Evaluation of Borehole Geophysical Logs at the Sharon Steel Farrell Works Superfund Site, Mercer County, Pennsylvania

by Steven D. McAuley

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Conversion Factors and Datum

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
	Area	
acre	4,047	square meter (m^2)
	Volume	
gallon (gal)	3.785	liter (L)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)

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

$$°F = (1.8 \times °C) + 32$$

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

$$°C = 5/9\ (°F - 32)$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

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Abstract

On April 14–15, 2003, geophysical logging was conducted in five open-borehole wells in and adjacent to the Sharon Steel Farrell Works Superfund Site, Mercer County, Pa. Geophysical-logging tools used included caliper, natural gamma, single-point resistance, fluid temperature, and heatpulse flowmeter. The logs were used to determine casing depth, locate subsurface fractures, identify water-bearing fractures, and identify and measure direction and rate of vertical flow within the borehole. The results of the geophysical logging were used to determine the placement of borehole screens, which allows monitoring of water levels and sampling of water-bearing zones so that the U.S. Environmental Protection Agency can conduct an investigation of contaminant movement in the fractured bedrock. Water-bearing zones were identified in three of five boreholes at depths ranging from 46 to 119 feet below land surface. Borehole MR-3310 (MW03D) showed upward vertical flow from 71 to 74 feet below land surface to a receiving zone at 63-68 feet below land surface, permitting potential movement of ground water, and possibly contaminants, from deep to shallow zones. No vertical flow was measured in the other four boreholes.

Introduction

The Sharon Steel Farrell Works Superfund Site is in Mercer County, southwest of Farrell, Pa., at and near the border between Ohio and Pennsylvania (fig. 1). The site was a disposal area for slag and spent pickle liquor acid (an acidic bath solution, in this case containing hydrochloric, sulfuric, and chromic acid, used in industrial cleaning or processing) from the former Sharon Steel Corporation Farrell Works, located across the Shenango River.

Beginning about 1900, the Sharon Steel Corporation used the area across the Shenango River, west and southwest of the manufacturing plant, to dispose of blast furnace slag, electric arc furnace slag, basic oxygen furnace slag, and sludge. From 1949 to 1981, millions of gallons of spent pickle liquor acid were dumped over the slag (CDM Federal Programs Corporation, 2001). It was thought that the acid would partially evaporate and then be neutralized by the slag. Ground-water contamination resulted from this activity. Contaminants detected in ground water included arsenic, lead, and chromium (CDM Federal Programs Corporation, 2001).

A Remedial Investigation/Feasibility Study (RI/FS), phase 2, is being conducted at the Sharon Steel Farrell Works Superfund Site by TetraTech/Black & Veach (TT/B&V). The investigation was focused on the shallow unconsolidated sediments, but the U.S. Environmental Protection Agency (USEPA) identified a need to monitor the bedrock aquifer. As part of the RI/FS, TT/B&V installed five boreholes to monitor the hydraulic head (water level) and chemical quality of the bedrock aquifer beneath the site (Black & Veach Special Projects Corporation, 2002). Borehole geophysical logging of the five bedrock monitor wells was needed to identify water-bearing fractures and to determine optimal screen intervals for use by the USEPA in determining contaminant movement in the fractured bedrock.

Purpose and Scope

This report describes borehole geophysical logs collected by the U.S. Geological Survey (USGS) in five boreholes at the Sharon Steel Farrell Works Superfund Site during April 14-15, 2003 (table 1). The results of borehole geophysical logging and flowmeter surveys performed by the USGS were used to (1) determine casing depth, (2) locate subsurface fractures, (3) identify water-bearing fractures, (4) identify zones of potential vertical flow within the borehole, (5) measure direction and rate of vertical borehole flow to monitor and evaluate contaminant movement, and (5) select the most appropriate depths to screen boreholes. This information will be used by the USEPA in conducting an investigation of contaminant movement in the fractured bedrock.

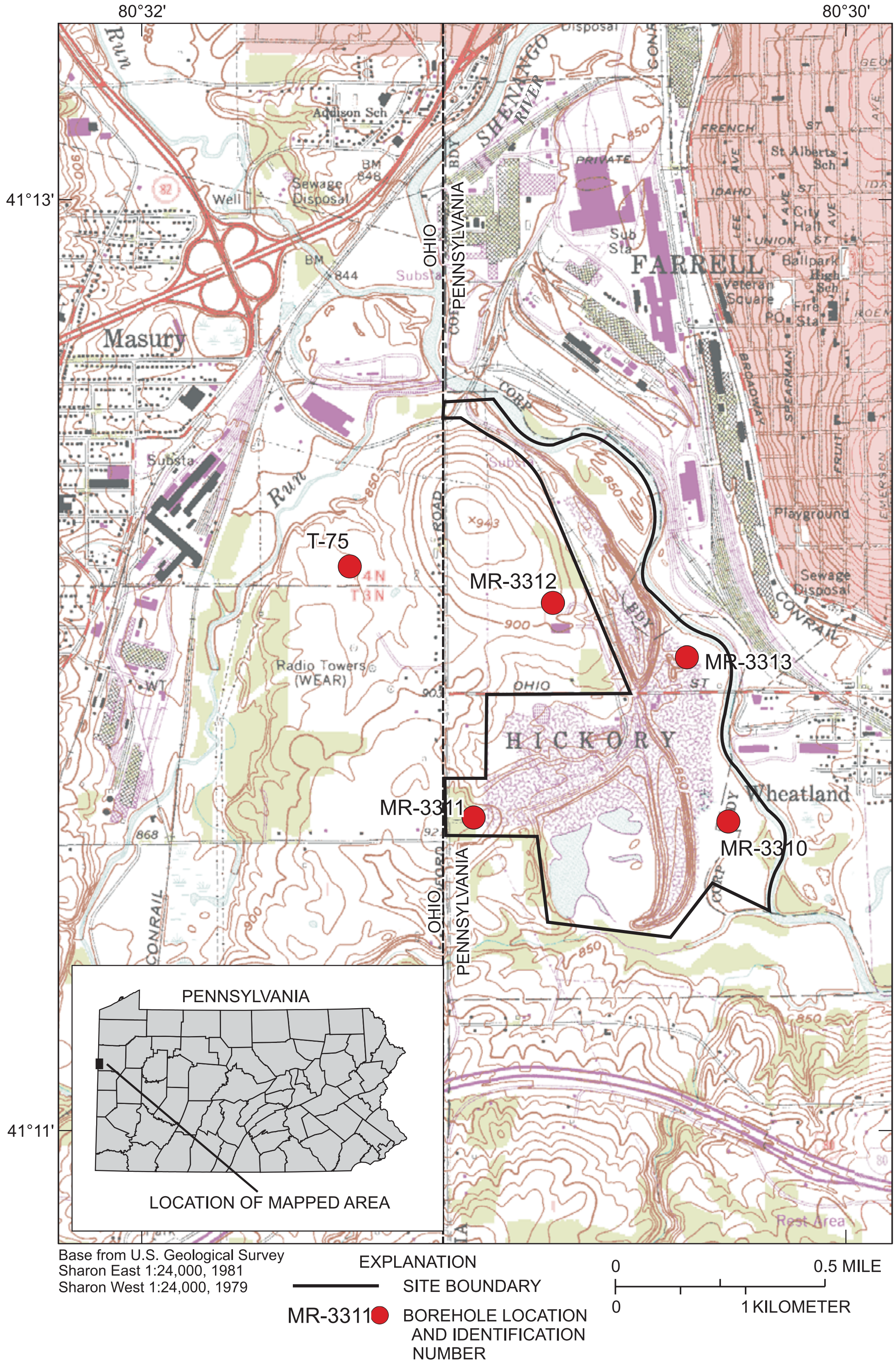


Figure 1. Location of Sharon Steel Farrell Works Superfund Site and boreholes logged, near Farrell, Pennsylvania.

Table 1. Well-identification numbers, latitude and longitude location, depth logged, casing depth, and geophysical logs collected.

[Logs collected: C, caliper; G, natural gamma; R, single-point resistance; T, temperature; V, heatpulse flowmeter]

U.S. Geological Survey well-identification number (fig. 1)	Site number	Latitude/ longitude (degrees, minutes, seconds)	Well depth logged (feet below land surface)	Casing depth (feet below land surface)	Logs collected
T-75	MW10	41°12′11″/ 80°31′24″	76	46	C, G, R, T
MR-3310	MW03D	41°11′38″/ 80°30′21″	113.7	63	C, G, R, T, V
MR-3311	MW4	41°11′38″/ 80°31′04″	146	108	C, G, R, T, V
MR-3312	MW7	41°12′06″/ 80°30′50″	77	20	C, G, R, T, V
MR-3313	MW01D	41°12′00″/ 80°30′28″	119	119	C, G

Study Area Location and Physiography

The Sharon Steel Farrell Works Superfund Site is within the glaciated section of the Appalachian Plateaus Physiographic Province in Mercer County, in western Pennsylvania, on 400 acres of land within 100 ft of the Ohio border. The site is on the Sharon West 7.5-minute USGS quadrangle (fig. 1). The site occupies a transition zone between a commercial and industrial area to the north and west and the rural and residential areas to the west and south of the site. The eastern border of the site is formed by the Shenango River, which flows generally in a southeasterly direction. Approximately 100 acres of wetlands are within the site boundaries. The site is within the 100- and 500-year floodplains of the Shenango River, and areas of the site west and south of the river are higher in elevation than areas north and east of the river by 100 ft or more.

Hydrogeologic Setting

The site is underlain by unconsolidated deposits of sand, silt, and clay to depths of 65 to 120 ft. Four hydrostratigraphic units have been identified at the site (CDM Federal Programs Corporation, 2001). A shallow, unconsolidated aquifer composed of silt and sand occurs at 10 to 30 ft below land surface (bls). A silt and clay semi-confining unit underlies the shallow aquifer to 20 ft bls. A deep aquifer of sand and gravel, from 70 to 120 ft bls, underlies the semi-confining unit, and bedrock underlies the deep aquifer below 120 ft bls. The bedrock consists of Mississippian age shales and sandstones of the Cuyahoga Group.

Ground water occurs and moves in the pore spaces of the unconsolidated sediments and fractures in the bedrock. Regional ground-water flow is generally from upland areas to valleys; thus, the site situated along the valley of the Shenango River is in an area of regional ground-water discharge. Locally, ground-water flow in the shallow, unconsolidated aquifer is to the east and southeast (CDM Federal Programs Corporation, 2001).

Borehole Geophysical Logs

The following geophysical logs were collected by the USGS:

1. caliper,
2. natural gamma,
3. single-point resistance (electrical),
4. fluid temperature,
5. fluid velocity (heatpulse flowmetering) if borehole flow was indicated by the fluid-temperature logs.

Borehole geophysical logs provide information on location and orientation of fractures, water-producing and water-receiving zones, intervals of vertical borehole flow, quantification of borehole flow, lithologic correlation, and borehole construction.

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 correct other geophysical logs for changes in borehole diameter. Caliper logs also can be correlated with fluid-temperature logs and heatpulse flowmetering to further identify fractures and water-producing and water-receiving zones.

The natural-gamma or gamma log measures the natural-gamma radiation (photons) activity, in counts per second, 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 the fluid-filled, dry-cased, or uncased parts of a borehole. However, casing does reduce the gamma response. The gamma log is used to correlate geologic units between boreholes (Keys, 1990).

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 stratigraphy between boreholes and may help identify water-producing zones (Keys, 1990).

A fluid-temperature log provides a continuous record of the vertical variation of temperature 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 volume of water between two sensitive thermistors (heat sensors) located the same distance from the heat source. A measurement of direction and rate is computed when a peak temperature is recorded by one of the thermistors. A flexible diverter is used to block the annular space around the tool to channel all 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; Keys, 1990).

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 or water-receiving zones.

In this study, the heatpulse flowmeter was used to identify borehole flow under static (nonpumping) conditions at depths at which the fluid-temperature logs indicated the possibility of flow. An attempt also was made to repeat the flowmeter survey while pumping the borehole at a rate of less than 1 gal/min. The bedrock boreholes may have low yields (less than 1 gal/min); thus, drawdown may not stabilize and flowmetering under pumping conditions may not be possible.

Evaluation of Borehole Geophysical Logs and Well Screen Placement

Locations of boreholes logged are shown in figure 1. The locational, borehole-identification, and other data for boreholes logged are presented in table 1.

T-75 (MW10)

The caliper log shows the total depth of the borehole is 76 ft (fig. 2). The caliper log indicates the borehole is cased with 4-in.-diameter casing to 46 ft bls. The water level in the borehole at the time of logging was 5.70 ft bls. The measuring point (MP) was the top of casing, 1.4 ft above land surface. The caliper log indicates a fracture from about 46.5 to 48.5 ft bls. The geologic log indicates silty clay with some coarse sand interbedded from surface to 27 ft bls, weathered shale from 27 to 44 ft bls, and competent shale from 44 to 76 ft bls (Michael Napolitan, Black & Veach Special Projects Corporation, written commun., 2004). The gamma log shows a general increase in activity below 45 ft bls because the probe is reading in the open uncased part of the borehole. Variations in gamma activity from 45 ft bls to the bottom of the borehole probably indicate slight differences in sand content within the shale as described in the geologic log (Michael Napolitan, Black & Veach Special Projects Corporation, written commun., 2004). The single-point-resistance log shows decreased electrical resistance at 57 and 68 ft bls. The single-point-resistance log is a mirror image of the gamma log in most places except for the interval from about 46 to 47 ft bls. This area may be too close to the casing bottom to get a correct reading from the single-point-resistance logging tool. The fluid-temperature log is likely showing the effect of cooling with depth from near-surface warming; the log then shows the effect of the geothermal gradient as temperature gradually increases. The heatpulse flowmeter was not run. A borehole screen placed from 44 to 54 ft bls would include the fracture from 46.5 to 48.5 ft bls.

MR-3310 (MW03D)

The caliper log shows the total depth of the borehole is 113.7 ft bls (fig. 3). The bottom of the borehole was covered with a layer of thick mud. The borehole is cased with 4-in.-diameter casing to 63 ft bls. The water level in the borehole at the time of logging was 1.3 ft bls. The MP was the top of casing, 2.5 ft above land surface. The caliper log shows a series of fractures from 63 to 68, 71 to 74, and 79 to 82 ft bls. The geologic log of the borehole drilling shows silt and clay to 51 ft bls, mostly silty sand to 61 ft bls, sandstone to 81 ft bls, siltstone to 89 ft bls, sandstone to 98 ft bls, and siltstone to 113 ft bls (Michael Napolitan, Black & Veach Special Projects Corporation, written commun., 2004). The gamma log shows increases in activity interspersed with decreases in activity from 60 to 113 ft bls. This change in activity indicates silty zones in the sandstone and sandy zones in the siltstone. Over the interval from 60 to 98 ft bls, gamma activity generally increases. The single-point-resistance log is a mirror image of the gamma log. The fluid-temperature log generally shows an increase with depth. Sudden or sharp changes in temperature, however, occur at the fracture zones. Minor temperature increases are shown at 71-74 and 79-82 ft bls, coinciding with fracture zones indicated by the caliper log, and also at 112 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured upward flow at 0.24 gal/min from the fracture at about 71-74 ft bls. Water exits the borehole at the fracture at 63-68 ft bls. No flow was measurable at 77, 86, 94, and 104 ft bls (fig. 3), although there was a minor turbulence at 94 ft bls. A borehole screen placed from 69 to 75 ft bls would include the water-producing fracture at 71-74 ft bls. If the water entering the borehole at the fracture opening from 71 to 74 ft bls is contaminated, cross-contamination of the receiving zone could occur.

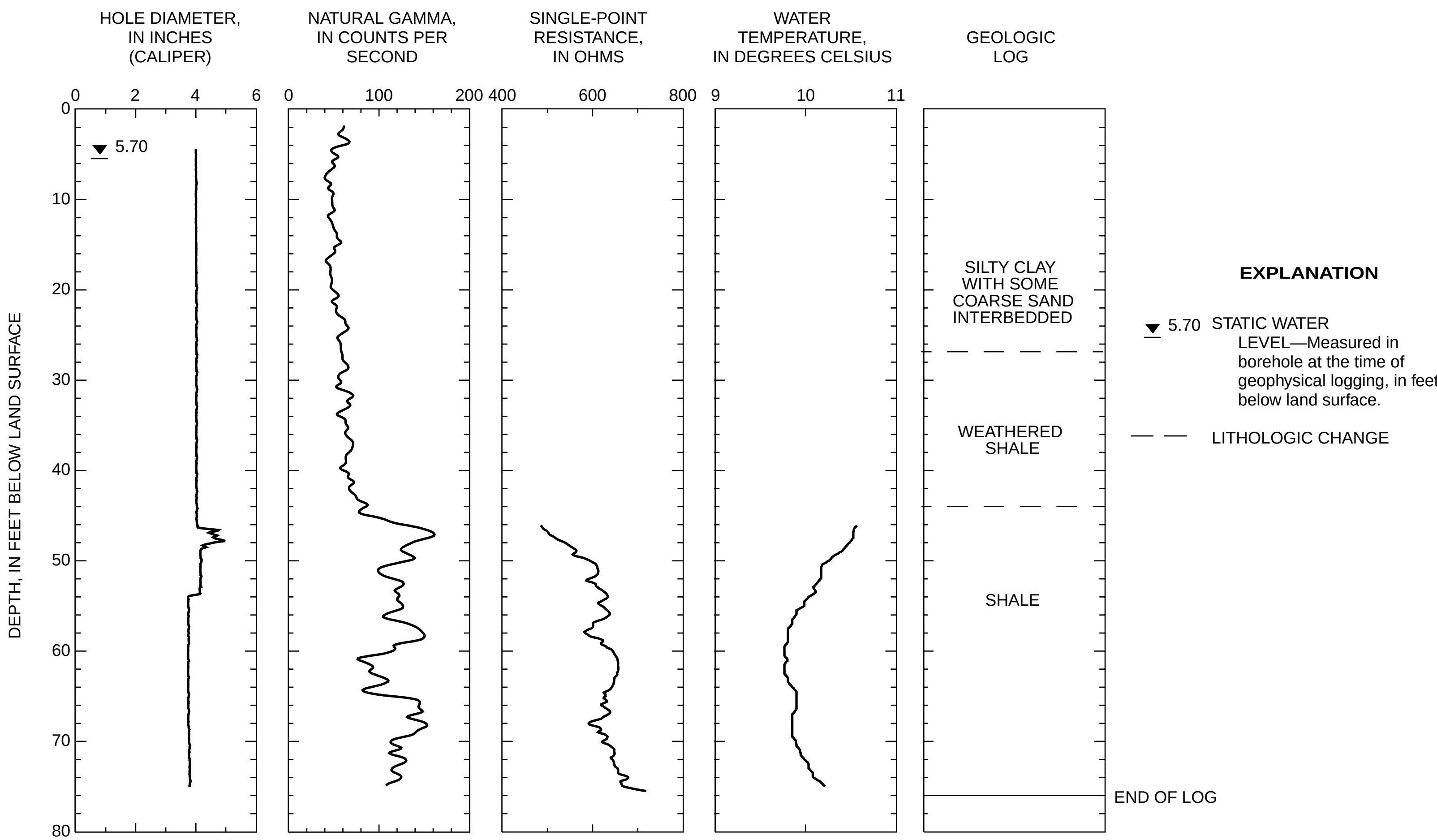
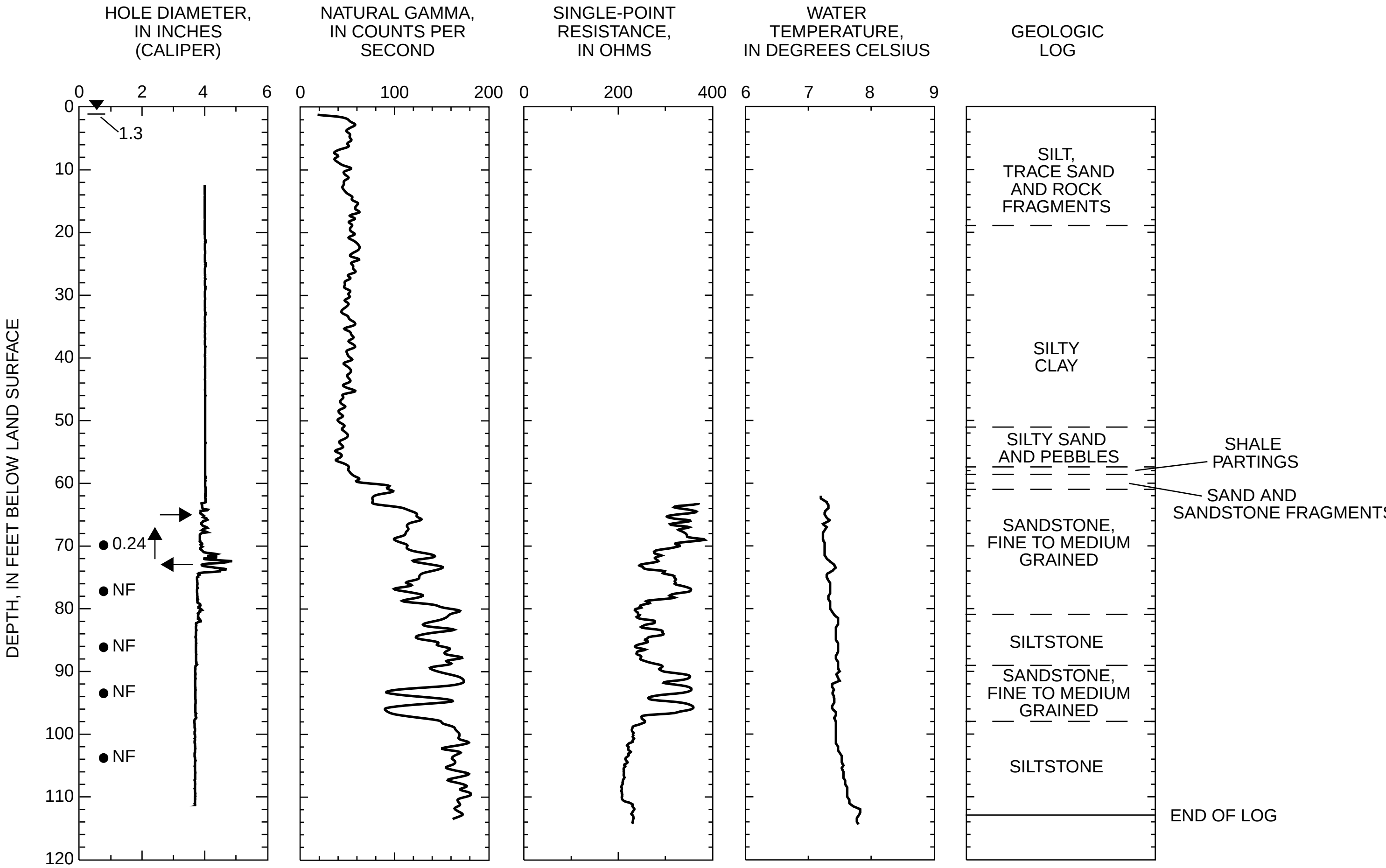


Figure 2. Borehole geophysical logs and water level in borehole T-75 (MW10), collected on April 14, 2003, at Sharon Steel Farrell Works Superfund Site, near Farrell, Pennsylvania (Geologic log from Black & Veach Special Projects Corporation, written commun. 2004).



EXPLANATION

- 1.3 — STATIC WATER LEVEL—Measured in borehole at the time of geophysical logging, in feet below land surface.
- ● 0.24 — BOREHOLE-FLOW MEASUREMENT UNDER NONPUMPING CONDITIONS—Circle at depth of flow measurement. Number is measured flow, in gallon per minute.
- ↑ — DIRECTION OF BOREHOLE FLOW UNDER NONPUMPING CONDITIONS
- ← — KNOWN (OR INFERRED) WATER-PRODUCING ZONE UNDER NONPUMPING CONDITIONS
- → — KNOWN (OR INFERRED) WATER-RECEIVING ZONE UNDER NONPUMPING CONDITIONS
- NF — NO FLOW
- — — — LITHOLOGIC CHANGE

Figure 3. Borehole geophysical logs, water level, and direction of borehole flow under nonpumping conditions in borehole MR-3310 (MW03D), collected on April 14, 2003, at Sharon Steel Farrell Works Superfund Site, near Farrell, Pennsylvania (Geologic log from Black & Veach Special Projects Corporation, written commun. 2004).

MR-3311 (MW4)

The caliper log shows the total depth of the borehole is 146 ft bls (fig. 4). The bottom of the borehole was covered with a layer of thick mud. The gamma, single-point-resistance, and fluid-temperature logs gave readings through the mud to about 150 ft bls. The borehole is cased with 4-in.-diameter casing to 108 ft bls. The water level in the borehole at the time of logging was 49.23 ft bls. The MP was the top of casing, 3.0 ft above land surface. The geologic log indicates sand, sandy silt, and silty sand to 100 ft bls, gravel with siltstone and sandstone fragments to 115 ft bls, and siltstone throughout the rest of the borehole (Michael Napolitan, Black & Veach Special Projects Corporation, written commun., 2004). The caliper log shows a fracture zone from 108 to 110 ft bls and minor fractures from 112 to 116 ft bls. The gamma log shows increases in activity interspersed with decreases in activity from 111 ft bls to the borehole bottom. This change in activity indicates sandy zones within the siltstone, probably as interbedded sandstone. The single-point-resistance log mirrors the gamma log and indicates stratigraphic changes. The fluid-temperature log shows an increase in temperature with depth, indicating no vertical borehole flow. A slight change in the slope on the fluid-temperature log at 110 ft bls coincides with the major fracture zone indicated on the caliper log, which may indicate minor lateral borehole flow. The fluid-temperature log shows increasing temperature with depth that is indicative of the geothermal gradient. Under nonpumping conditions, the heatpulse flowmeter measured no flow at 130 ft bls. A screen set from 108 to 118 ft bls would include the major fractures from 108 to 116 ft bls.

MR-3312 (MW7)

The caliper log shows the total depth of the borehole is 77 ft bls (fig. 5). The borehole is cased with 5-in.-diameter casing to 20 ft bls. The water level in the borehole at the time of logging was 7.36 ft bls. The MP was the top of casing, 0.5 ft bls. The caliper log showed no apparent fracture zones. The geologic log indicates silty clay with traces of sand and gravel to 20 ft bls and shale from casing bottom to borehole bottom. The gamma log shows increases in activity interspersed with decreases in activity from 20 to 77 ft bls that indicate sandy zones interspersed within the shale. The single-point-resistance log exhibits an inverse relation with the gamma log. The changes in fluid temperature are gradual after initial changes from 20 to 23 ft bls, indicating the absence of water-producing or water-receiving zones. Under nonpumping conditions, the heatpulse flowmeter measured no flow at 34 and 56 ft bls. A low-volume pump was placed into the borehole at a depth of about 19 ft bls. The heatpulse flowmeter was set at 34 ft bls. No flow was measured at any depth in the borehole. The water level did not stabilize even at pumping rates that averaged about 0.4 gal/min. Because the casing was below land surface and the borehole had no cap, rainwater may have filled up the borehole. Under present conditions, the borehole provides little useful information, does not clearly demonstrate a connection to a water-bearing zone, and could be abandoned and (or) plugged without loss of information about the flow system.

MR-3313 (MW01D)

The caliper log shows the total depth of the borehole is 119 ft bls (fig. 6). The borehole is cased with 4-in.-diameter steel casing to 119 ft bls. The water level in the borehole at the time of logging was 5.88 ft bls. The MP was the top of casing, 2.4 ft above land surface. A casing-depth indicator was run along the length of the casing and confirmed that the casing runs to 119 ft bls, the entire length of the borehole. The geologic log shows gravel to 4 ft bls, sandy silt and silt to 108 ft bls, gravel to 115.5 ft bls, and siltstone to 166 ft bls. The geologic log reports water at 10 gal/min at 122 ft bls. When drilling at 144 ft, the geologists log reports that the upper hole was collapsing. The entire hole below casing likely collapsed after the drilling tools were removed. Because the borehole was cased to the bottom, no fluid-temperature, single-point-resistance, or heat-pulse-flowmeter logs were run. It is not necessary to set a screen in this borehole, and plugging of the hole would reduce the potential for migration of contaminants along the lower portion of the annular seal of the casing.

Summary

On April 14–15, 2003, the USGS, in cooperation with the USEPA, logged five boreholes drilled into the bedrock of the Mississippian-age Cuyahoga Group at the Sharon Steel Farrell Works Superfund Site, near Farrell, Pa. The borehole geophysical logging and flow measurements were conducted to (1) determine casing depth, (2) locate subsurface fractures, (3) identify water-bearing fractures, (4) identify zones of potential vertical flow within the borehole, (5) measure direction and rate of the vertical borehole flow to monitor and evaluate contaminant movement, and (6) select the most appropriate depths to screen boreholes. The USEPA will use this information to conduct an investigation of contaminant movement in the bedrock.

The boreholes logged ranged from 76 to 150 ft in depth. Water-bearing zones were indicated in three of the five boreholes and ranged in depth from 46 to 119 ft bls. Upward vertical flow from a water-bearing zone at 71-74 ft bls to a water-bearing zone at 63-68 ft bls was identified with the heatpulse flowmeter in borehole MR-3310 (MW03D) and could permit movement of ground water (and contaminants) from deeper bedrock to more shallow water-bearing zones. Optimal screen intervals ranged from 44 to 118 ft bls.

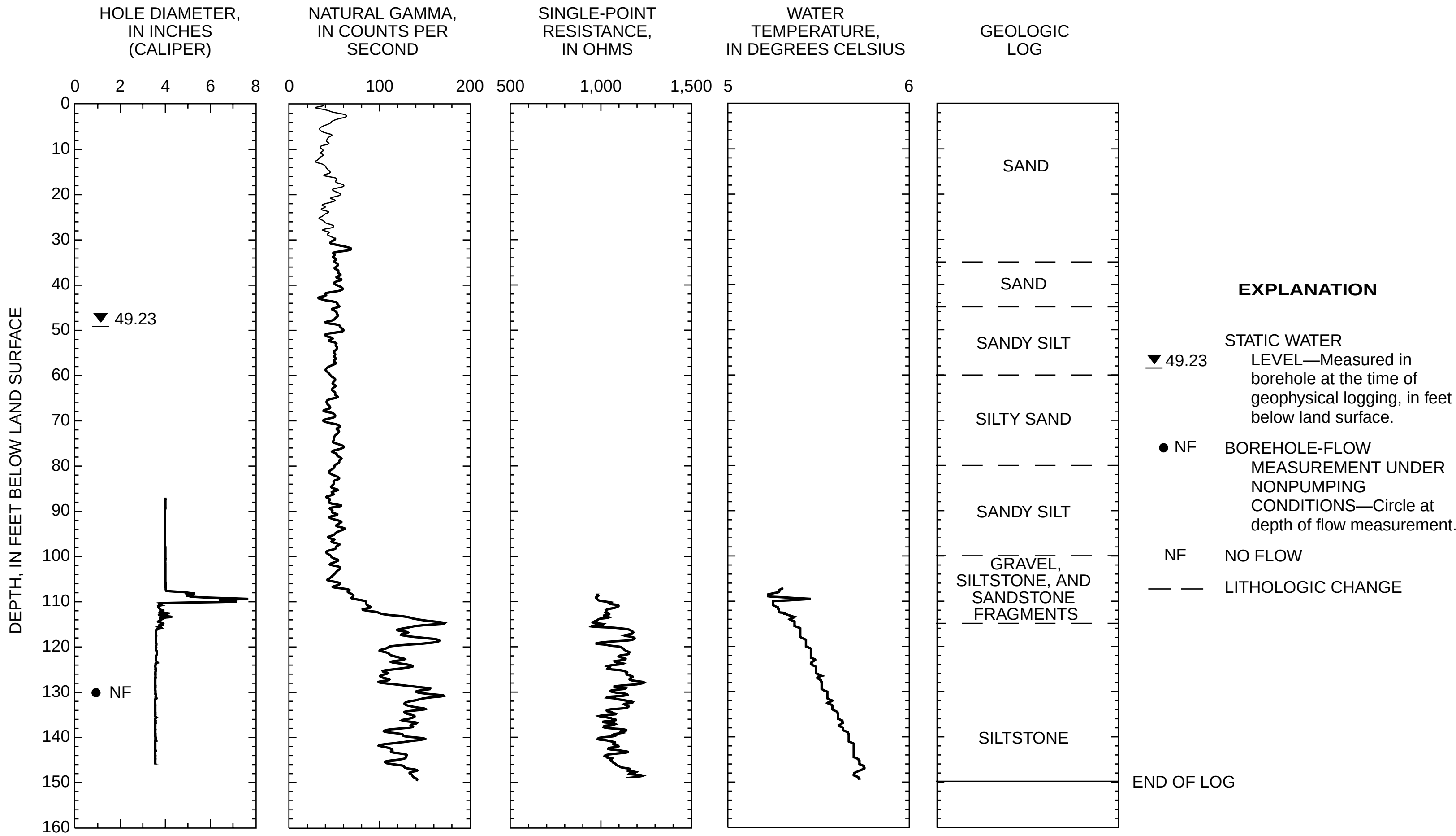


Figure 4. Borehole geophysical logs, water level, and direction of borehole flow under nonpumping conditions in borehole MR-3311 (MW4), collected on April 15, 2003, at Sharon Steel Farrell Works Superfund Site, near Farrell, Pennsylvania (Geologic log from Black & Veach Special Projects Corporation, written commun. 2004).

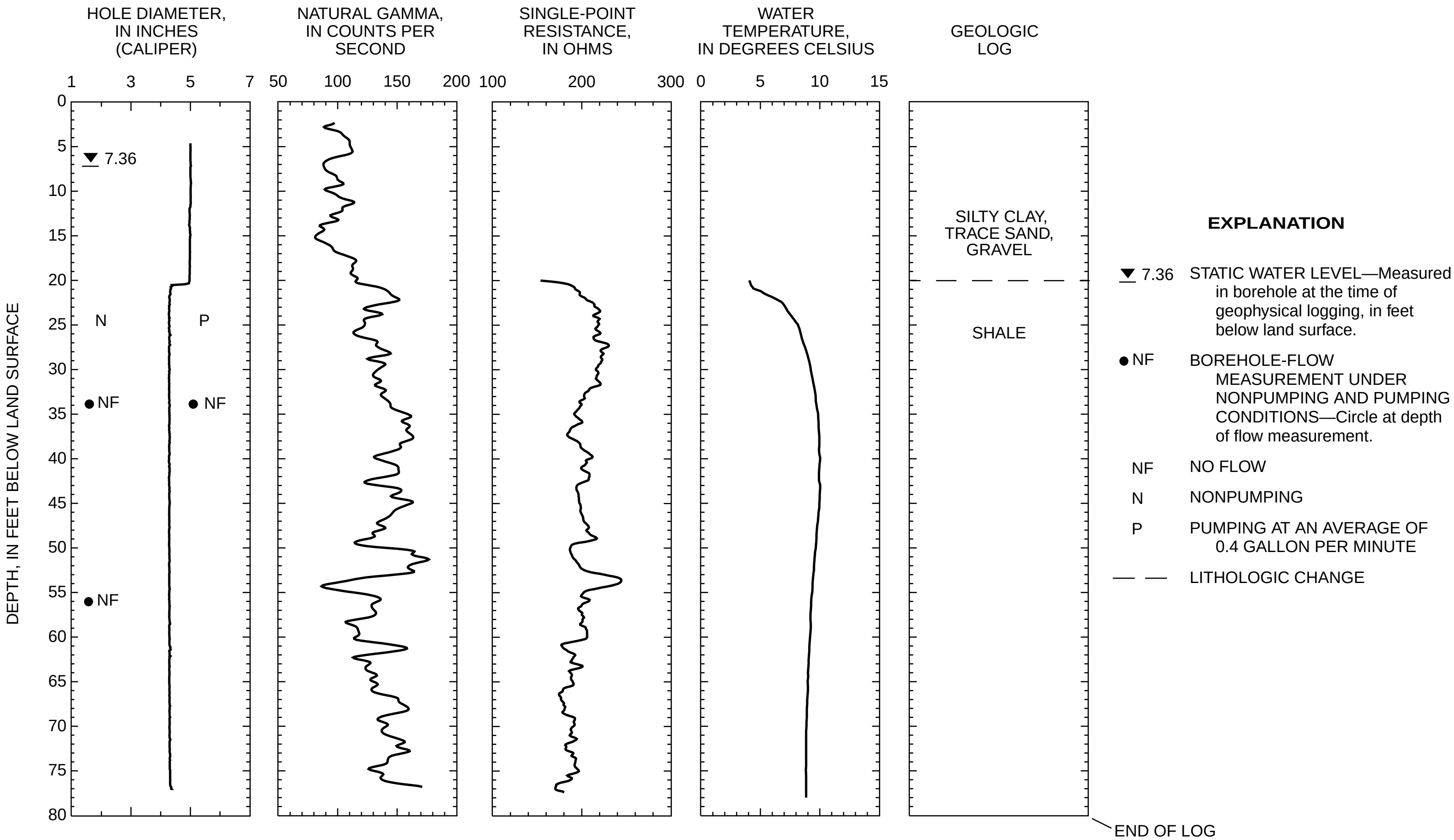


Figure 5. Borehole geophysical logs, water level, and direction of borehole flow under nonpumping and pumping conditions in borehole MR-3312 (MW7), collected on April 15, 2003, at Sharon Steel Farrell Works Superfund Site, near Farrell, Pennsylvania (Geologic log from Black & Veach Special Projects Corporation, written commun. 2004).

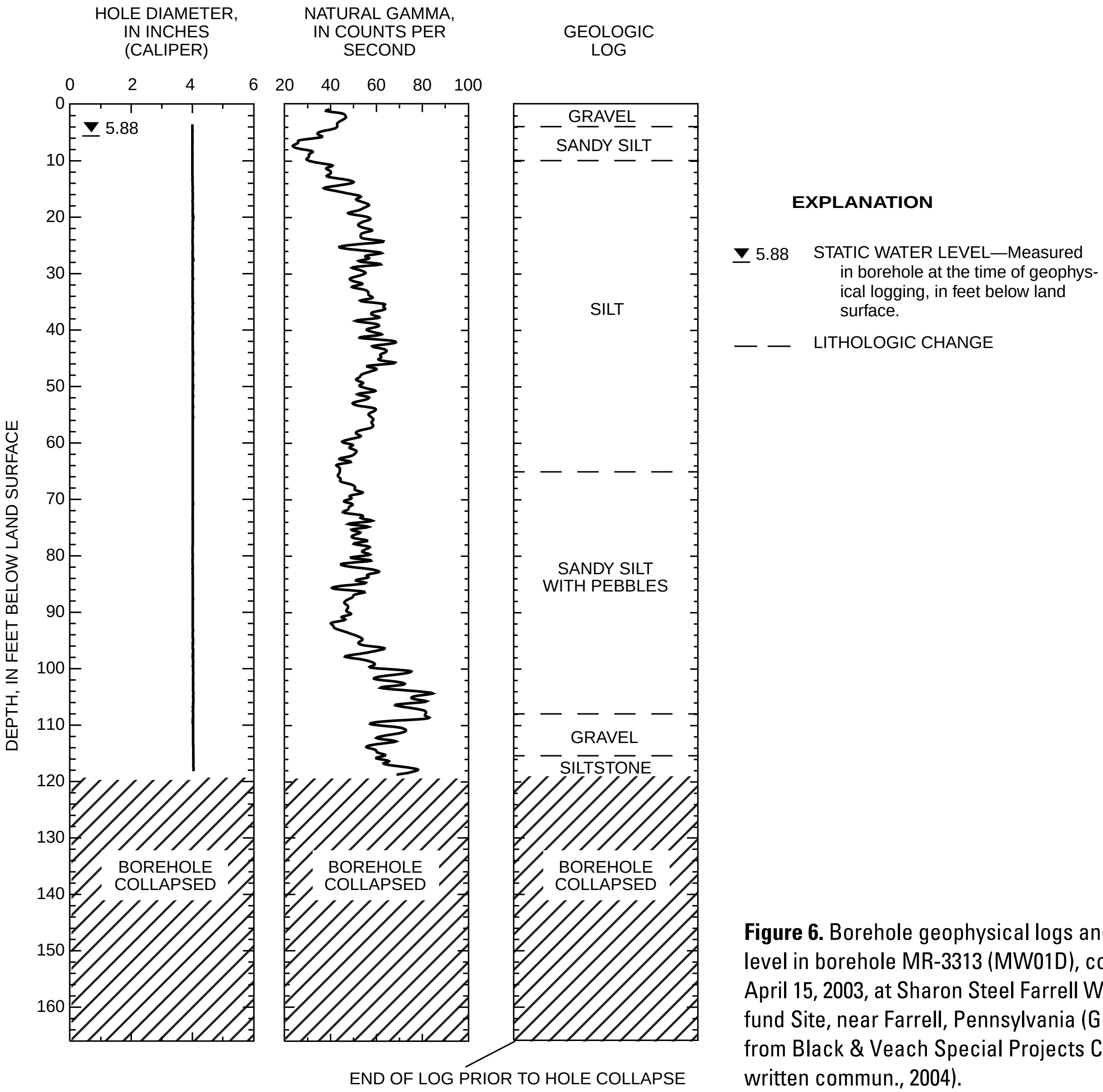


Figure 6. Borehole geophysical logs and water level in borehole MR-3313 (MW01D), collected on April 15, 2003, at Sharon Steel Farrell Works Superfund Site, near Farrell, Pennsylvania (Geologic log from Black & Veach Special Projects Corporation, written commun., 2004).

Acknowledgments

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