U.S. Department of the Interior
U.S. Geological Survey

DESCRIPTION OF BOREHOLE GEOPHYSICAL AND GEOLOGIST LOGS, BERKS SAND PIT SUPERFUND SITE, LONGSWAMP TOWNSHIP, BERKS COUNTY, PENNSYLVANIA

Open-File Report 03-399

In cooperation with the
U.S. ENVIRONMENTAL PROTECTION AGENCY

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by Dennis J. Low and Randall W. Conger

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New Cumberland, Pennsylvania
2003

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CONVERSION FACTORS AND DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).
Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

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ABSTRACT

Between October 2002 and January 2003, geophysical logging was conducted in six boreholes at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pa., to determine (1) the water-producing zones, water-receiving zones, zones of vertical borehole flow, orientation of fractures, and borehole and casing depth; and (2) the hydraulic interconnection between the six boreholes and the site extraction well. The boreholes range in depth from 61 to 270 feet. Geophysical logging included collection of caliper, natural-gamma, single-point-resistance, fluid-temperature, fluid-flow, and acoustic-televiewer logs. Caliper and acoustic-televiewer logs were used to locate fractures, joints, and weathered zones. Inflections on fluid-temperature and single-point-resistance logs indicated possible water-bearing fractures, and flowmeter measurements verified these locations. Single-point-resistance, natural-gamma, and geologist logs provided information on stratigraphy. Flowmeter measurements were conducted while the site extraction well was pumping and when it was inactive to determine the hydraulic connections between the extraction well and the boreholes.

Borehole geophysical logging and heatpulse flowmetering indicate active flow in the boreholes. Two of the boreholes are in ground-water discharge areas, two boreholes are in ground-water recharge areas, and one borehole is in an intermediate regime. Flow was not determined in one borehole. Heatpulse flowmetering, in conjunction with the geologist logs, indicates highly weathered zones in the granitic gneiss can be permeable and effective transmitters of water, confirming the presence of a two-tiered ground-water-flow system.

The effort to determine a hydraulic connection between the site extraction well and six logged boreholes was not conclusive. Three boreholes showed decreases in depth to water after pumping of the site extraction well; in two boreholes, the depth to water increased. One borehole was cased its entire depth and was not revisited after it was logged by the caliper log. Substantial change in flow rates or direction of borehole flow was not observed in any of the three wells logged with the heatpulse flowmeter when the site extraction well was pumping and when it was inactive.

INTRODUCTION

In January 1982, homeowners near the Berks Sand Pit Superfund Site complained about the quality of their well water. The principal contaminants of concern were identified as 1,1,1-trichloroethane (TCA) and 1,1-dichloroethene (DCE). On September 1, 1984, the Berks Sand Pit was listed on the National Priorities List (NPL) and on September 29, 1988, a Record of Decision was issued by the U.S. Environmental Protection Agency (USEPA) to remediate the site by ground-water pump and treat. Recent efforts to improve the remediation process by the injection of a chemical oxidant had limited success. This led USEPA to undertake an effort to understand the connection of fractures between an onsite extraction well and selected monitor wells.

The site extraction well is a 6-in. diameter, 200 ft deep well that is cased to a depth of 45 ft. The site extraction well, which commonly has been pumping 40 to 60 gal/min since about 1996, was shut down on October 25, 2002, prior to the onset of borehole geophysical logging on October 28, 2002. The cessation of pumping the site extraction well permitted the ground-water system to equilibrate to non-stress conditions. Borehole geophysical logging under nonpumping conditions for six boreholes was completed on November 1, 2002. Heatpulse-flowmeter logging under nonpumping conditions for three wells was completed on October 31, 2002. The site extraction well was then returned to continuous service at an extraction rate of approximately 40 gal/min. Three boreholes were then re-logged with the heatpulse flowmeter on November 7 and 8, 2002, and two boreholes were re-logged with the heatpulse flowmeter on January 10, 2003.

Purpose and Scope

This report describes borehole geophysical logs collected by the U.S. Geological Survey (USGS) in six boreholes at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pa. (table 1, fig. 1). This report identifies the location of one or more water-producing and water-receiving zones in five of the six logged boreholes. The purpose of the logging was to determine the hydraulic interconnection between the site extraction well and the logged boreholes. Caliper, natural-gamma, single-point-resistance (electric), fluid-temperature, heatpulse-flowmeter, and acoustic-televiewer logs were collected.

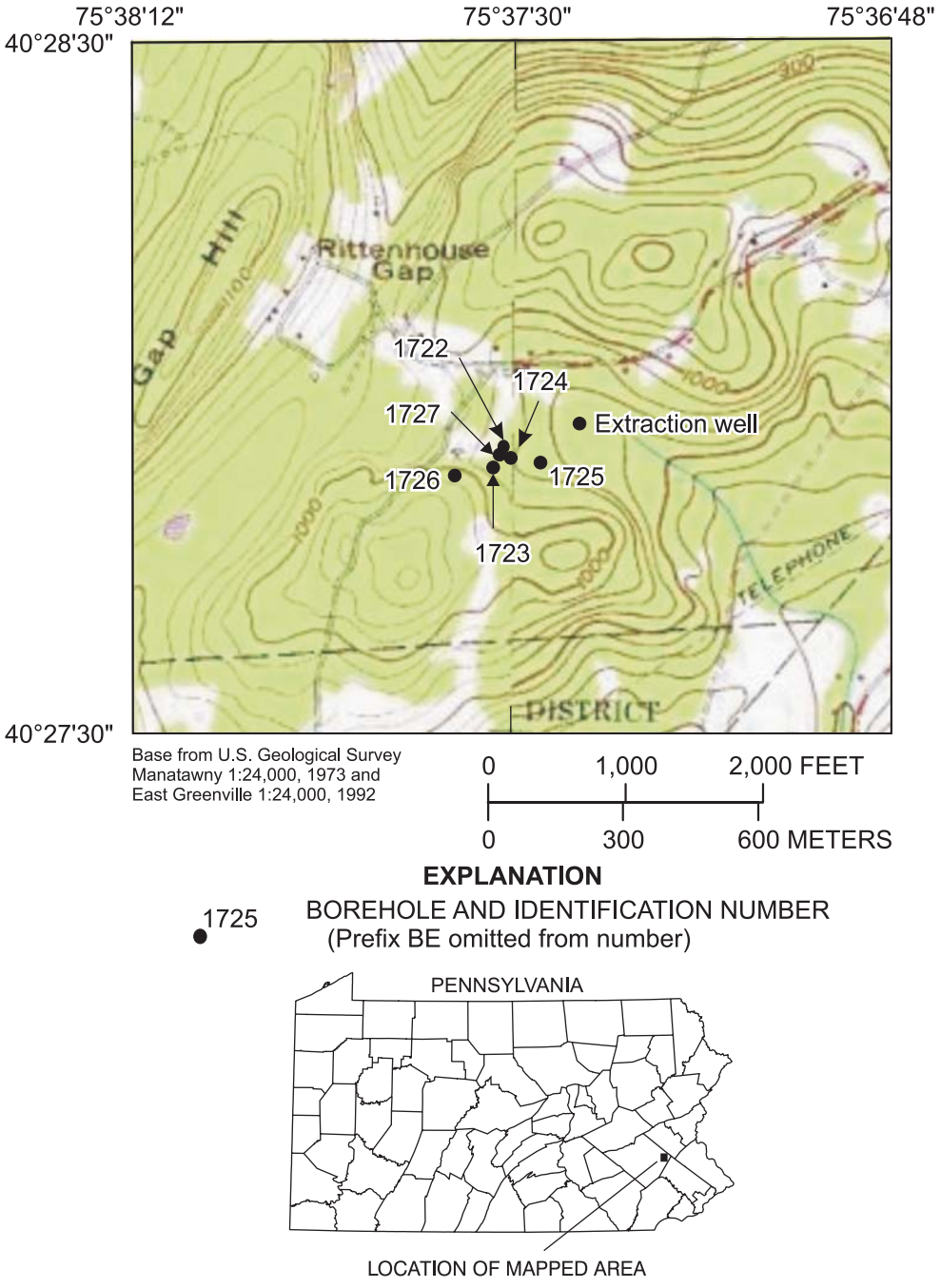

Figure 1. Location of boreholes and site extraction well at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania.

Table 1. *Boreholes logged at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

[A, acoustic televiewer; C, caliper; N, natural gamma; R, single-point resistance; T, fluid temperature; V, heatpulse flowmeter; NGVD, National Geodetic Vertical Datum of 1929]

U.S. Geological Survey borehole-identification number	Berks Sand Pit borehole-identification number	Depth logged (feet)	Casing length (feet)	Altitude of land surface (feet above NGVD 29)	Geophysical logs collected
BE-1722	MW-2	270	270	979.5	C
BE-1723	MW-3	155	31	993.2	A, C, N, R, T, V
BE-1724	MW-4	61	57	966.3	C, V
BE-1725	MW-6	152	58	962.2	A, C, N, R, T, V
BE-1726	MW-7	152	32	1,013.0	A, C, N, R, T, V
BE-1727	MW-9	151	50	980.3	C, N, R, T, V

Borehole Geophysical and Geologist Logs

Borehole geophysical and geologist logs provide information on well construction, location and orientation of fractures, water-producing and water-receiving zones, intervals of vertical borehole flow, quantification of borehole flow, and lithologic correlation. The subsurface information that can be determined by the use of geologist logs, borehole geophysics, and the geophysical methods employed are summarized in the following table.

Borehole geophysical and geologist logs and applicable subsurface information

[A, acoustic televiewer; C, caliper; N, natural gamma; R, single-point resistance; T, fluid temperature; V, heatpulse flowmeter; DG, geologist]

Borehole geophysical log	Subsurface information
A, C	Location and orientation of fractures and water-producing zones
R, T	Location of water-producing and water-receiving zones
T, V	Intervals of vertical borehole flow
V	Quantification of borehole flow
N, R	Lithologic correlation
C, N	Casing length
C	Borehole diameter
DG	Depth to bedrock, depth of water-bearing zones, lithologies of rocks penetrated, competence of rock

The acoustic televiewer is a sonic imaging tool that scans the borehole wall with an acoustic beam. The reflected acoustic waves are recorded digitally on a portable computer, and images of transit time and amplitude of the waves are produced. The logs are corrected for magnetic orientation, magnetic declination (true north), and borehole deviation from vertical by the logging software. Fractures are detected by longer transit times and decreased signal amplitudes. Because the returned data is oriented to true north and corrected for borehole deviation from vertical, strike and dip for each fracture or bedding plane can be determined. When coupled with other logs, the acoustic televiewer can aid in the identification of water-producing and water-receiving zones. However, if multiple fractures are close together it is difficult to specifically identify which fracture is producing or receiving water. The acoustic televiewer can be used underwater in 6- to 8-in. diameter boreholes.

Caliper logs record the average borehole diameter, which may be related to fractures, lithology, or drilling methods. Caliper logs can be used to identify fractures and possible water-producing or water-receiving zones and to correct other geophysical logs for changes in borehole diameter. They also can be correlated with fluid-temperature logs and heatpulse flowmetering to identify additional fractures and water-producing and water-receiving zones.

The natural-gamma or gamma log measures the natural-gamma radiation (photons) emitted from all rocks. The most common emitters of gamma radiation are uranium-238, thorium-232, their daughter elements, and potassium-40. These radioactive elements are concentrated in clays by adsorption, precipitation, and ion exchange. Fine-grained sediments such as shale or siltstone usually emit more gamma radiation than sandstone, limestone, or dolomite. The gamma log can be collected in or out of water or casing. However, casing does reduce the gamma response. The gamma log is used to correlate geologic units between wells (Keys, 1988).

The single-point-resistance log records the electrical resistance of a formation between the probe in a water-filled borehole below casing and an electrical ground at land surface. Generally, electrical resistance increases with formation grain size and decreases with borehole diameter, water-producing fractures, and increasing concentration of dissolved solids of borehole water. The single-point-resistance log is used to correlate geology between wells and may help identify water-producing zones. (Keys, 1988).

A fluid-temperature log provides a continuous record of the vertical temperature variation in the water in a borehole. Temperature logs are used to identify water-producing and water-receiving zones and to determine zones of vertical borehole flow. Intervals of vertical borehole flow are characterized by little or no temperature gradient. (Williams and Conger, 1990).

The direction and rate of borehole-water movement was determined by the use of a heatpulse flowmeter. The heatpulse flowmeter operates by heating a small sheet of water between two sensitive thermistors (heat sensors) located the same distance from the heat source. The time it takes for the heated water to move upward or downward past one of the thermistors is recorded. Because the thermistors are located in a channel of fixed diameter, the flow rate can be determined from the time it takes for the peak of the heatpulse to pass one of the thermistors. A flexible divertor is used to block the annular space around the tool to channel all the flow through the measurement channel. The range of flow measurement is about 0.01-1.5 gal/min in a 2- to 10-in.-diameter borehole (Conger, 1996).

Some heatpulse-flowmeter measurements may be influenced by (1) poor seal integrity between the borehole and heatpulse flowmeter and (2) contributions of water from storage within the borehole. If the seal between the borehole and flowmeter is not complete, some water can bypass the flowmeter, resulting in measurements of flow that are less than the actual rate. Although the heatpulse flowmeter is a calibrated probe, the data are used primarily as a relative indicator to identify water-producing zones.

The geologist log (Michael Baker, Jr., Inc., written commun., 2002) consists of a series of notes and visual observations that concentrate on descriptions of material penetrated, rate of penetration, and presence or increase of water blown from the borehole. Overburden, saprolite, and strongly weathered rock were penetrated by a 6- to 10-in. diameter auger; consolidated bedrock was penetrated by an air-hammer or cored. As drilling advances, the geologist collects small samples of rock cuttings at known depths and provides comments on texture, color, competence, and predominant rock or mineral. More detailed descriptions are available if the borehole is cored. These descriptions also may include information on foliation and fractures. Changes in drilling speed indicate possible voids, fractures, lithology, and rock competence. Approximately every 20 ft, the driller adds another length of drill rod. In conjunction, the driller typically blows the borehole with air pressure and the geologist is then able to estimate the volume of water entering the borehole and note the increase of flow into the borehole over the previous 20 ft.

DESCRIPTION OF BOREHOLE GEOPHYSICAL AND GEOLOGIST LOGS

The locations of boreholes logged are shown on figure 1. The reference measuring point for all geophysical and geologist logs is land surface. Depth of wells, casing lengths, and water levels at the time of logging are given in feet below land surface (ft bls). A cross-reference between USGS borehole-identification numbers and site-identification numbers is shown in table 1.

BE-1722 (MW-2)

The water level measured at the time of borehole geophysical logging on November 1, 2002, was 44.58 ft bls. The caliper log (fig. 2) shows the total depth of the borehole is 270 ft. The caliper log also shows the borehole is cased its entire depth with 4-in.-diameter casing. The geologist log is summarized in fig. 2; detailed descriptions are presented in table 2. As a result of insufficient data (only one water level measurement and no heatpulse-flowmeter measurements), it is impossible to determine if BE-1722 is affected by the pumping of the site extraction well.

Table 2. *Geologist log for borehole BE-1722 (MW-2) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

[ft bls, feet below land surface; gal/min, gallons per minute]

Depth (ft bls)	Comment
0–5	**SAND**, trace clay, granitic gneiss pebbles
5–8.5	**SAND**, quartz rich seams, decomposed granitic gneiss
8.5–10	**SAPROLITE**, quartz rich, trace mica
10–12	**GRANITIC GNEISS**, feldspar and quartz, some hornblende and mica; highly weathered
12–12.5	**CLAY**, granitic pebbles; decomposed rock
12.5–14	**GRANITIC GNEISS**, feldspar and quartz rich, some mica; wet; highly weathered
14–47	**GRANITIC GNEISS**, micaceous quartz; damp; highly weathered Producing water from hole at 41 ft bls
47–51	**GRANITIC GNEISS**, hard; weathered
51–157	**GRANITIC GNEISS**, quartz, hornblende, biotite Producing about 6 gal/min by 71 ft bls Producing about 20 gal/min by 95 ft bls Producing about 30 gal/min by 120 ft bls Increase amount of weathering at 144 ft bls
157–158	**PEGMATITE,** quartz rich, abundant plagioclase; moderately broken Fracture from 154–163 ft bls
158–163	**GRANITIC GNEISS**, hornblende and chlorite rich; moderately broken
163–164.5	**PEGMATITE**, quartz rich, abundant plagioclase, some hornblende and chlorite; moderately broken
164.5–231	**GRANITIC GNEISS**, hornblende, chlorite, quartz, plagioclase vary in amount; moderately broken Fractures constant at 45°, 70°, and 30° Very closely fractured 180–181 and 183–186 ft bls; fractures near perpendicular to foliation pattern Slickensides along fracture at 202.5 ft bls Fractures are weathered, small fracture zone from 214–214.5 ft bls No fractures from 221–232 ft bls
231–232.5	**PEGMATITE**, massive quartz, hornblende blebs, some plagioclase; slickensides on fracture surface
232.5–300	**GRANITIC GNEISS**, quartz rich with varying amounts of hornblende, plagioclase, orthoclase, chlorite; moderately to closely fractured, some weathered fracture surfaces; poor to well foliated Slickensides at 271, 287 ft bls

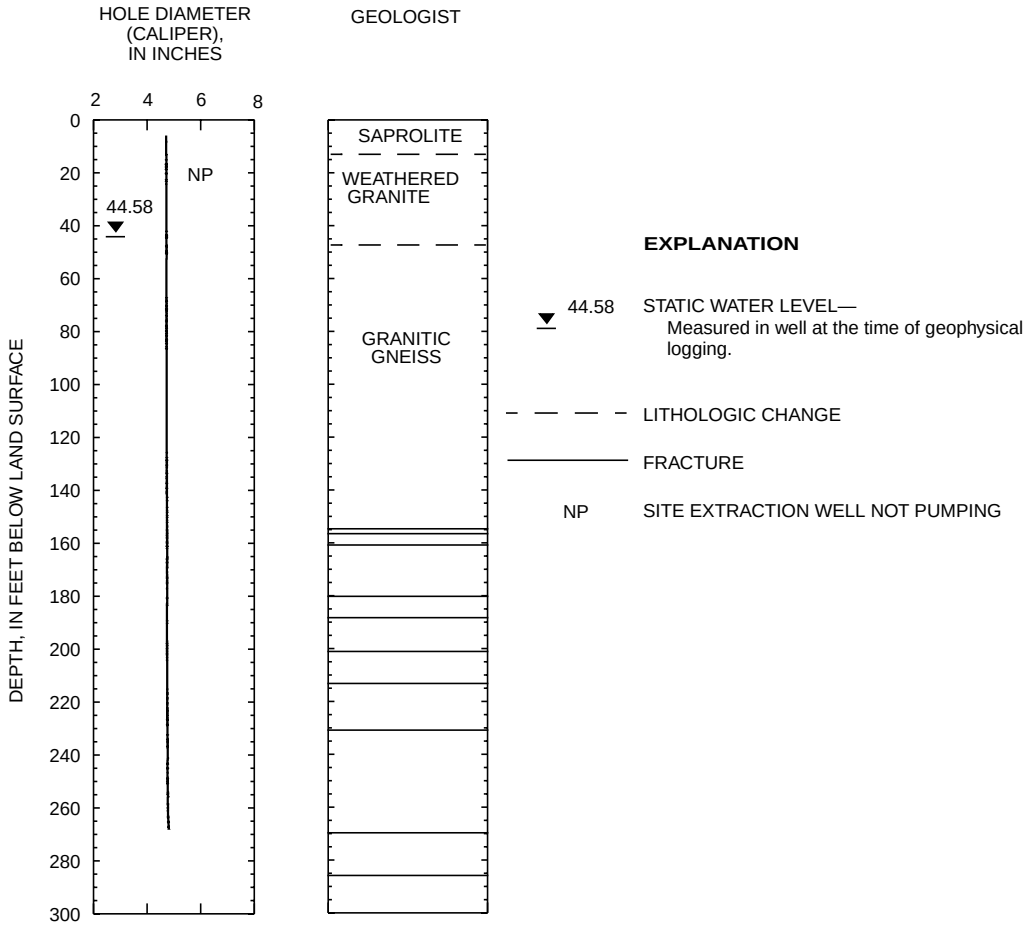

Figure 2. Geologist and caliper logs for borehole BE-1722 (MW-2), Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania. (Geologist log collected from August 11 through September 12, 1987. Caliper log collected on November 1, 2002.)

BE-1723 (MW-3)

The water level measured at the time of borehole geophysical logging on October 28, 2002, was 53.71 ft bls. The caliper log (fig. 3) shows the total depth of the borehole is 155 ft. The caliper log also shows the borehole is cased with 6-in.-diameter casing to 31 ft bls. The caliper log shows major fractures at 54 to 56, 79 to 81, 82 to 84, and 100 to 101 ft bls plus numerous smaller fractures throughout the openhole interval. The single-point-resistance log shows changes in slope at 62, 64, 70, 79 to 81, 82 to 84, 100 to 101, 110, 117, 127, and 143 ft bls that correlate to fractures shown on the caliper log. The fluid-temperature log shows minor changes in slope at 64, 80, 82, 100, 102, 111, 117, 128, and 143 ft bls that correlate closely to fractures shown on the caliper log. The acoustic-televiewer log shows 44 fractures (table 3). Sixty-one percent (29 of 44) of the fractures strike north to northwest and dip to the northeast (18 of 44) or southwest (11 of 44). The geologist log is summarized in fig. 3; detailed descriptions are presented in table 4.

Table 3. *Locations of fractures and measurement of strike and dip determined from acoustic-televiewer log for borehole BE-1723 (MW-3) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

[ft bls, feet below land surface; strike and dip in degrees; Receiving, zone where water exits borehole; Producing, zone where water enters the borehole; —, no comment]

Depth (ft bls)	Comment	Strike of fracture	Dip of fracture	Depth (ft bls)	Comment	Strike of fracture	Dip of fracture
55	Receiving	N26W	47NE	99	—	N14W	29NE
56	Receiving	N18W	63NE	101	—	N58E	51SE
57	—	N33W	73NE	102	—	N9E	50SE
59	—	N60W	77SW	104	—	N77W	55NE
59	—	N59W	75SW	105	—	N34E	66SE
60	—	N70W	30NE	106	—	N43E	64SE
62	—	N3W	74NE	106	—	N36E	60SE
63	—	N55W	27NE	107	—	N34E	65SE
64	—	N71E	55NW	108	—	N18E	35SE
67	—	N10W	73NE	109	—	N59W	75SW
69	Producing	N75W	49NE	111	Producing	N36W	53NE
70	—	N74W	78SW	116	Receiving	N24E	66SE
73	—	N49W	11NE	117	Receiving	N16E	62SE
73	—	N61W	66SW	117	Receiving	N29E	65SE
73	—	N39E	40NW	122	—	N37W	69SW
74	—	N68W	80SW	123	—	N83W	34NE
74	—	N65W	7SW	127	Producing	N63E	33SE
76	—	N77W	78SW	128	Producing	N55W	43SW
79	Receiving	N89E	26SE	139	—	N37W	26NE
83	Receiving	N41W	42NE	142	Producing	N33E	22NW
87	—	N52W	39NE	142	Producing	N67W	27NE
94	—	N67W	51NE	143	Producing	N57W	45SW

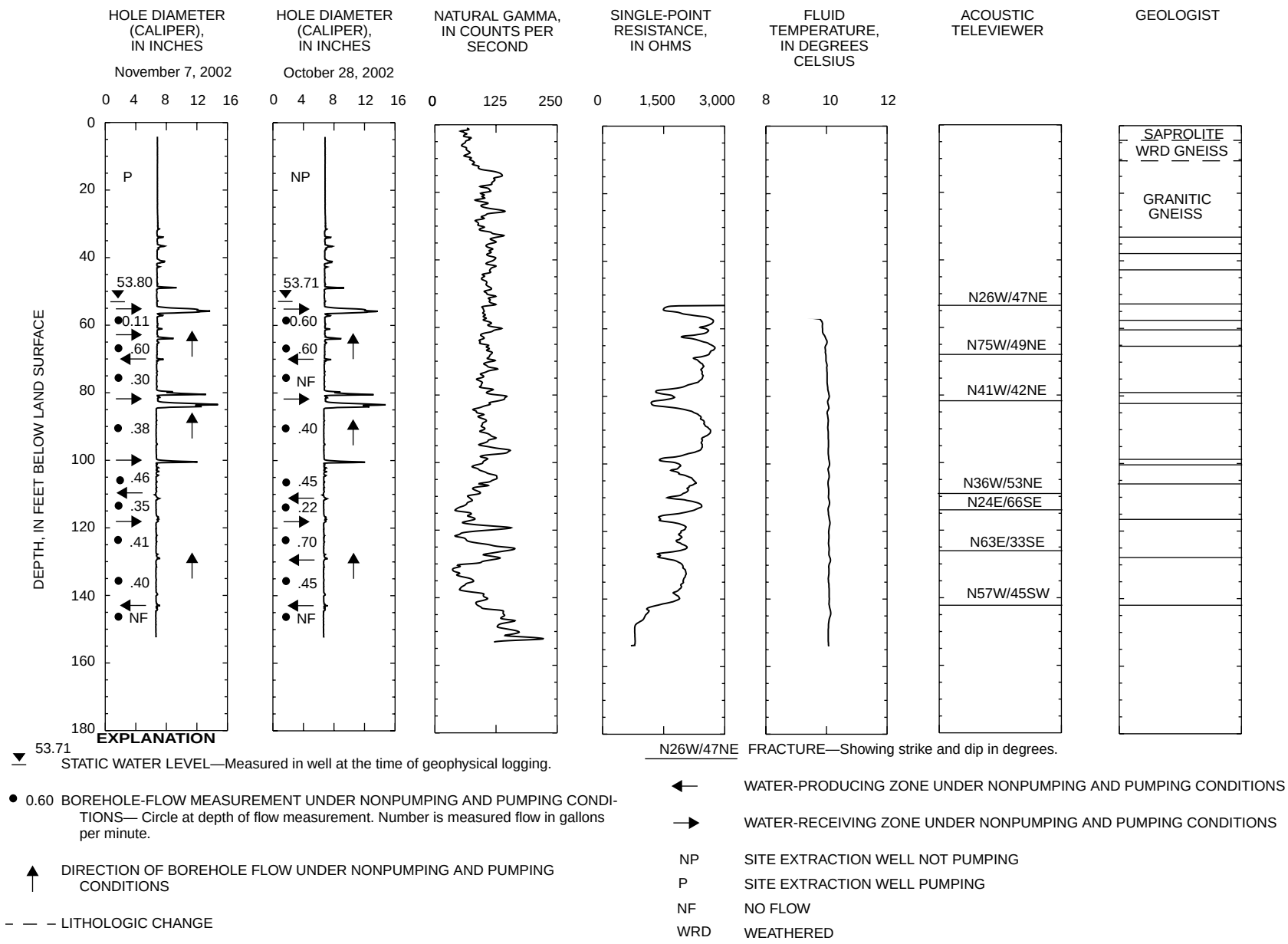

Figure 3. Geologist log, borehole geophysical logs, and direction of flow within borehole BE-1723 (MW-3), Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania. (Geologist log collected from August 24 through September 2, 1987. Borehole geophysical logs collected on October 28, 2002. Direction of flow data collected on October 28 and November 7, 2002.)

Table 4. *Geologist log for borehole BE-1723 (MW-3) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

[ft bls, feet below land surface]

Depth (ft bls)	Comment
0–3.5	**SAPROLITE**, some sand, quartz clasts, small granitic fragments
3.5–9	**GRANITIC GNEISS**, abundant quartz, albite, some hornblende, chlorite, mica; highly weathered
	Auger refusal at 9 ft bls
9–24	**GRANITIC GNEISS**, increase in quartz, less weathered
24–53	**GRANITIC GNEISS**, quartz with abundant plagioclase, little orthoclase and hornblende
	Highly stained and fractured from 32–35.5 ft bls
	Fractures at 38.5–39.5, 40.5–41 ft bls
53–56	**SAND**, medium grained, quartz rich, some mica, random clasts of granitic gneiss; no resistance
56–155	**GRANITIC GNEISS**, quartz, hornblende, increase in orthoclase
	No resistance 81–82.5 ft bls
	Soft zones at 59, 62.5–63, 77–79, 79.5–80, 97–98, 100.3–100.8, 106.5, 115–116, 126–128, 141–141.5 ft bls

On October 28, 2002, when the site extraction well was not pumping, the heatpulse-flowmeter measurements indicated upward flow at 59, 67, 90, 106, 114, 123, and 135 ft bls; no flow was measured at 146 ft bls (table 5). The largest producing zones are at depths of approximately 69, 111, 128, and 143 ft bls. Major water-receiving zones are at depths of approximately 55, 79, 83, and 117 ft bls.

Table 5. *Summary of heatpulse-flowmeter measurements for borehole BE-1723 (MW-3) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

Depth (feet below land surface)	Flow rate when the site extraction well was not pumping (gallon per minute)	Flow direction when the site extraction well was not pumping	Flow rate when the site extraction well was pumping (gallon per minute)	Flow direction when the site extraction well was pumping
	Measured October 28, 2002		Measured November 7, 2002	
59	0.60	up	0.11	up
67	.60	up	.60	up
75	no flow	not determined	.30	up
90	.40	up	.38	up
106	.45	up	.46	up
114	.22	up	.35	up
123	.70	up	.41	up
135	.45	up	.40	up
146	no flow	not determined	no flow	not determined

After several days of continuous pumping of the site extraction well, borehole BE-1723 was again logged with the heatpulse flowmeter on November 7, 2002. The heatpulse-flowmeter measurements indicated that (1) borehole BE-1723 is in an area of ground-water discharge (upward borehole flow), (2) the direction of vertical flow remained identical, and, in general, (3) the same fractures were hydraulically active during the nonpumping and pumping measurements.

Noticeable differences were observed between nonpumping and pumping conditions. Under pumping conditions, the borehole flow at 59 ft bls decreased by 0.49 gal/min, indicating that a fracture at 65 ft bls became a receiving zone. Also under pumping conditions, flow at 75 ft bls increased from no flow to 0.30 gal/min (table 5). Although upward flow at 90 and 106 ft bls remained virtually identical, there were larger changes in the flow rates as measured on October 28 and November 7 at 114 (upward flow increased 0.13 gal/min), 123 (upward flow decreased 0.29 gal/min), and 146 ft bls (upward flow decreased 0.05 gal/min).

The depth to water in borehole BE-1723 increased slightly under pumping conditions. The depth to water on October 28, 2002, was 53.71 ft bls, and on November 7, 2002, was 53.80 ft bls. At the Allentown, Pa., airport, precipitation for the period of October 21 through October 28 totaled 0.90 in. and from October 29 through November 7 totaled 0.98 in. *(http://wcg08.met.psu.edu/cgi-bin/ida2.cgi)*.

In summary, changes in vertical borehole flow and water levels were measured between nonpumping and pumping conditions. The changes, however, were minor and are difficult to assign to the effects of pumping the site extraction well. Additional work, such as packer testing, would be useful in determining any hydraulic connection between borehole BE-1723 and the site extraction well.

BE-1724 (MW-4)

The water level measured at the time of borehole geophysical logging on October 31, 2002, was 34.59 ft bls. The caliper log (fig. 4) shows the total depth of the borehole is 61 ft. The caliper log also shows the borehole is cased with 6-in.-diameter casing to 57 ft bls. The caliper log shows a major fracture from 57 to 61 ft bls. An obstruction at 61 ft bls prevented logging of the borehole to its original depth of 150 ft. No other borehole geophysical logs were run in well BE-1724 on October 31, 2002. The geologist log is summarized in fig. 4; detailed descriptions are presented in table 6.

Table 6. *Geologist log for borehole BE-1724 (MW-4) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

[ft bls, feet below land surface]

Depth (ft bls)	Comment
0–2	**SANDY**, some clay, silt, small quartz pebbles
2–14	**SAPROLITE**, some sand and silt, small granitic clasts
14–31.5	**SAPROLITE,** micaceous, quarts, trace hornblende; wet Split spoon refusal at 31.5 ft bls
31.5–63	**GRANITIC GNEISS**, some quartz and mica, little hornblende and plagioclase; hard; fractures; weathered
63–64.5	**PEGMATITE**, quartz rich, some chlorite, hornblende, plagioclase; hard; moderately fractured; weathered
64.5–112.5	**GRANITIC GNEISS**, feldspar rich, quartz, some hornblende, chlorite, quartz veins; hard; closely fractured
112.5–116.5	**PEGMATITE**, quartz rich, some chlorite, hornblende, hard; closely fractured
116.5–150	**GRANITIC GNEISS**, quartz rich, varying amounts plagioclase, hornblende, chlorite, hard; closely fractured Scattered slickensides

After several months of continuous pumping of the site extraction well, borehole BE-1724 was logged with the heatpulse flowmeter on January 10, 2003. The heatpulse-flowmeter measurements indicated downward flow at 45 and 55 ft bls and no flow at 35 ft bls (table 7). Water enters the borehole through a break in casing at approximately 39 ft bls and exits the borehole through the major fracture at 57 to 61 ft bls. Downward vertical flow indicates borehole BE-1724 is in a ground-water recharge area.

Table 7. *Summary of heatpulse-flowmeter measurements for borehole BE-1724 (MW-4) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

Depth (feet below land surface	Flow rate when the site extraction well was pumping (gallon per minute)	Flow direction when the site extraction well was pumping
	Measured January 10, 2003	
35	no flow	not determined
45	0.26	down
55	.32	down

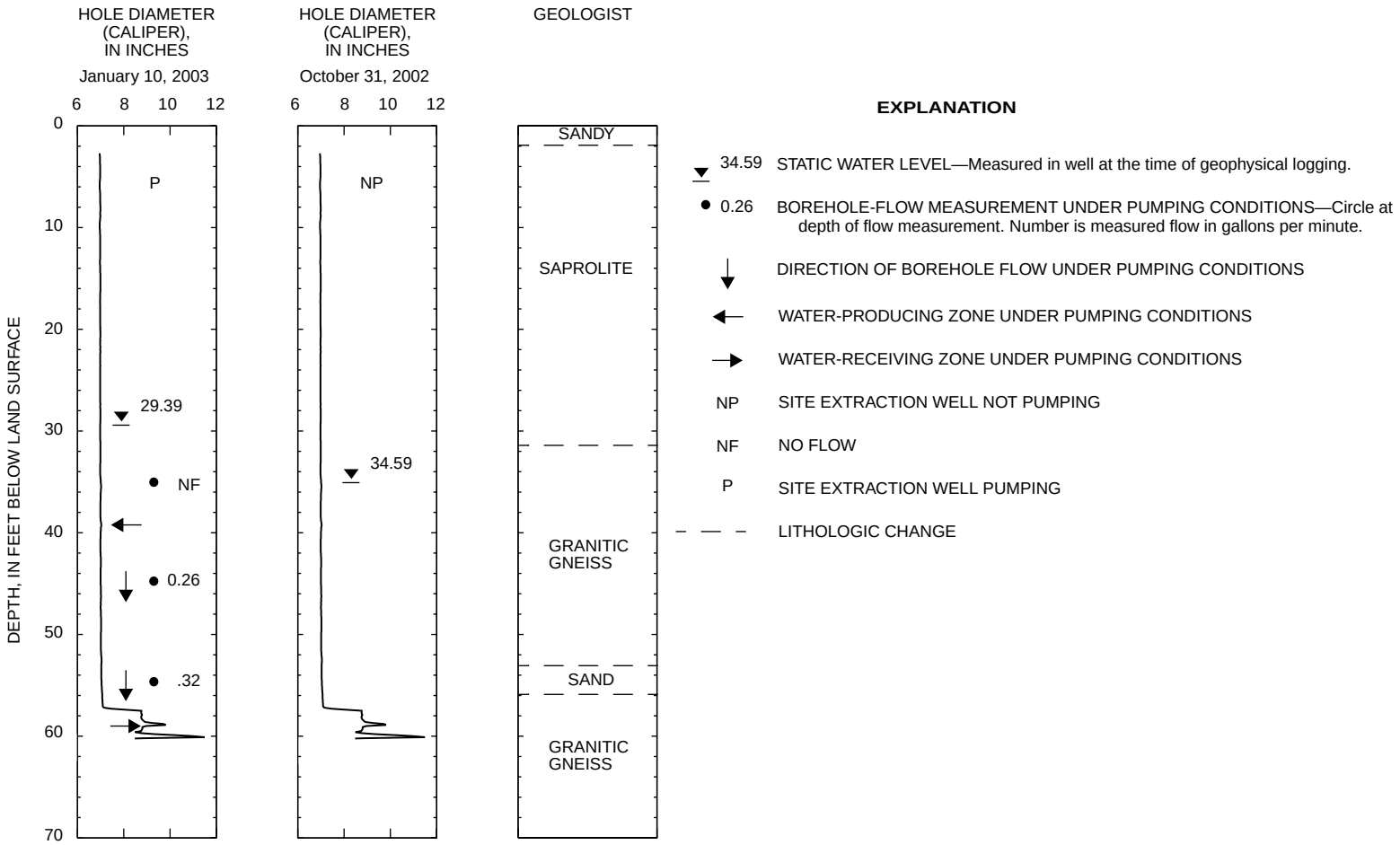

Figure 4. Geologist and caliper logs and direction of flow within borehole BE-1724 (MW-4), Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania. (Geologist log collected from August 14, 1987 through September 1, 1987. Caliper log collected on October 31, 2002. Direction of flow data collected on January 10, 2003.)

Despite pumping from the site extraction well, water levels show a marked rise of 5.20 ft between October 31, 2002, and January 10, 2003. This increase in water levels is probably the result of ground-water recharge. Above-normal precipitation at the Allentown, Pa., airport was reported for October 2002 and near normal for November and December 2002. Total precipitation for the months of October, November, and December 2002 were 6.84, 3.32, and 4.95 in., respectively; the total precipitation from January 1 through January 10, 2003, was 1.19 in. *(http://wcg08.met.psu.edu/cgi-bin/ida2.cgi)*. The considerable change in water levels between pumping and nonpumping conditions suggests minimal influence of the site extraction well on borehole BE-1724, but this influence can not be confirmed with the available data.

BE-1725 (MW-6)

The water level measured at the time of borehole geophysical logging on October 29, 2002, was 36.94 ft bls. The caliper log (fig. 5) shows the total depth of the borehole is 152 ft. The caliper log also shows the borehole is cased with 6-in.-diameter casing to 58 ft bls. The caliper log shows major fractures at 58 to 60, 62 to 68, and 101 to 103 ft bls plus numerous smaller fractures throughout the openhole interval. The natural-gamma log indicates abrupt changes in lithology from 29 to 32, 35 to 48, 82 to 87, and 100 to 115 ft bls. The geologist log (fig. 5, table 8) indicates substantial variation in the presence of chlorite and magnetite. The single-point-resistance log shows changes in slope at 67, 79, 86, 102, and 127 ft bls that correlate to fractures shown on the caliper log. The large change in slope at 48 ft bls is related to a break in the casing. The temperature log shows abrupt changes in slope at 48 and 58 ft bls that correlate to the break in casing and the bottom of casing, respectively. A slight change in slope at about 102 ft bls correlates to a major fracture.The acoustic-televiewer log shows 17 fractures (table 9). Fifty-nine percent (10 of 17) of the fractures strike north to northwest and dip to the northeast.

Table 8. *Geologist log for borehole BE-1725 (MW-6) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

[ft bls, feet below land surface; gal/min, gallons per minute]

Depth (ft bls)	Comment
0–2.5	**SANDY LOAM and SAND**, some clay, silt, granitic clasts
2.5–11	**SAPROLITE**, clay and sand, some mica and small granitic clasts
11–20	**SAPROLITE,** micaceous, quarts, trace hornblende
20–30.7	**SAPROLITE,** micaceous, quarts, some hornblende; wet
30.7–34.5	**GRANITIC GNEISS**, quartz, mica, hornblende in varying amounts; moist to wet; hard; foliated; highly weathered Auger refusal at 34.5 ft bls
34.5–45	**CLAY**, soft to hard with hard granitic fragments; producing about 2 gal/min
45–120	**GRANITIC GNEISS**, quartz, hornblende, and chlorite; hard; borehole collapsing to 60 ft bls Producing about 30 gal/min by 66 ft bls Magnetite rich at 88 ft bls; very hard Producing about 50 gal/min by 100 ft bls
120–140	**GRANITIC GNEISS**, quartz rich, little chlorite and hornblende; foliated
120–150	**GRANITIC GNEISS**, chlorite and hornblende rich, abundant quartz, some plagioclase

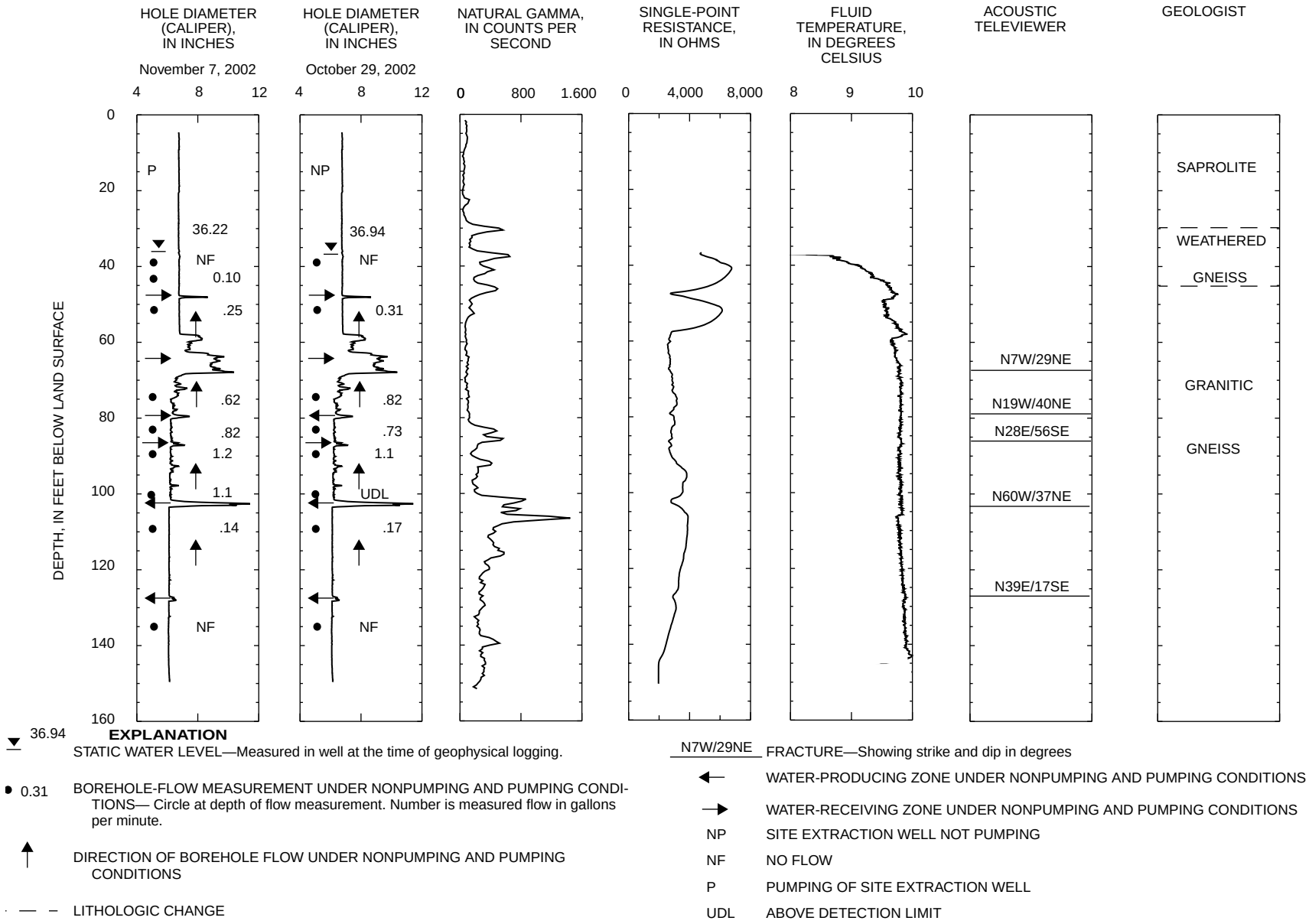

Figure 5. Geologist log, borehole geophysical logs, and direction of flow within borehole BE-1725 (MW-6), Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania. (Geologist log collected from August 20, 1987 through September 26, 1987. Borehole geophysical logs collected on October 29, 2002. Direction of flow data collected on October 29 and November 7, 2002.)

Table 9. *Locations of fractures and measurement of strike and dip determined from acoustic-televiewer log for borehole BE-1725 (MW-6) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

[ft bls, feet below land surface; strike and dip in degrees; Receiving, zone where water exits borehole; Producing, zone where

water enters borehole; Trace, zone where small amount of water enters or leaves borehole; —, no comment]

Depth (ft bls)	Comment	Strike of fracture	Dip of fracture	Depth (ft bls)	Comment	Strike of fracture	Dip of fracture
68	Receiving	N7W	29NE	94	—	N12W	42NE
72	—	N13W	62NE	97	—	N74W	39NE
74	—	N6W	53NE	103	Producing	N60W	37NE
76	—	N27W	61NE	127	Producing	N39E	17SE
77	—	N80E	38SE	127	Producing	N43W	17NE
79	Receiving	N19W	40NE	128	Producing	N90E	75SE
87	Receiving/Producing	N28E	56SE	132	—	N2E	4NW
91	—	N31W	54NE	149	—	N32E	52SE
93	—	N12E	32NW				

On October 29, 2002, when the site extraction well was not pumping, the heatpulse-flowmeter measurements indicated upward flow at 53, 75, 84, 90, 100, and 110 ft bls; no flow was measured at 40 and 136 ft bls (table 10). The suite of borehole geophysical logs indicates water enters the borehole at 127 to 128 and 101 to 103 ft bls under nonpumping conditions. Water exits the borehole through fractures at 58 to 68, 79 to 80, and 86 to 88 ft bls and the break in casing at 48 ft bls.

Table 10. *Summary of heatpulse-flowmeter measurements for borehole BE-1725 (MW-6) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

[—, not measured]

Depth (feet below land surface)	Flow rate when the site extraction well was not pumping (gallons per minute)	Flow direction when the site extraction well was not pumping	Flow rate when the site extraction well was pumping (gallons per minute)	Flow direction when the site extraction well was pumping
	Measured October 29, 2002		Measured November 7, 2002	
40	no flow	not determined	no flow	not determined
44	—	—	0.10	up
53	0.31	up	.25	up
75	.82	up	.62	up
84	.73	up	.82	up
90	1.1	up	1.2	up
100	not determined	up	1.1	up
110	.17	up	.14	up
136	no flow	not determined	no flow	not determined

After several days of continuous pumping of the site extraction well, borehole BE-1725 was again logged with the heatpulse flowmeter on November 7, 2002. The heatpulse-flowmeter measurements indicated that (1) borehole BE-1725 is in an area of ground-water discharge (upward borehole flow), (2) the direction of vertical flow remained identical, and (3) the same fractures were hydraulically active during the nonpumping and pumping measurements.

Minor differences in vertical flow rates were observed under nonpumping and pumping conditions. Under pumping conditions, the borehole flow rates on November 7 generally decreased (table 10); the exceptions are at 84 (upward flow increased 0.09 gal/min) and 90 ft bls (upward flow increased 0.1 gal/min). In addition, the fracture at 80 ft bls that was a producing zone on October 29 was a receiving zone on November 7 (fig. 5).

A considerable change in water levels was measured under nonpumping and pumping conditions. The depth to water under pumping conditions decreased 0.72 ft compared to the nonpumping water level (fig. 5). At the Allentown, Pa., airport, precipitation for the period of October 21 through October 29 totaled 1.25 in. and from October 30 through November 7 totaled just 0.63 in. The most significant amounts of precipitation in October were on October 10 (1.18 in.), October 11 (2.55 in.), and October 16 (1.23 in.) *(http://wcg08.met.psu.edu/cgi-bin/ida2.cgi)*.

In summary, changes in vertical borehole flow and water levels were measured between nonpumping and pumping conditions. The changes in borehole flow, however, were minor and may be the result of precipitation events as evidenced by a change in water levels. Additional work, such as packer testing, would be useful in determining any hydraulic connection between borehole BE-1725 and the site extraction well.

BE-1726 (MW-7)

The water level measured at the time of borehole geophysical logging on October 29, 2002, was 65.15 ft bls. The caliper log (fig. 6) shows the total depth of the borehole is 152 ft. The caliper log also shows the borehole is cased with 6-in.-diameter casing to 32 ft bls. The caliper log shows a major fracture at 32 to 33 ft bls plus smaller fractures at 48, 69, 80, and 97 ft bls. The natural-gamma log shows minor changes in lithology at 53 to 57, 114 to 118, and 146 to 148 ft bls. The geologist log, however, does not indicate any substantial change in lithology (table 11). The single-point-resistance log shows changes in slope at 69, 80, 97, 108, 111, and 114 ft bls that correlate to small fractures on the caliper log. The temperature log shows a minor change in slope at 80 ft bls that correlates to a small fracture. The acoustic-televiewer log shows 48 fractures (table 12). Fifty-eight percent (28 of 48) of the fractures strike north to northwest and 33 percent (16 of 48) dip to the southwest.

Table 11. *Geologist log for borehole BE-1726 (MW-7) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

[ft bls, feet below land surface; gal/min, gallons per minute]

Depth (ft bls)	Comment
0–5.5	**SAND**, some clay, granitic clasts
5.5–20	**GRANITIC GNEISS**, quartz rich, some hornblende and mica; hard; highly weathered
20–60	**GRANITIC GNEISS,** abundant quartz and plagioclase, some mica and hornblende; hard; highly weathered Vadose zone at 22 ft bls Producing 3 gal/min by 39 ft bls
60–87	**GRANITIC GNEISS**, plagioclase rich, abundant quartz, chlorite and hornblende Fracture at 80 ft bls Producing about 4 gal/min by 80 ft bls
87–107	**GRANITIC GNEISS**, quartz and mica, albite feldspar-rich Producing 5–6 gal/min by 96 ft bls Lost water momentarily at 107 ft bls
107–115	**PEGMATITE**, magnetite rich, some chlorite and hornblende, quartz; fractured
115–145	**GRANITIC GNEISS**, quartz and plagioclase rich, some hornblende and chlorite Producing about 3–4 gal/min
145–153	**GRANITIC GNEISS**, hornblende and chlorite rich, quartz, some mica Calculated 8 gal/min

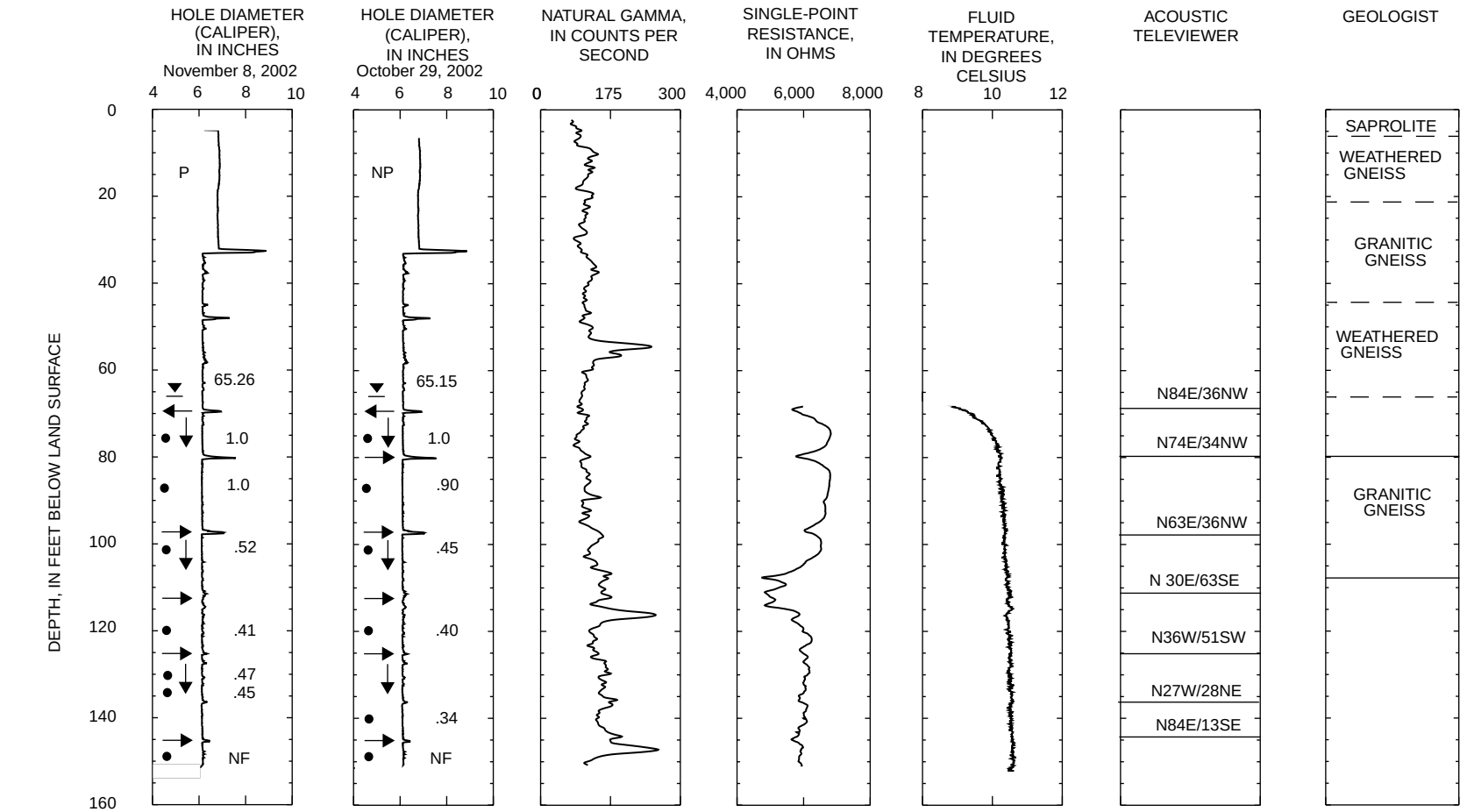

Figure 6. Geologist log, borehole geophysical logs, and direction of flow within borehole BE-1726 (MW-7), Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania. (Geologist log collected from August 20 through September 29, 1987. Borehole geophysical logs collected on October 29, 2002. Direction of flow data collected on October 29 and November 8, 2002.)

Table 12. *Summary of acoustic-televiewer measurements for borehole BE-1726 (MW-7) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

[ft bls, feet below land surface; strike and dip in degrees; Producing, zone where water enters borehole; Trace, zone where small amount of water enters or leaves borehole; Receiving, zone where water exits borehole; —, no comment]

Depth (ft bls)	Comment	Strike of fracture	Dip of fracture	Depth (ft bls)	Comment	Strike of fracture	Dip of fracture
67	—	N56E	49NW	115	—	N79W	38NE
69	Producing	N84E	36NW	116	—	N65E	66SE
70	—	N33W	54NE	118	—	N39W	39SW
71	Trace	N87E	60NW	118	—	N10W	61SW
75	Trace	N30W	84NE	120	—	N33W	42NE
77	Trace	N48E	65SE	122	—	N45E	61SE
77	Trace	N36W	85NE	123	—	N50W	65SW
80	Receiving/Neutral	N74E	34NW	124	Receiving	N35W	77SW
91	—	N39E	61SE	125	Receiving	N41W	29SW
93	—	N34W	72SW	125	Receiving	N36W	51SW
96	—	N50E	68NW	127	Receiving	N34W	26NE
97	Receiving	N74W	45NE	129	—	N70W	70SW
97	Receiving	N63E	36NW	129	—	N62W	68SW
98	—	N46E	58NW	131	—	N1W	40NE
103	—	N40E	56SE	132	—	N48W	50SW
105	—	N19W	69SW	132	—	N41W	59SW
106	—	N33E	44SE	136	Receiving	N27W	28NE
106	—	N24W	60SW	143	—	N85W	43SW
108	—	N76W	42NE	144	—	N20E	60SE
108	—	N53E	50SE	144	—	N13E	44NW
111	Receiving	N30E	63SE	145	Receiving	N84E	13SE
112	Receiving	N43E	62SE	146	—	N81W	58SW
113	—	N28W	64SW	146	—	N81W	59NE
115	—	N49E	44SE	147	—	N62W	74NE

On October 29, 2002, when the site extraction well was not pumping, the heatpulse-flowmeter measurements indicated downward flow at 76, 87, 102, 120, and 140 ft bls; no flow was measured at 148 ft bls (table 13). The suite of borehole geophysical logs indicates water enters the borehole at 69 ft bls at the contact between the heavily weathered and less heavily weathered granitic gneiss and flows downward under nonpumping conditions. Water exits the borehole through fractures at 80, 97, 111 to 112, 124 to 125, 127, 136, and 147 ft bls.

After several days of continuous pumping of the site extraction well, borehole BE-1726 was again logged with the heatpulse flowmeter on November 8, 2002. The heatpulse-flowmeter measurements indicated that (1) borehole BE-1726 is in an area of ground-water recharge (downward borehole flow) with all of the recharge water flowing through weathered granitic gneiss and (2) the magnitude and direction of vertical flow were essentially similar. The same fractures were hydraulically active during the nonpumping and pumping measurements.

Table 13. *Summary of heatpulse-flowmeter measurements for borehole BE-1726 (MW-7) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

Depth (feet below land surface)	Flow rate when the site extraction well was not pumping (gallon per minute)	Flow direction when the site extraction well was not pumping	Flow rate when the site extraction well was pumping (gallon per minute)	Flow direction when the site extraction well was pumping
	October 29, 2002		November 8, 2002	
76	1.0	down	1.0	down
87	.9	down	1.0	down
102	.45	down	.52	down
120	.40	down	.41	down
129	—	—	.47	down
134	—	—	.45	down
140	.34	down	—	—
148	no flow	not determined	no flow	not determined

Minor differences were observed between nonpumping and pumping conditions. Under pumping conditions, the borehole flow at 87 ft bls increased by 0.1 gal/min, indicating the fracture at 80 ft bls was no longer a receiving zone. Also under pumping conditions, flow at 102 ft bls increased 0.07 gal/min to 0.52 gal/min (table 13).

The depth to water in borehole BE-1726 increased slightly under pumping conditions. The depth to water on October 29, 2002 was 65.15 ft bls, and on November 8, 2002 was 65.26 ft bls. At the Allentown, Pa., airport, precipitation for the period of October 21 through October 29 totaled 1.25 in. and from October 30 through November 7 totaled just 0.63 in. *(http://wcg08.met.psu.edu/cgi-bin/ida2.cgi)*.

In summary, changes in vertical borehole flow and water levels were measured between nonpumping and pumping conditions. The changes in borehole flow, however, were minor and difficult to interpret. Additional work, such as packer testing, would be useful in determining any hydraulic connection between borehole BE-1726 and the site extraction well.

BE-1727 (MW-9)

The water level measured at the time of borehole geophysical logging on October 31, 2002, was 38.00 ft bls. The caliper log (fig. 7) of October 31, 2002, shows the total depth of the borehole is 151 ft. The caliper log also shows the borehole is cased with 6-in.-diameter casing to 50 ft bls. The caliper log on October 31, 2002, shows an obstruction of the borehole from 50 to 58 ft bls and small fractures at 58, 60, 92, and 126 to 128 ft bls. The natural-gamma log only shows minor variation in lithology. The geologist log (fig. 7, table 14) indicates moderate fracturing throughout most of the borehole. Areas that are very fractured or strongly weathered appear to be permeable zones that permit the movement of water into and out of the borehole. The contact between weathered and less weathered granitic gneiss may be a major receiving zone. The single-point-resistance log shows changes in slope at 54, 65, and 126 ft bls that correlate to variations in weathering or the presence of fractures as shown on the caliper or geologist log. The temperature log shows a minor change in slope at 52 ft bls that correlates to a change to less weathered granitic gneiss.

Table 14. *Geologist log for borehole BE-1727 (MW-9) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

[ft bls, feet below land surface]

Depth (ft bls)	Comment
0–1	**CLAY**, some sand, small granitic clasts
1–9.5	**SAPROLITE**, sand, some clay, random granitic clasts; dry
9.5–13	**GRANITIC GNEISS,** quartz with abundant plagioclase, very hard; dry; foliated and fractured; highly weathered Auger refusal at 13 ft bls
13–52	**GRANITIC GNEISS**, quartz rich, micaceous; alternating layers of resistant and less resistant rock; highly fractured and weathered
52–72.5	**GRANITIC GNEISS**, quartz rich, occasional quartz and chlorite veins, abundant plagioclase, some hornblende; moderately to closely fractured; foliated; slickensides along fracture at 70 ft bls; hard
72.5–73.2	**MICA**, biotite; highly fractured; hard
73.2–130.3	**GRANITIC GNEISS**, quartz rich, abundant mica, variable amounts of hornblende, chlorite, plagioclase, and feldspar; foliated; moderately fractured; hard Quartz vein from 80.3–80.7 ft bls Series of fractures 80.5–82 ft bls dipping at 60°–65° Very fractured 84–85, 90–92, 106–108 ft bls
130.3–132	**PEGMATITE**, quartz and plagioclase; slightly fractured; hard
132–139.5	**GRANITIC GNEISS**, quartz, mica, some chlorite, little hornblende; closely fractured; friable; highly weathered
139.5–140.5	**PEGMATITE**, quartz and plagioclase; hard
140.5–151	**GRANITIC GNEISS**, biotite and quartz rich, abundant plagioclase, chlorite filled fractures; well foliated; moderately fractured; slightly weathered

Prior to logging with the heatpulse flowmeter on January 10, 2003, the well was cleaned out and the obstruction removed. The caliper log of January 10, 2003, shows the total depth of the borehole is 146 ft bls. The caliper log also shows a major fracture at 54 to 55 ft bls that probably is related to the contact between weathered and less weathered granitic gneiss.

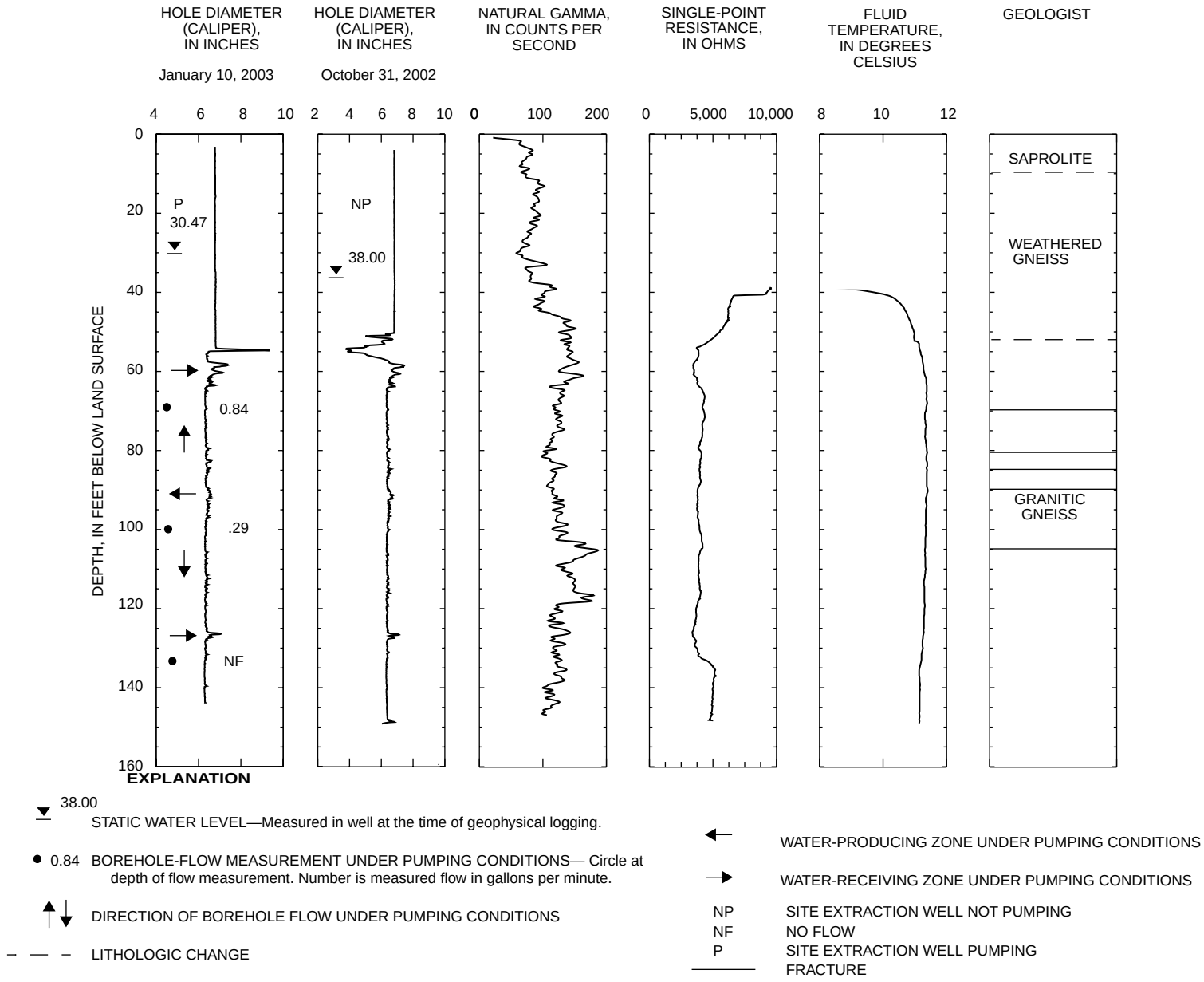

Figure 7. Geologist log, borehole geophysical logs, and direction of flow within borehole BE-1727 (MW-9), Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania. (Geologist log collected from August 12 to September 18, 1987. Borehole geophysical logs collected on October 31, 2002. Direction of flow data collected on January 10, 2003.)

The heatpulse-flowmeter measurements indicated downward and upward flow (table 15). This suggests that borehole BE-1727 is in an intermediate hydrologic regime. Water enters the borehole at a fracture described on the geologist log at approximately 90 to 92 ft bls. The upward flow exits the borehole through small fractures from approximately 54 to 64 ft bls and (or) the contact between highly weathered and less weathered granitic gneiss. The downward flow exits the borehole through a small fracture at approximately 126 to 128 ft bls.

Table 15. *Summary of heatpulse-flowmeter measurements for borehole BE-1727 (MW-9) at the Berks Sand Pit Superfund Site, Longswamp Township, Berks County, Pennsylvania*

Depth (feet below land surface)	Flow rate when the site extraction well was pumping (gallon per minute)	Flow direction when the site extraction well was pumping
	Measured January 10, 2003	
70	0.84	up
100	.29	down
134	no flow	not determined

Despite pumping from the site extraction well, water levels rose 7.53 ft between October 31, 2002, and January 10, 2003. This increase in water levels may be the result of a decrease in evapotranspiration as colder weather set in. Above-normal precipitation at the Allentown, Pa., airport was reported for October 2002 and near-normal precipitation for November and December 2002. Total precipitation for the months of October, November, and December 2002 were 6.84, 3.32, and 4.95 in., respectively; the total precipitation from January 1 through January 10, 2003, was 1.19 in. *(http://wcg08.met.psu.edu/cgi-bin/ida2.cgi)*. The considerable change in water levels between pumping and nonpumping conditions suggests minimal influence of the site extraction well on borehole BE-1727, but this influence can not be confirmed with the available data.

SUMMARY AND CONCLUSIONS

Borehole geophysical logging by the U.S. Geological Survey was conducted on six boreholes to aid in locating water-producing and water-receiving zones and to confirm depth of boreholes and length of casing. Heatpulse-flowmeter measurements were obtained in three wells (BE-1723, BE-1725, BE-1726) to determine if borehole flow rates and direction of borehole flow changed when the site extraction well was pumping and when the site extraction well was inactive. Two wells (BE-1724, BE-1727) were not flowmetered prior to pumping of the site extraction well and, therefore, can not be used to indicate how hydraulic conditions changed. One well (BE-1722) was cased its entire length and no flow measurements were collected. The results of the borehole geophysical logging and heatpulse-flowmeter measurements indicated active flow in the boreholes; two of the boreholes (BE-1723, BE-1725) were in ground-water discharge areas, two boreholes (BE-1724, BE-1726) were in ground-water recharge areas, and one borehole (BE-1727) was in an intermediate regime. Heatpulse-flowmeter measurements, in conjunction with geologist logs, indicate that highly weathered zones in the granitic gneiss can be permeable and effective transmitters of water, confirming the presence of a two-tiered ground-water-flow system.

The effort to determine a hydraulic connection between the site extraction well and five heatpulse-flowmetered boreholes is not conclusive. Boreholes BE-1724 and BE-1727, which were heatpulse flowmetered only under pumping conditions, showed considerable decreases (5.20 and 7.53 ft, respectively) in depth to water measured before pumping and after pumping of the site extraction well. In the remaining three boreholes, no substantial change in source, direction, or amount of flow within individual boreholes was observed during heatpulse flowmetering while the site extraction well was pumped or inactive. The depth to water level in borehole BE-1725 under pumping conditions decreased 0.72 ft compared to the nonpumping water level, suggesting that pumping of the site extraction well did not affect this borehole. The depth to water in boreholes BE-1723 and BE-1726 increased, which could indicate a potential hydraulic connection between the site extraction well or simply be the result of changes in precipitation. A second study employing a packer would provide additional information regarding a hydraulic connection between the site extraction well and boreholes BE-1723, BE-1725, and BE-1726.

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