150	25.1	
650	387.5	1,150	25.0	
770	390.0	1,150	25.0	
830	387.5	1,150	24.9	
920	387.5	1,150	24.9	
1010	387.0	1,150	25.0	
1100	387.5	1,150	25.0	
1190	387.5	1,150	25.1	
1280	387.5	1,150	25.1	
1325	387.5	1,150	25.4	
1365	390.0	1,150	25.6	
1380	394.5	1,700	24.8	
1385	394.5	1,700	--	
1402	394.5	1,700	25.8	
1415	394.5	1,700	--	Pump off 10:45 a.m., 2-17-78.
2	384.0	0	--	
50	[b]384.0	--	--	

[a]Water levels measured by airline method except b/, see below.
[b]Electric tape measurement.

TABLE 6.--Perforations in the George test well. (Mills knife cuts 1/2" x 3", mostly 2-3 cuts at 2-foot intervals)

Depth to perforated zone (ft below land surface)	
350-360	755-765
375-390	804-806
400-410	813-821
416-420	862-868
495-507	873-875
633-637	884-900
680-690	

Note: All perforations open the well to aquifers in the Wanapum Basalt except the last (884-900 ft), which is in the Vantage Member of the Ellensburg Formation.

TABLE 7.--Theoretical drawdown of the water level in the Wanapum Basalt at George test well (18/25-15E1) caused by pumping of irrigation wells tapping this unit in T.18 N., R.25 E. (Locations of wells are shown in figure 16)

Well	Depth (ft)	Distance from well 18/25-15E1 (ft)	Distance from well 18/25-15E1 (mi)	Pumping rate (data from USBR) (gal/min)	Theoretical drawdown at 15E1 after pumping 100 days (see text) (ft)
18/25-4H1	740	10,950	2.1	2,900	8.2
18/25-16M1	750	4,350	.8	1,300	5.4
18/25-23K1	714	9,700	1.8	2,600	7.8
18/25-25C1	595	15,000	2.8	2,600	6.2
18/25-27J1	750	11,700	2.2	2,400	6.5
18/25-27N1	748	12,000	2.3	2,400	6.3
18/25-28B1	694	8,200	1.6	2,400	7.7
18/25-28D1	507	10,100	1.9	1,200	3.5
18/25-34B1	560	14,600	2.8	1,200	2.9
18/25-35K1	730	17,950	3.4	2,400	5.1
18/25-35M1[a]	600?	18,200	3.5	1,300	2.7
				Total	62.3

[a]Well started pumping in 1978.