LOCATIONS OF FRACTURE INTERVALS INFERRED FROM BOREHOLE LOGS OF EIGHT WELLS AT THE HOLTON CIRCLE SUPERFUND SITE, LONDONDERRY, NEW HAMPSHIRE

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.40	millimeter
inch (in.)	2.540	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Velocity	
foot per second (ft/s)	0.3048	meter per second

Temperature

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows: °F = 9/5 (°C) +32.

Sea Level: In this report, "sea level" refers to the 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 Sea Level Datum of 1929.

Locations of Fracture Intervals Inferred From Borehole Logs of Eight Wells at the Holton Circle Superfund Site, Londonderry, New Hampshire

by Bruce P. Hansen

ABSTRACT

Ground water in fractured bedrock at the Holton Circle Superfund site in Londonderry, New Hampshire, contains volatile organic compounds and chloride concentrations as high as 23,500 mg/L. Geophysical logs obtained from eight bedrock observation wells that range in depth from 65 to 382 feet were used to identify depths of possible water-bearing fractures. Logs included natural gamma, spontaneous potential, single-point resistance, caliper, temperature, and fluid resistivity. All but the natural-gamma log had anomalies that indicate possible fractures. Anomalies at the same depths on several logs from a single well support identification of likely fractures. Charts presented in the report show depths of anomalies that may indicate fractures.

INTRODUCTION

Volatile organic compounds and high concentrations of dissolved constituents, principally sodium (Na) and chloride (Cl), are present in ground water at the Holton Circle Superfund site in Londonderry, N.H. (fig. 1). Water in the bedrock moves primarily through fractures in the foliated schist. During October and November 1990, eight wells were drilled into bedrock by the U.S. Environmental Protection Agency (USEPA) to characterize the hydrology of the site. In cooperation with the USEPA, the U.S. Geological Survey (USGS) logged these eight wells by means of six borehole geophysical methods to identify the locations of possible fractures and fracture zones. Borehole logs were run on each of the eight wells between November 16, 1990, and January 23, 1991. The purpose of this report is to describe the logging methods used, present the logs obtained, and identify depths of possible fractures in each well logged.

The author thanks James M. Di Lorenzo, Waste Management Division, U.S. Environmental Protection Agency, Boston, Mass., who provided background information and logistical assistance during the logging survey.

BOREHOLE LOGS

A borehole logger with single-conductor logging cable was used for this survey. Continuous

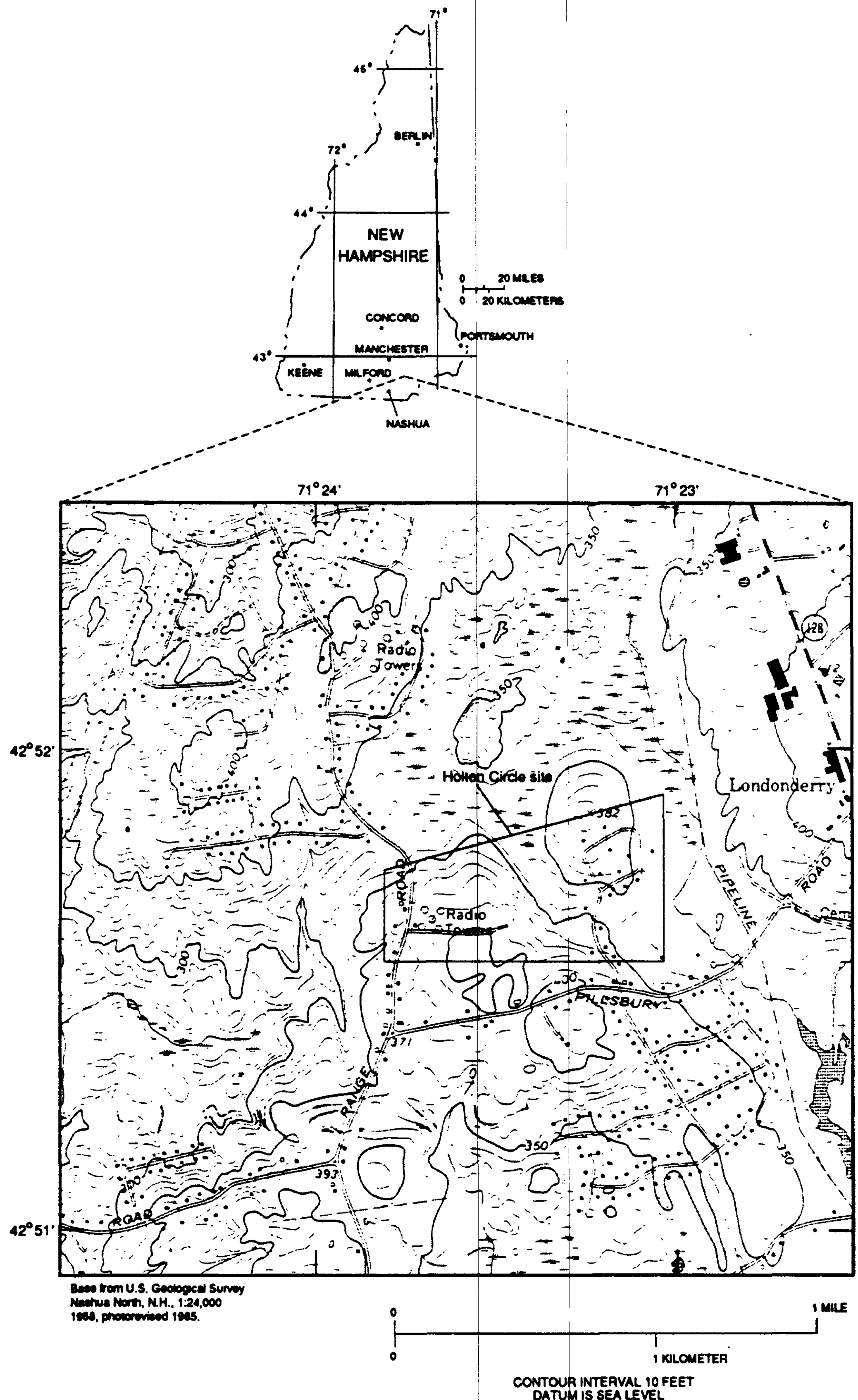


Figure 1.--Location of the Holton Circle Superfund site, Londonderry, New Hampshire.

graphic pen plots and digital data from each 0.1 ft interval were recorded.

Borehole logs obtained from each of the eight wells included natural gamma, spontaneous potential (SP), single-point-resistance, caliper, temperature, and fluid resistivity. Logging methods and methods of analysis are discussed briefly below. Detailed descriptions of the theory, application, and analysis of borehole geophysics for ground-water investigations can be found in Keys (1990).

Natural Gamma

Natural-gamma logs are a measure of the gamma radiation from naturally occurring radioactive elements in subsurface formations. A probe lowered through the borehole detects the gamma radiation and transmits a signal through the logging cable to the surface. In New England, gamma radiation results largely from the potassium-40 radioisotope; generally, the amount (counts) of gamma radiation detected from a bedrock unit is directly related to the amount of potassium feldspar in the rock. Minerals deposited or precipitated in fractures sometimes have different natural-gamma characteristics than the adjacent bedrock and cause a deviation in the log trace. An enlarged borehole diameter at intersecting fractures also can cause minor deflection of the log trace by changing the amount of gamma radiation detected.

Spontaneous Potential

The SP log is a record of the spontaneous voltage measured between an electrode grounded at the surface and a second electrode in the well. When the electrode in the well is moved through the rock-water system, small changes in voltage, usually in the millivolt range, are recorded. Contacts between lithologic units or fractures intersected by the borehole commonly cause changes in voltage. SP voltage is a function of the chemical activities of fluids in the borehole and in adjacent rock or fractures, borehole and (or) rock temperature, and type and quantity of clay present. Because SP voltage is largely related to contrasts between the salinity of the fluid in the borehole and fluid in the formation or fracture, changes in either will cause an SP response. If the borehole fluid is fresher than the formation water, the SP response is negative opposite permeable beds or zones; this is called the standard response. If the salinities are reversed, SP response is positive opposite permeable beds or zones. SP response is zero (straight line) when the salinities of the borehole and formation or fracture fluid are the same. An increase in borehole diameter decreases the magnitude of the SP recorded.

Single-Point Resistance

The single-point-resistance log measures the resistance between an electrode grounded at the surface and an electrode that is moved through the well bore. The resistance measured is a function of the resistance of the formation, the formation water, and the borehole water. The volume of investigation of the single-point-resistance method is small--about 5 to 10 times the electrode diameter. When a borehole in resistive rock is filled with saline water, thin resistive units are difficult to identify on the log because most of the current flows in the borehole. Single-point-resistance logs are sensitive to changes in borehole diameter, partly because of the small volume of investigation. [The volume of investigation is the volume of borehole fluid and invaded and uninvaded formation surrounding the geophysical logging probe that determines 90 percent of the measurement obtained from the probe; the radius of this volume generally depends on both probe configuration and properties of the formation and fluids (Keys, 1990)]. An increase in borehole diameter will decrease the apparent resistance. For this reason, the technique can be used to locate fractures that cause borehole enlargement.

Caliper

Caliper logs provide a continuous record of borehole diameter. Changes in borehole diameter may be related to well construction, drilling technique, lithology, structure, and fractures. The caliper probe used for this study has three interconnected arms that drive a linear potentiometer. Changes in resistance, transmitted to land surface as voltage changes, are proportional to average hole diameter. Fractures are commonly detected by the three-arm caliper probe. If the three arms enter the openings of a dipping fracture at different depths, the separate responses indicate three individual fractures rather than one. A three-arm caliper probe may not function correctly in holes that deviate appreciably from vertical because the weight of the tool can force one arm to close, which closes the other two arms.

Temperature

Temperature logs are a measure of the borehole-fluid temperature. A small electrical current is conducted through a thermistor in the temperature probe to measure changes in resistance that result from temperature changes. If there is no flow of fluid in or adjacent to the borehole, the temperature gradually increases with depth, reflecting the geothermal gradient. The geothermal gradient in New England is about 0.76 degree Celsius per 100 feet of depth. To identify possible water-bearing fractures, investigators examine temperature logs for evidence of changing geothermal gradients caused by the vertical flow of fluid in the borehole. Other factors that can affect the temperature log and its interpretation are the vertical flow of fluid in the borehole caused by water removal before logging, ground-water recharge, and seasonal fluctuations in air temperature.

Fluid Resistivity

The resistance of water in a borehole is measured directly by fluid-resistivity logging. The log is not affected by the resistance of the formation or by fluids within the formation adjacent to the borehole. Variations in the fluid resistivity log commonly indicate points of ground-water inflow, such as those associated with fractures. Because fluid resistivity is affected by temperature, interpretation of this log requires a temperature log.

INFERRED LOCATIONS OF FRACTURES

Locations of the eight wells logged (MW1D through MW8D) are shown on figure 2. The wells were drilled by the air-percussion method and are approximately 6 in. in diameter. The wells are uncased except for steel surface casing set into bedrock through thin unconsolidated surficial deposits. Characteristics of the wells are given in table 1.

Plots of the logs, constructed from digital data recorded from each 0.1-ft interval, are shown in figures 3 through 10. All depths shown on the logs are from the top of the well casing.

Graphic pen plots of the log data were used to identify possible fractures. Some details on these graphic plots are not as obvious on the digital logs shown in this report. The six logs for each of the eight wells were examined for deflections in the log trace that may indicate fractures or fracture zones. These deflections are referred to as "anomalies" and are commonly observed at the same depths on more than one log from a well. The more logs that indicate an anomaly at the same depth, the greater the probability that a fracture zone is present. Some of the log anomalies, however, may result from some other unknown physical or lithologic conditions along the borehole, and not all fractures can be detected

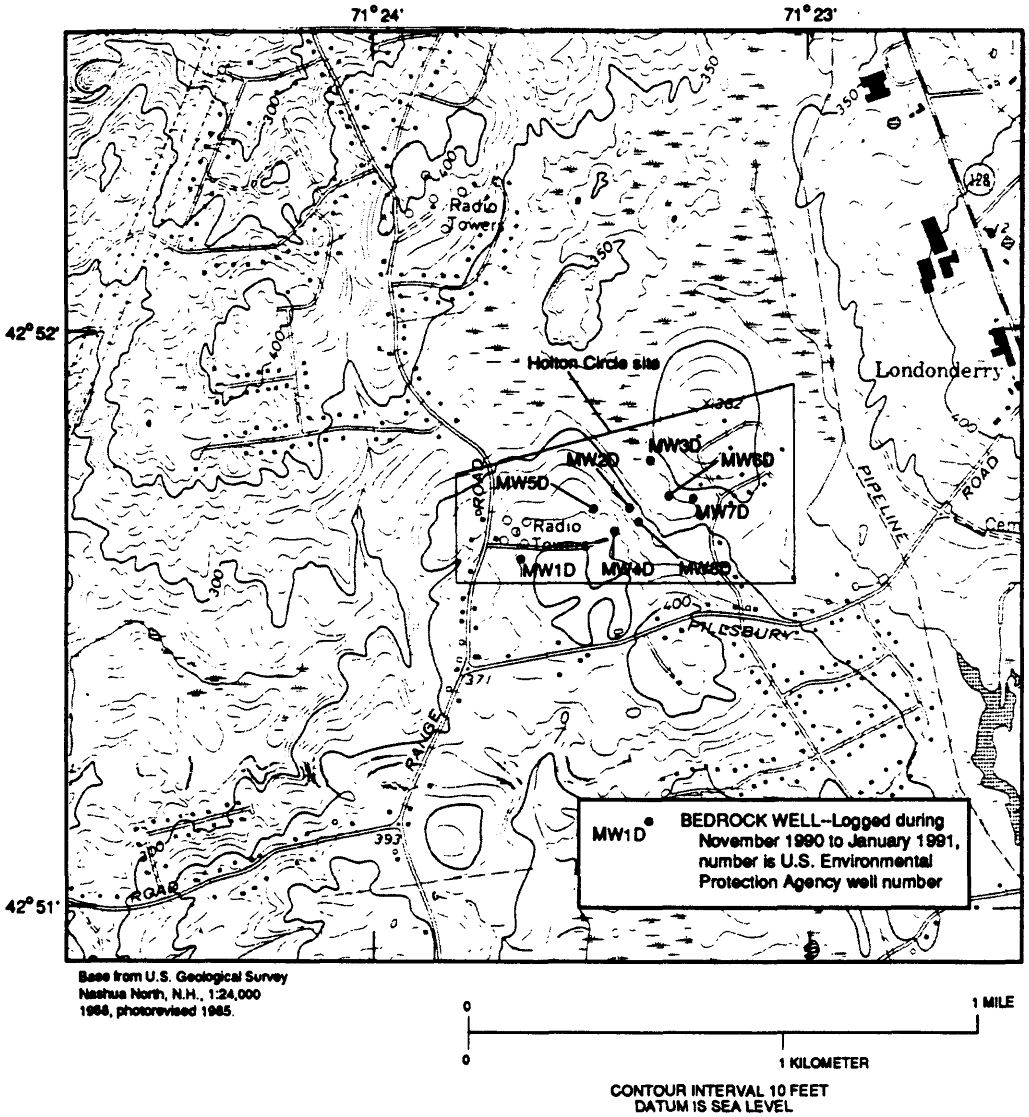


Figure 2.--Locations of wells logged at the Holton Circle Superfund site.

with the logs. Anomalies on the temperature and fluid resistivity logs usually indicate fluid movement into or out of fractures.

The depths of anomalies that were noted on logs for each well are shown on figures 11 through 18. The natural-gamma logs were not included because they appear primarily to indicate variations in lithology; few of the anomalies observed on these natural-gamma logs correspond to anomalies on the other logs. Some peaks on the natural-gamma logs (figs. 3-10) probably indicate lithologic units or mineralized zones that have a higher concentration of potassium-40.

Table 1.--Characteristics of wells drilled during October and November 1990 at Holton Circle Superfund site, Londonderry, New Hampshire

[USEPA, U.S. Environmental Protection Agency; mm/dd/yy, month, day, year. All wells are 6 inches in diameter]

USEPA well number	Well depth below land surface (feet)	Depth to bedrock below land surface (feet)	Top of casing above land surface (feet)	Bottom of casing below land surface (feet)	Length of casing (feet)	Elevation of top of casing (feet)	Water level below top of casing (feet)	Depth of water level measurement (mm/dd/yy)
MW1D	185	26	1.70	36	37.7	391.44	9.80	11/19/90
MW2D	185	17	1.50	29	30.5	361.27	20.93	11/16/90
MW3D	185	16	1.75	23	24.75	341.54	6.53	11/22/90
MW4D	185	21	1.85	28	29.85	386.24	49.66	11/15/90
MW5D	185	31	1.45	38	39.45	384.03	25.67	11/15/90
MW6D	185	6	1.25	16	17.25	339.78	4.00	01/22/91
MW7D	382	5	.91	16	16.91	342.10	2.84 3.30	11/19/90 01/23/91
MW8D	65	17	1.85	22	23.85	359.15	19.29	11/16/90

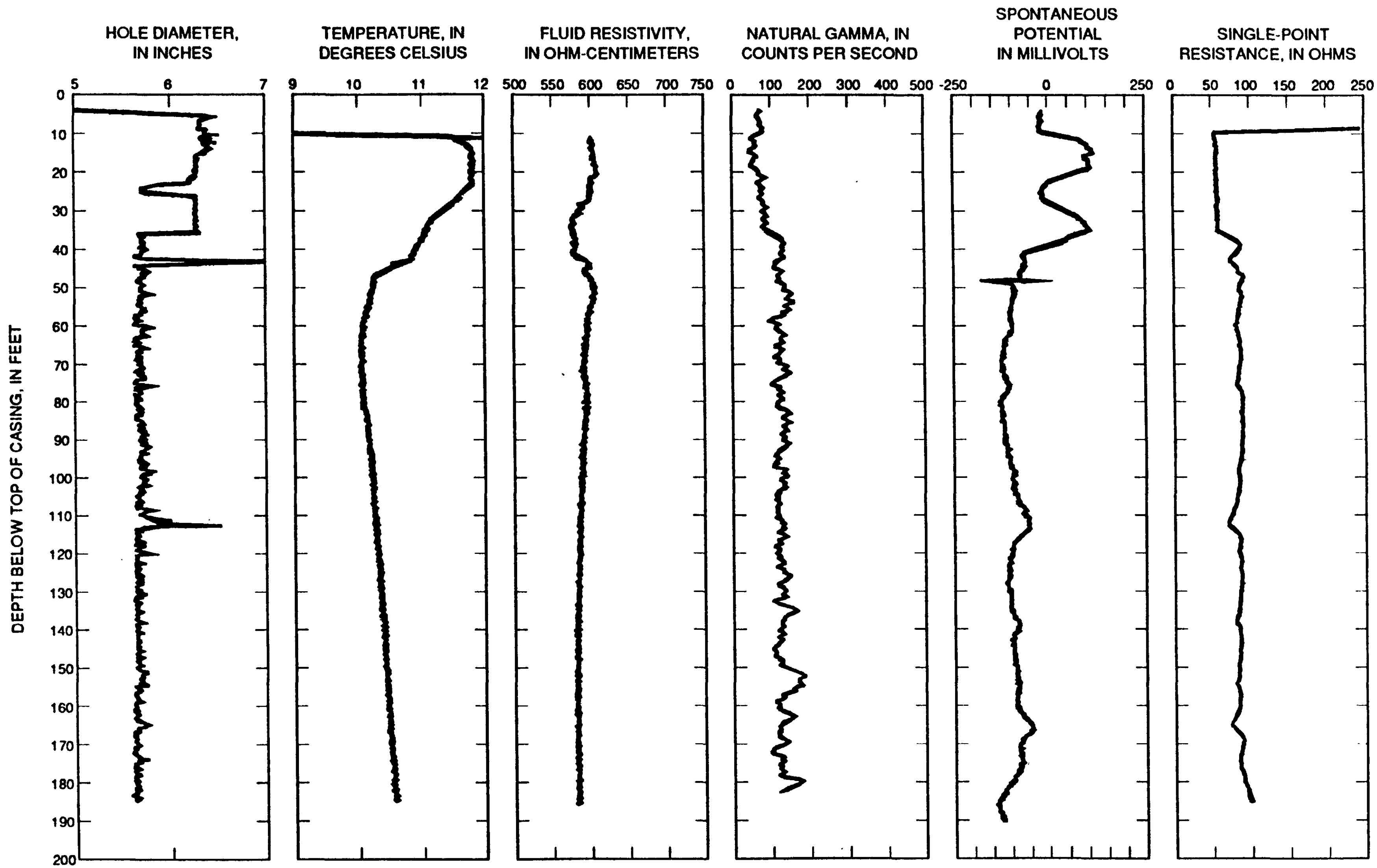


Figure 3.--Borehole geophysical logs for well MW1D.

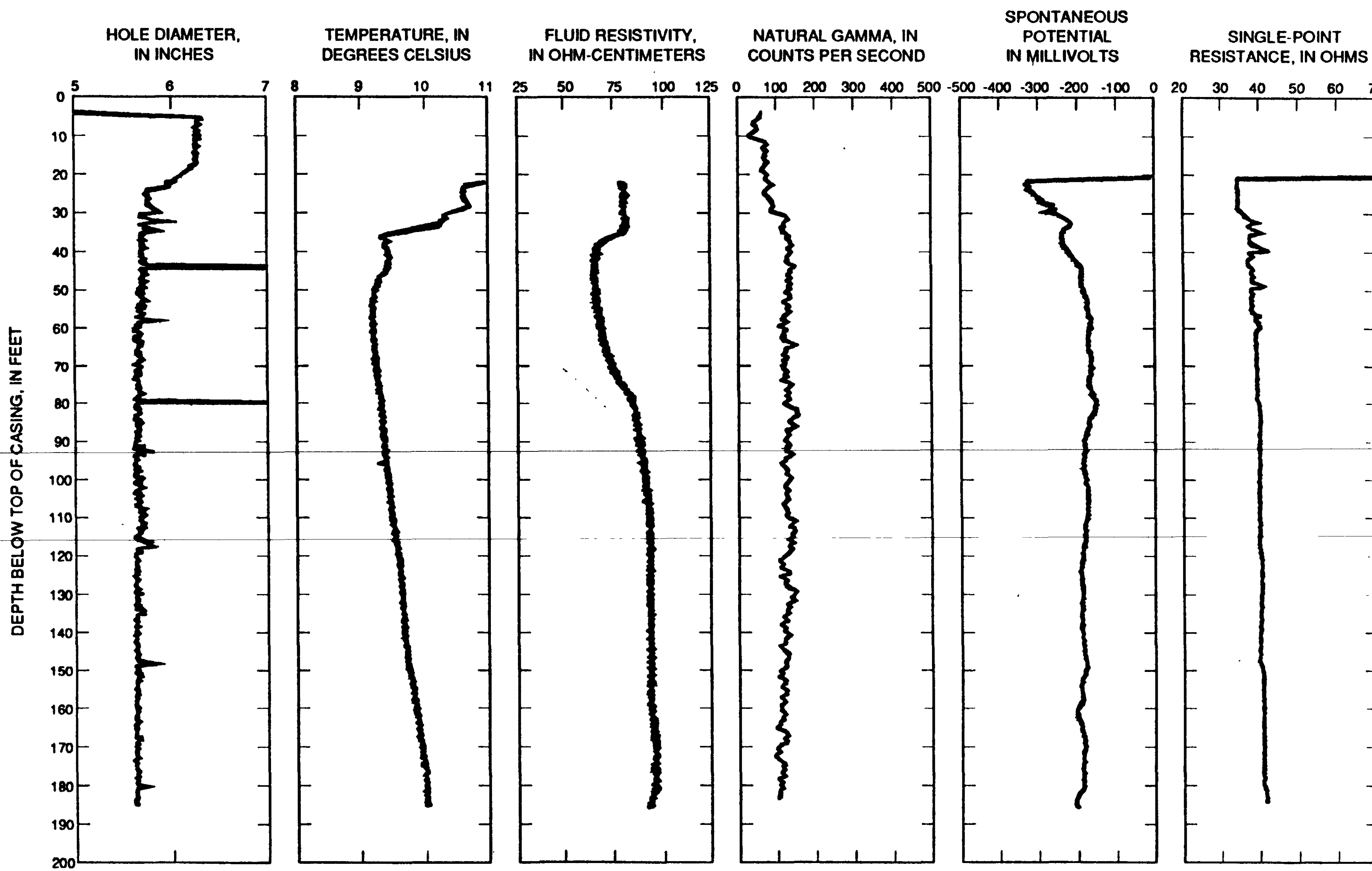


Figure 4.--Borehole geophysical logs for well MW2D.

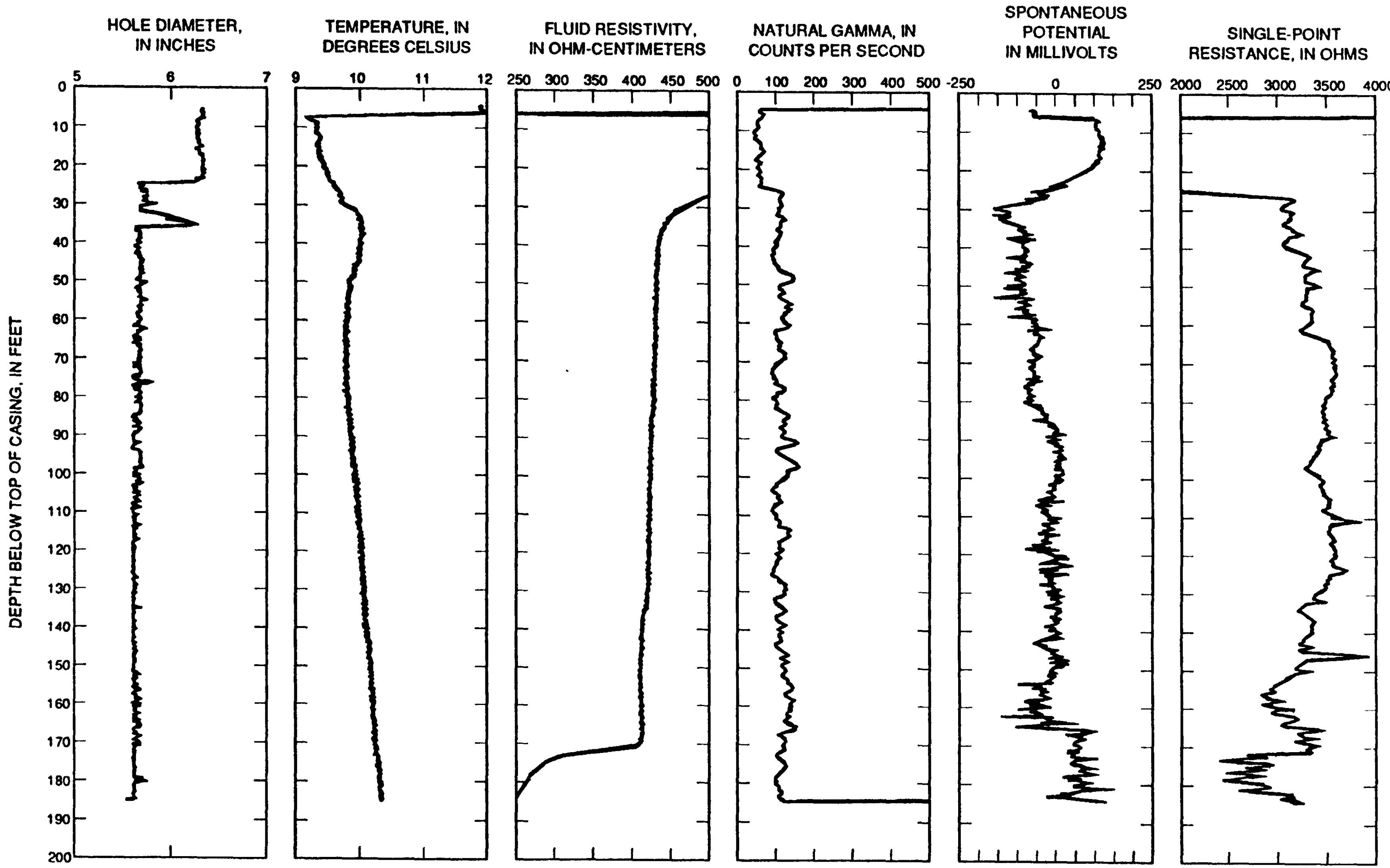


Figure 5.--Borehole geophysical logs for well MW3D.

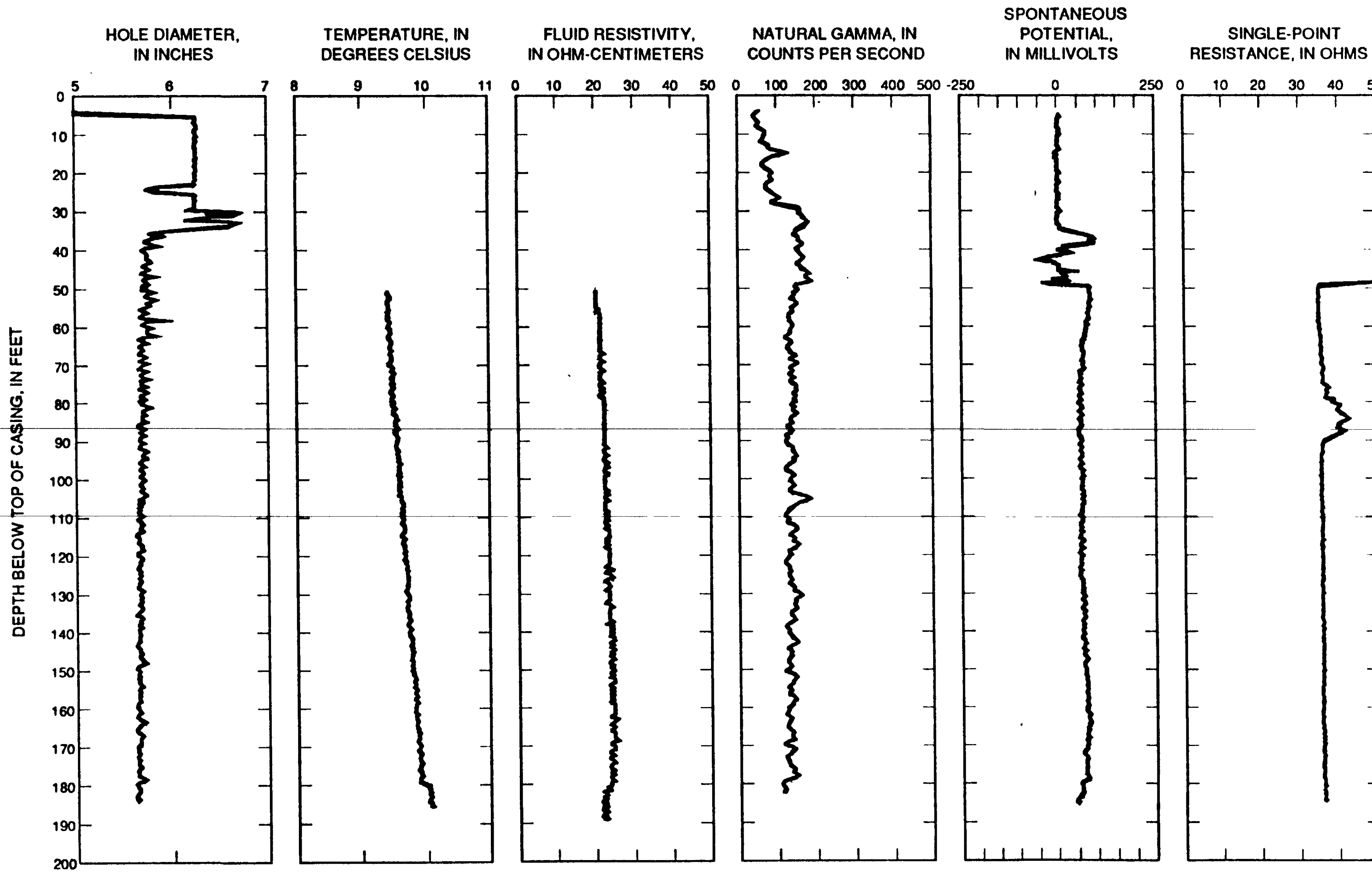


Figure 6.--Borehole geophysical logs for well MW4D.

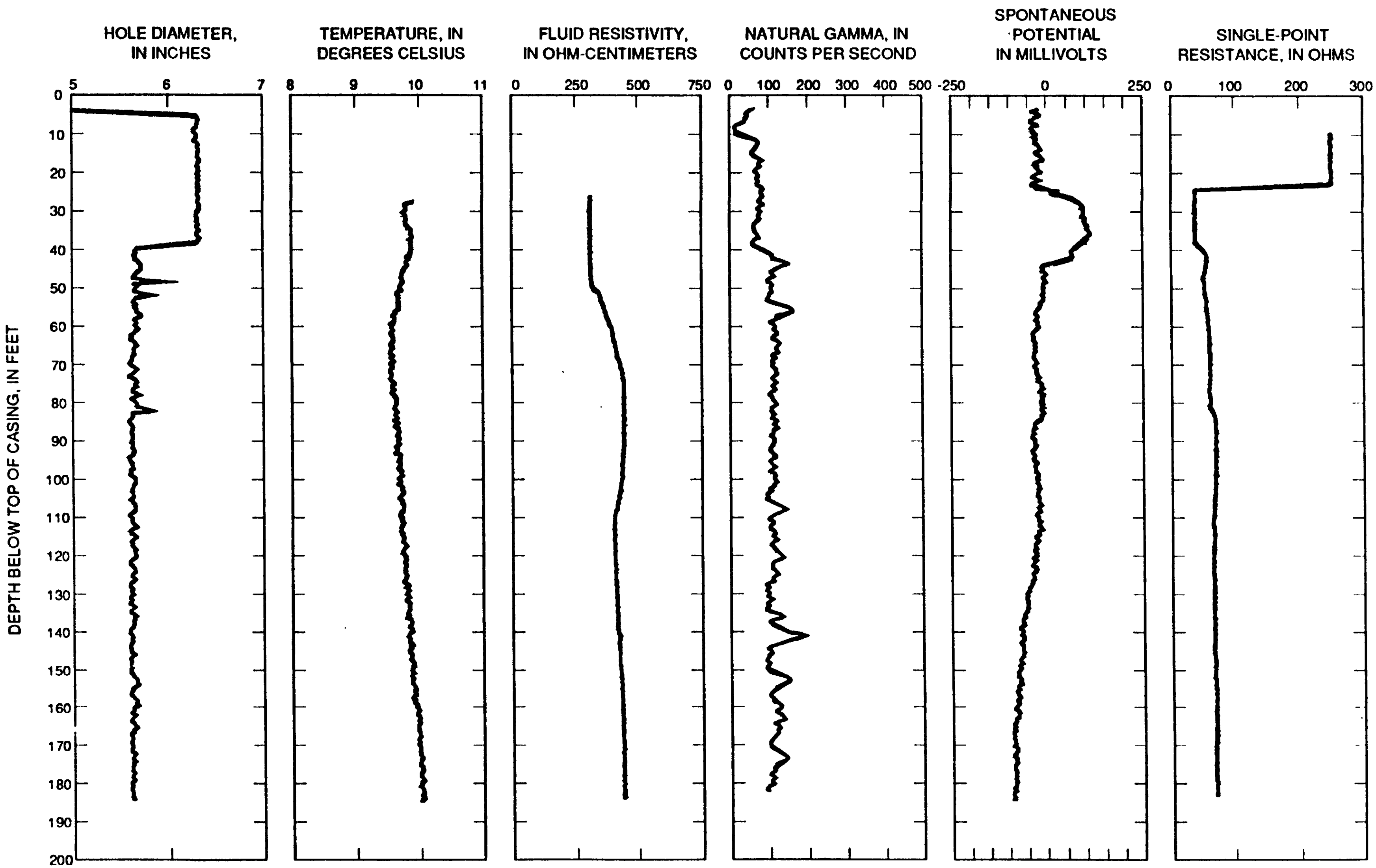


Figure 7.--Borehole geophysical logs for well MW5D.

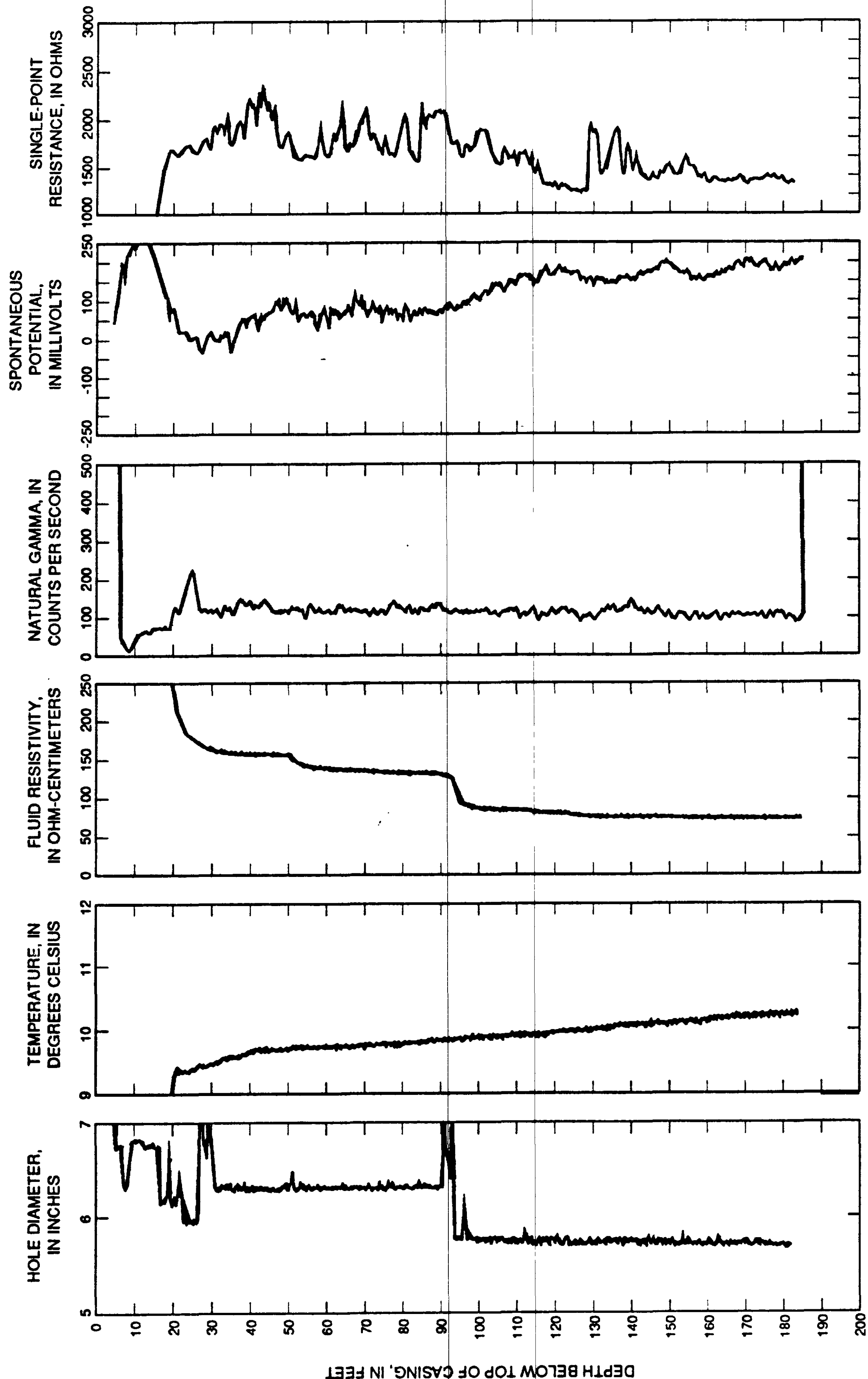


Figure 8.--Borehole geophysical logs for well MW6D.

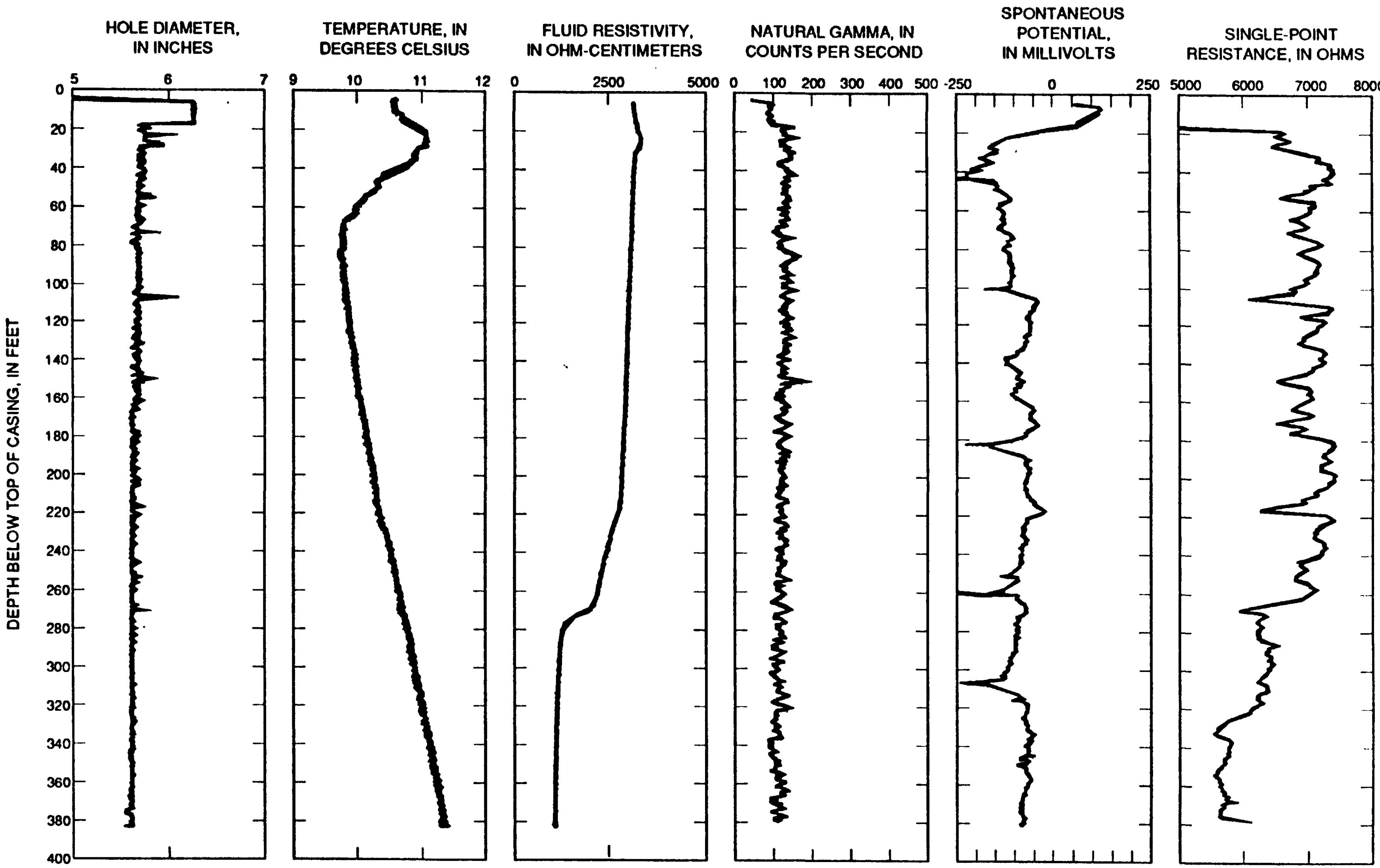


Figure 9.--Borehole geophysical logs for well MW7D.

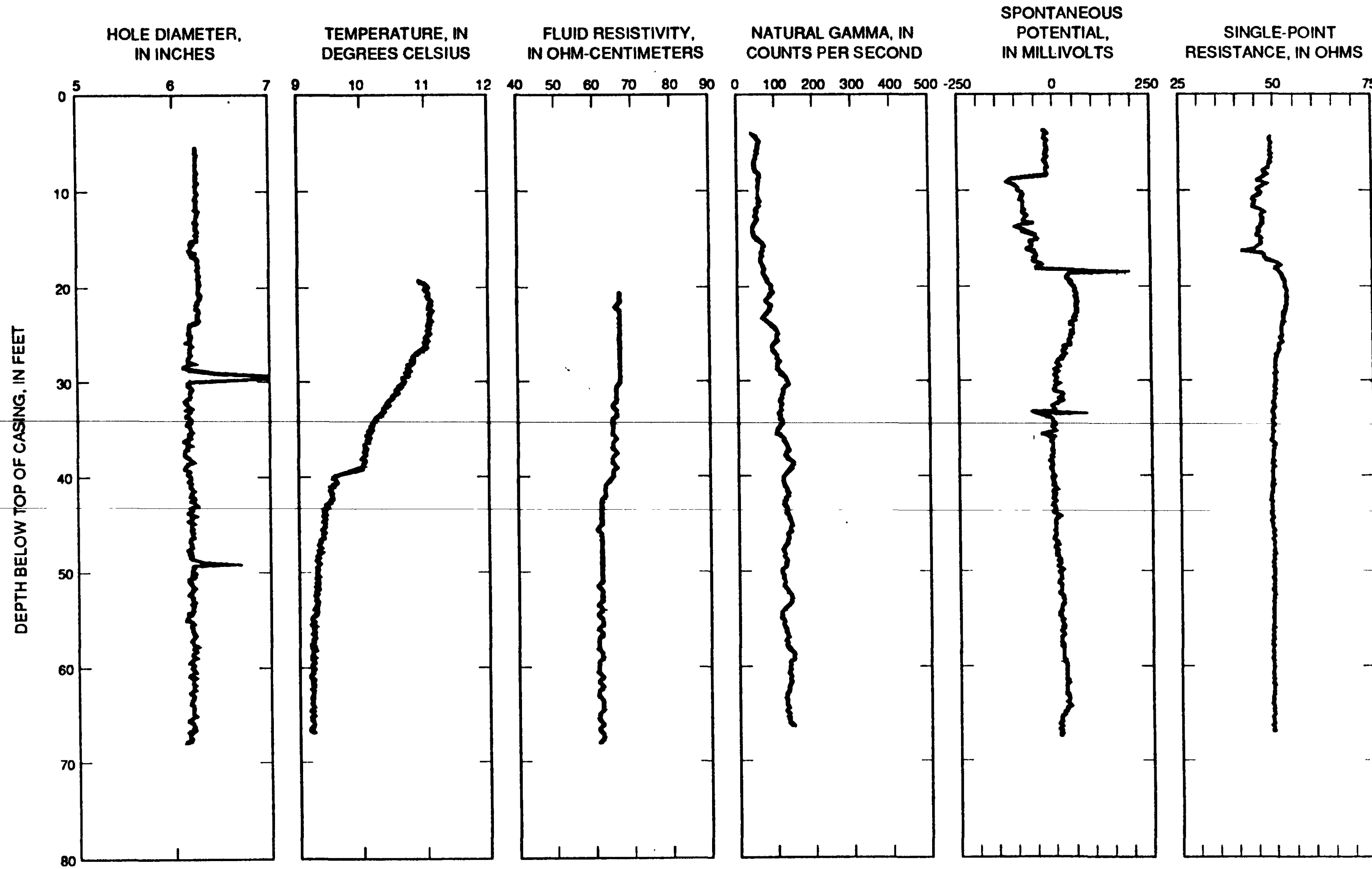
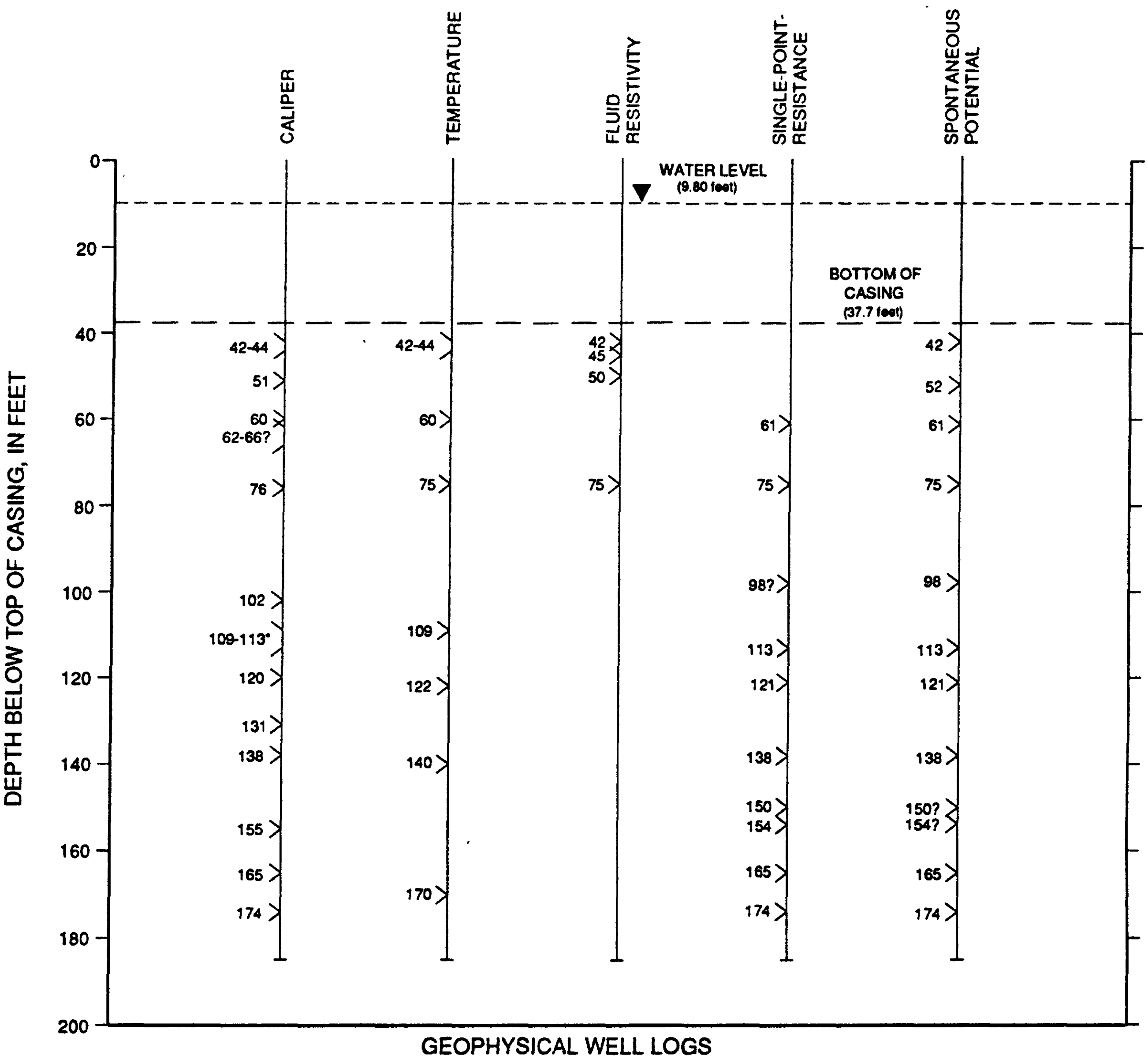


Figure 10.--Borehole geophysical logs for well MW8D.



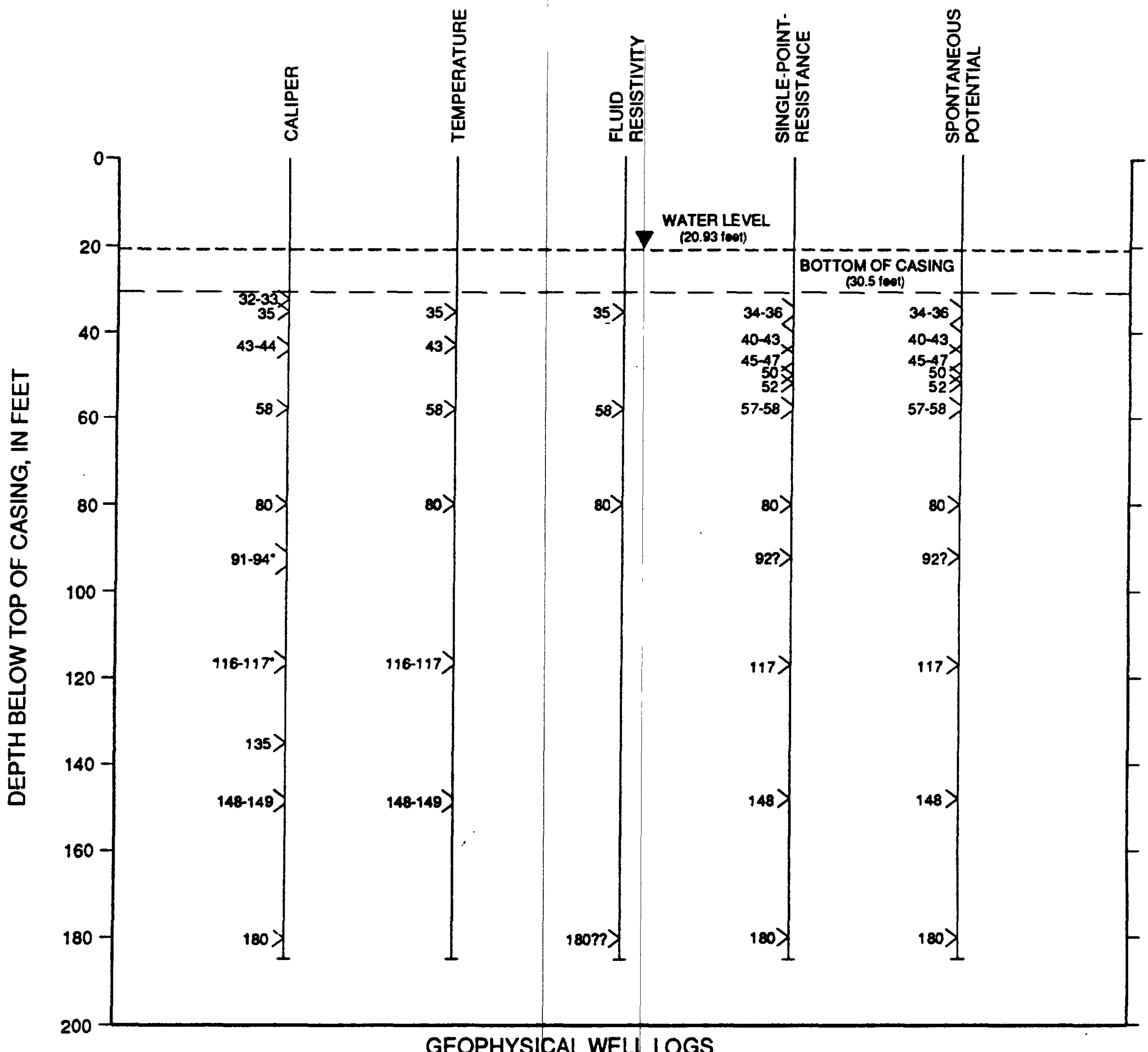
EXPLANATION

174 > POSSIBLE FRACTURE LOCATION-- Based on anomaly on indicated log. Number is depth below top of well casing

* POSSIBLE HIGH-ANGLE FRACTURE

? POORLY DEFINED ANOMALY-- Multiple queries if very poorly defined

Figure 11.-- Depths of borehole-log anomalies that indicate fractures in well MW1D.



EXPLANATION

180 > POSSIBLE FRACTURE LOCATION-- Based on anomaly on indicated log. Number is depth below top of well casing

* POSSIBLE HIGH-ANGLE FRACTURE

? POORLY DEFINED ANOMALY-- Multiple queries if very poorly defined

Figure 12.-- Depths of borehole-log anomalies that indicate fractures in well MW2D.

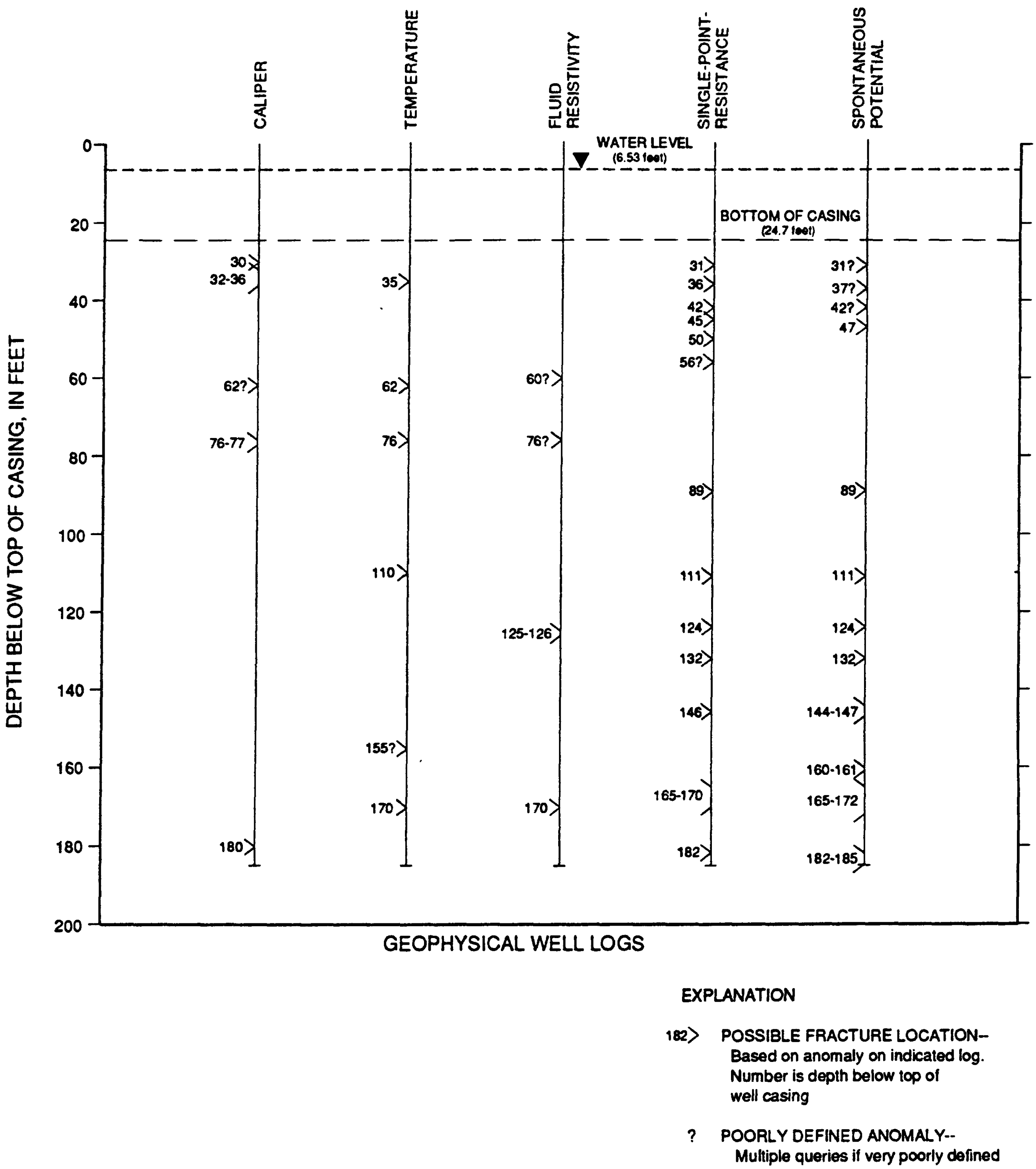


Figure 13.-- Depths of borehole log anomalies that indicate fractures in well MW3D.

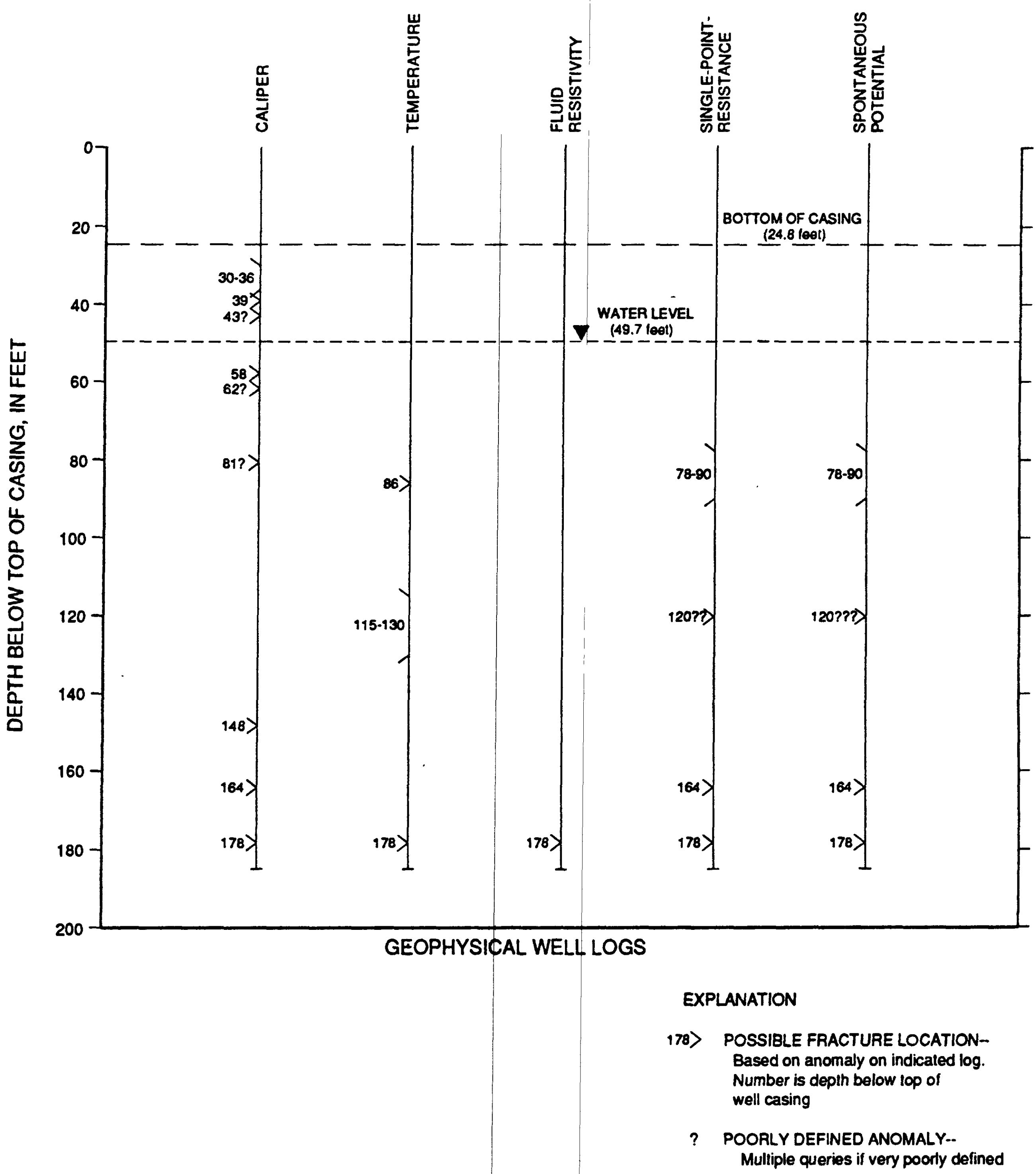


Figure 14.-- Depths of borehole log anomalies that indicate fractures in well MW4D.

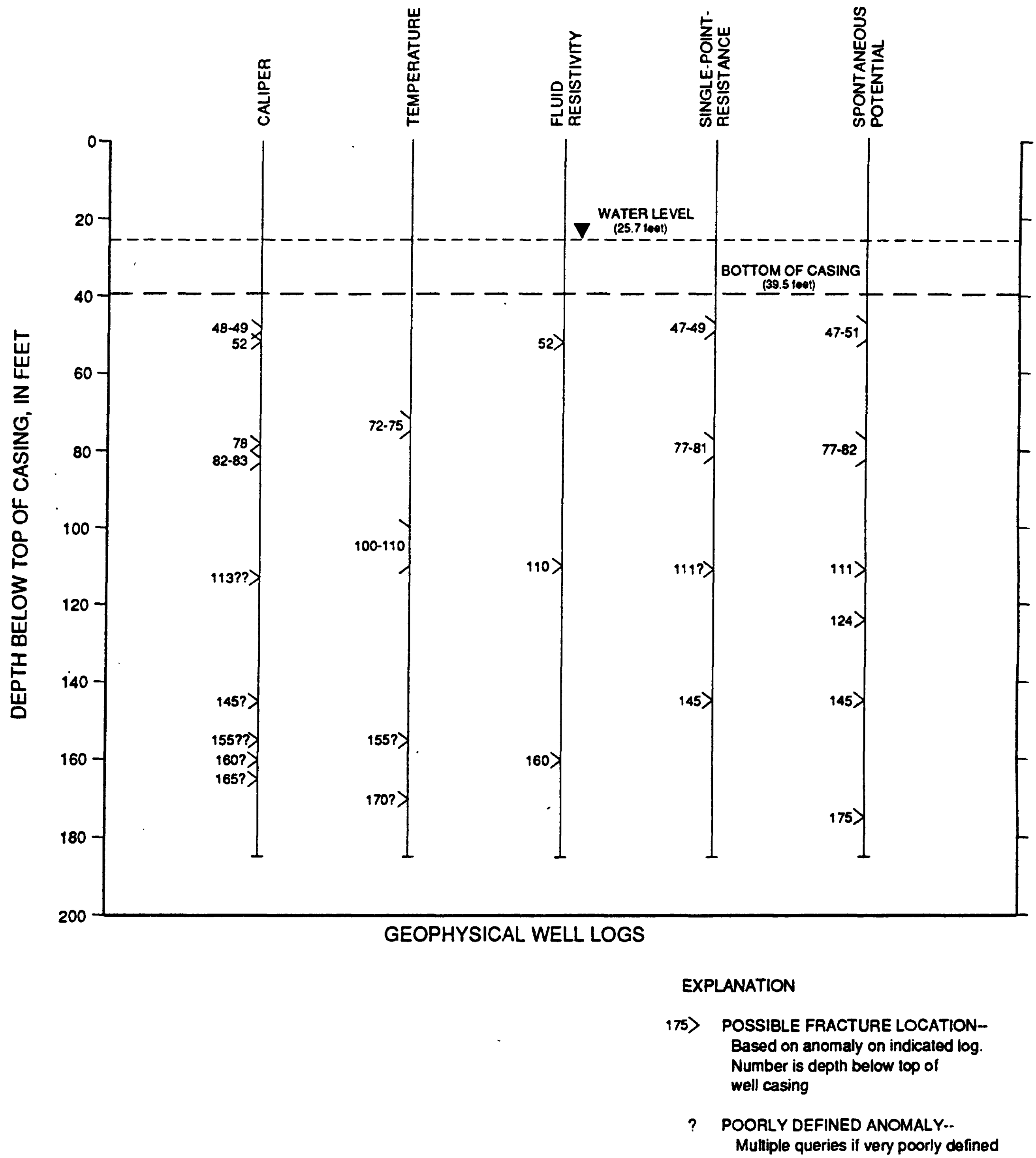


Figure 15.-- Depths of borehole log anomalies that indicate fractures in well MW5D.

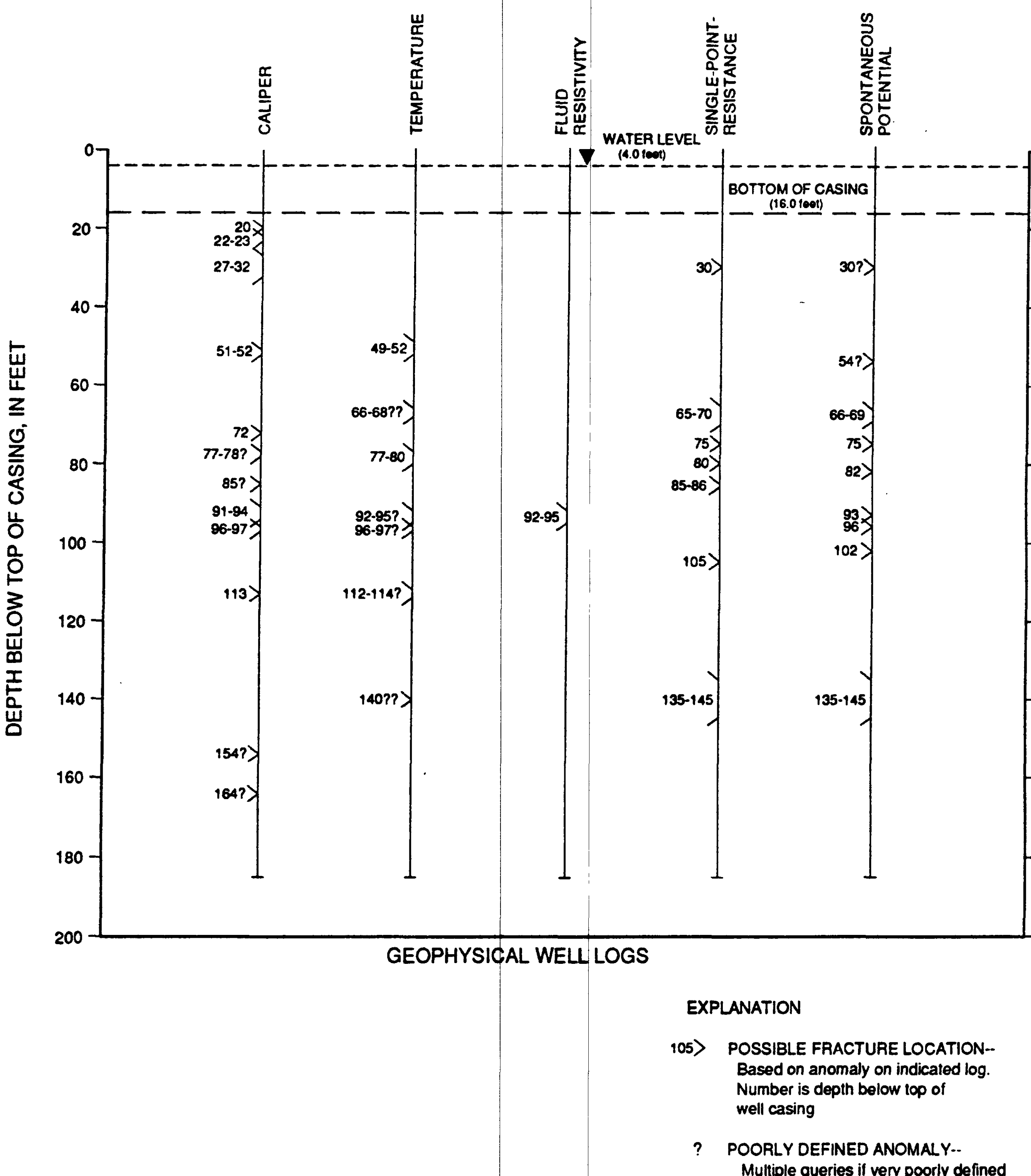


Figure 16.-- Depths of borehole log anomalies that indicate fractures in well MW6D.

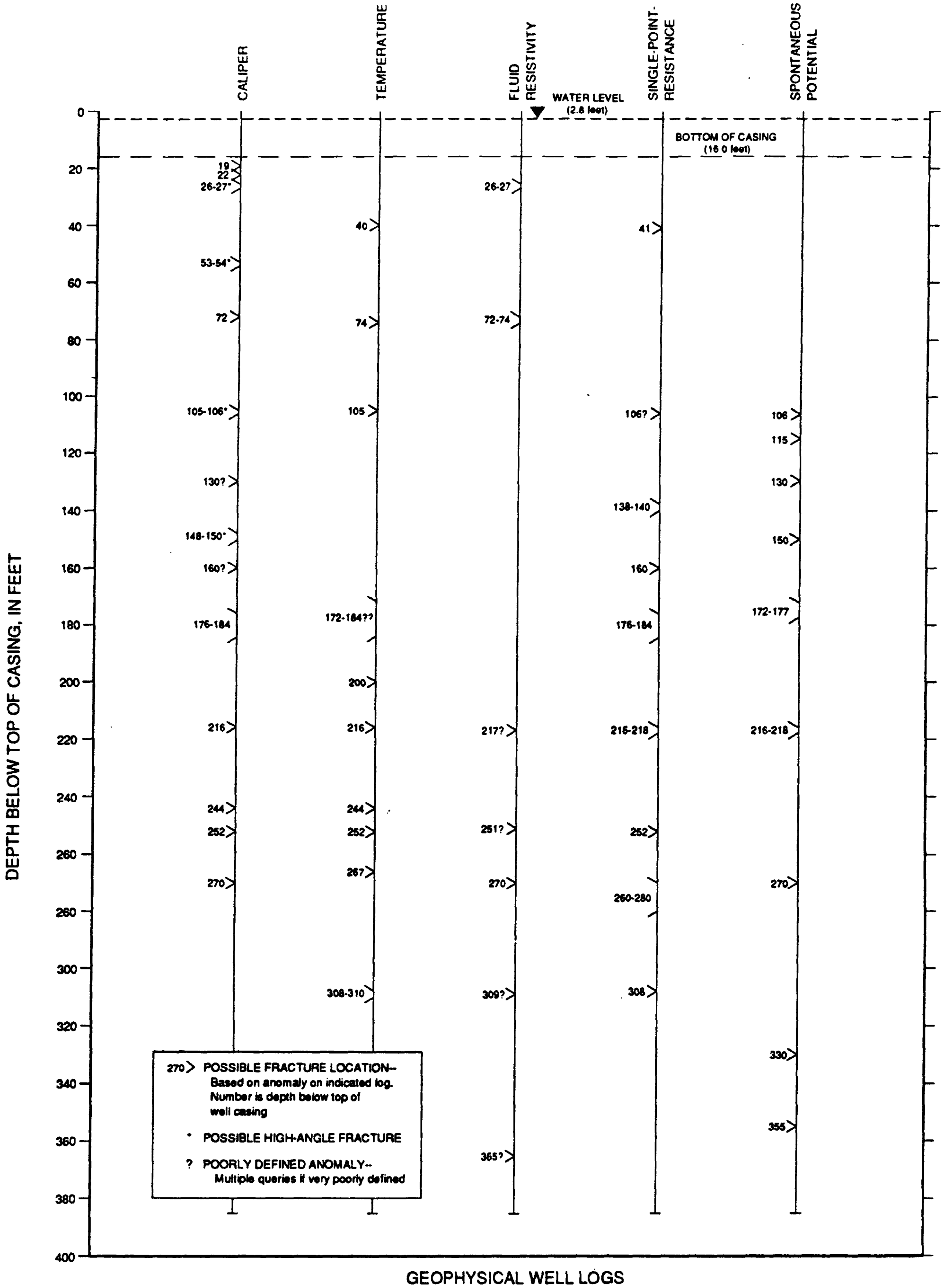


Figure 17.-- Depths of borehole log anomalies that indicate fractures in well MW7D.

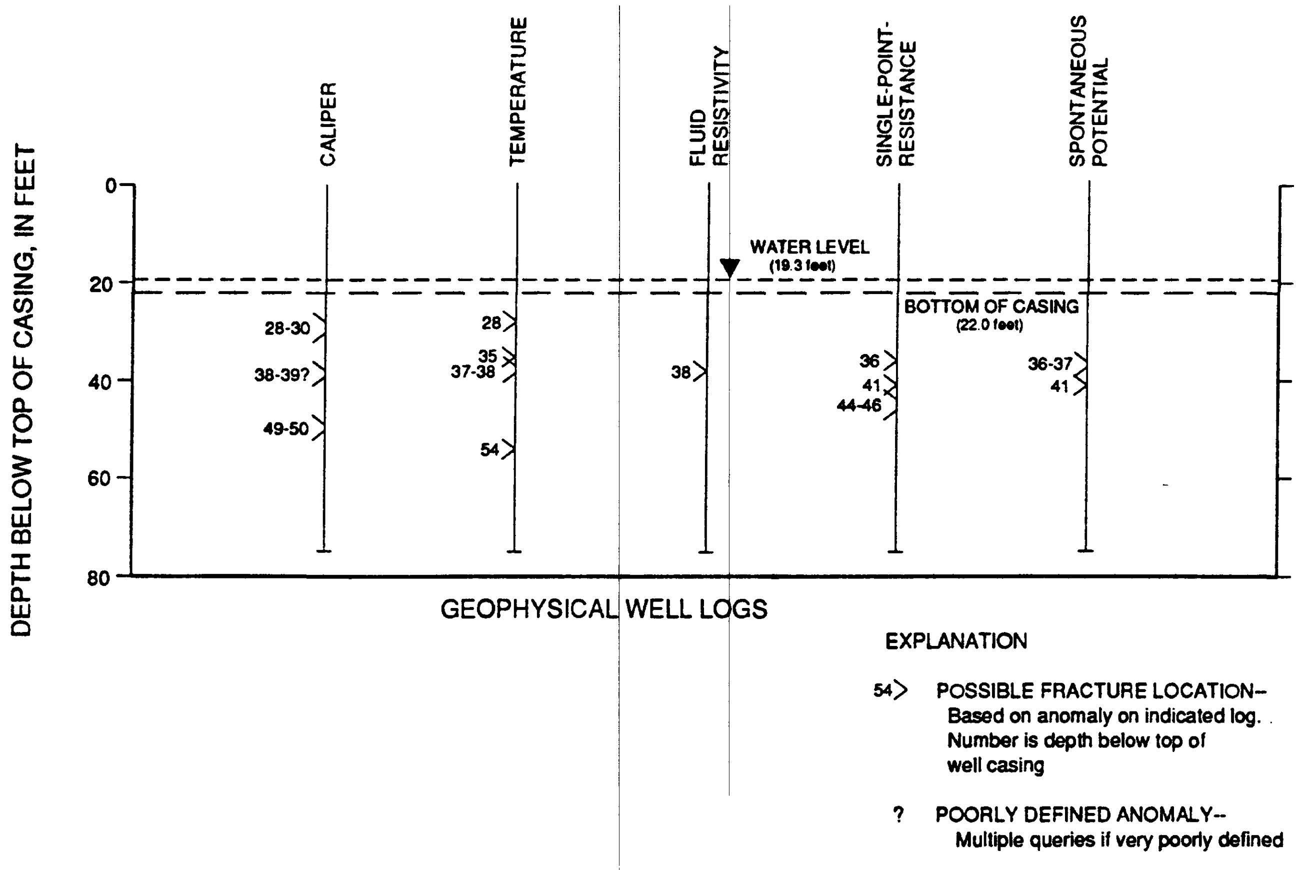


Figure 18.-- Depths of borehole log anomalies that indicate fractures in well MW8D.

SUMMARY

Eight wells that were drilled to characterize the bedrock hydrology at the Holton Circle Superfund site were logged to identify depths of possible water-bearing fractures. Borehole geophysical logs included natural gamma, spontaneous potential, single-point resistance, caliper, temperature, and fluid resistivity. All but the natural-gamma log were useful for identifying anomalies indicative of possible fractures. Depths of anomalies are shown on charts for each of the eight wells logged.

REFERENCE CITED

Keys, W.S., 1990, Borehole geophysics applied to ground-water investigations: U.S. Geological Survey Techniques of Water Resources Investigations, book 2, chap. E2, 150 p.