Water Resources Program

OPEN-FILE TECHNICAL REPORT

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

DRILLING, HYDROLOGIC TESTING, AND PIEZOMETER INSTALLATION NEAR SINKING CREEK LINCOLN COUNTY, WASHINGTON

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OFTR 92-1

This Open-File Technical Report presents the results of a hydrologic investigation by the Water Resources Program, Department of Ecology. It is intended as a working document and has received internal review. This report may be circulated to other Agencies and the Public, but is not a formal Ecology Publication.

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Reviewed by: ______________________

Supervisor: ______________________

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ABSTRACT

During the summer of 1991, two NX-size (3-inch diameter) core holes and one shallow, 8-inch, auger hole were drilled at two locations within the Columbia River Basalts where Sinking Creek is adjoined by two springs (one active, the other inactive). The Wagner core hole penetrates the lower 141 ft. of the Priest Rapids Member basalt (Wanapum Formation), the Quincy interbed claystone (0.5 ft.), and the top 43 ft. of the Roza Member basalt (Wanapum Formation). The Rosman Core hole penetrates 10 ft. of Quaternary alluvium, 174 ft. of Priest Rapids basalt, 141 ft. of the Roza Member, 0.5 ft. of Vantage Member claystone interbed, and the top 9.5 ft. of the Grande Ronde Formation basalt. Core samples indicate that the Quincy interbed is absent at the Rosman site. The shallow auger hole penetrates 9.5 ft. of Quaternary alluvium, the lower 5 ft. of which is coarse gravel and sand.

Two short injection tests in the Rosman core hole and one pumping test of the nearby Baring Spring pool failed to demonstrate a direct hydraulic connection between the basalt aquifers and the spring. From the pumping test, a minimum transmissivity of 6000 ft^2/day is calculated for the Quaternary alluvium.

One piezometer was installed in the Wagner core hole within the Priest Rapids basalt. Two piezometers were installed in the Rosman core hole; one each in the Priest Rapids Member and the Roza Member. One piezometer was screened in the gravel of the alluvium in the shallow auger hole. Water levels in the two Rosman core hole piezometers and the shallow piezometer indicated a downward, ground-water flow potential at this site, at the time of installation.

ACKNOWLEDGEMENTS

Many thanks to Art Larson of Environmental Investigations and Laboratory Services (Department of Ecology) and Linton Wildrick, of the Water Resources Program, for their careful review of the document.

INTRODUCTION

Ground water within the Columbia River Basalt Group (CRBG) of eastern Washington is the main source of water for crop irrigation in several counties, including Lincoln County, Washington. Since the late 1960s ground water levels in many of the agricultural areas of Lincoln County have experienced dramatic decline, especially during the irrigation season (Wildrick, 1982 and Olson, 1989). More recently, spring-fed, perennial and intermittent streams and lakes in these areas have shown a continuing depletion that is suspected to be a result of declining water tables or hydraulic heads in the basalt aquifers (Wildrick, 1982, and 1991). Sinking Creek, in northern Lincoln County, is one these features.

This paper describes the methods and results of drilling, hydrologic testing, and piezometer installation in three test holes near two springs along Sinking Creek. Both springs are suspected to have hydraulic connection to the basalt aquifers, and do presently, or have in the past, contributed to flow in Sinking Creek.

Purpose of the study

Three main purposes of the project were: 1. To test for hydraulic interconnection between springs and basalt aquifers through hydrologic testing conducted in drill holes; 2. To monitor water levels in the basalt aquifers during successive cycles of irrigation by installing piezometers in the holes. This will allow long-term analysis of pumping effects on the surface and subsurface hydrologic regimen, and; 3. To gather reliable stratigraphic and lithologic information from the drilling for local and regional hydrostratigraphic correlation.

Location of the study area

The study area is in northern Lincoln County, Washington, near the northern edge of the Columbia Plateau (or *Columbia Basin*, as described by Freeman and others (1945)) physiographic province, and just south of the towns of Wilbur and Creston (Figure 1).

The Wagner core hole (Figure 2, Plates 1 and 2) is on property owned by Clarence Wagner and son Dan, who use the land for ranging cattle and growing wheat and hay. The drill hole is approximately 100 ft. northeast of the extinct "Wagner Spring" (T25N/R35E-12K1s). Land surface elevation of the Wagner hole is approximately 2090 ft. above mean sea

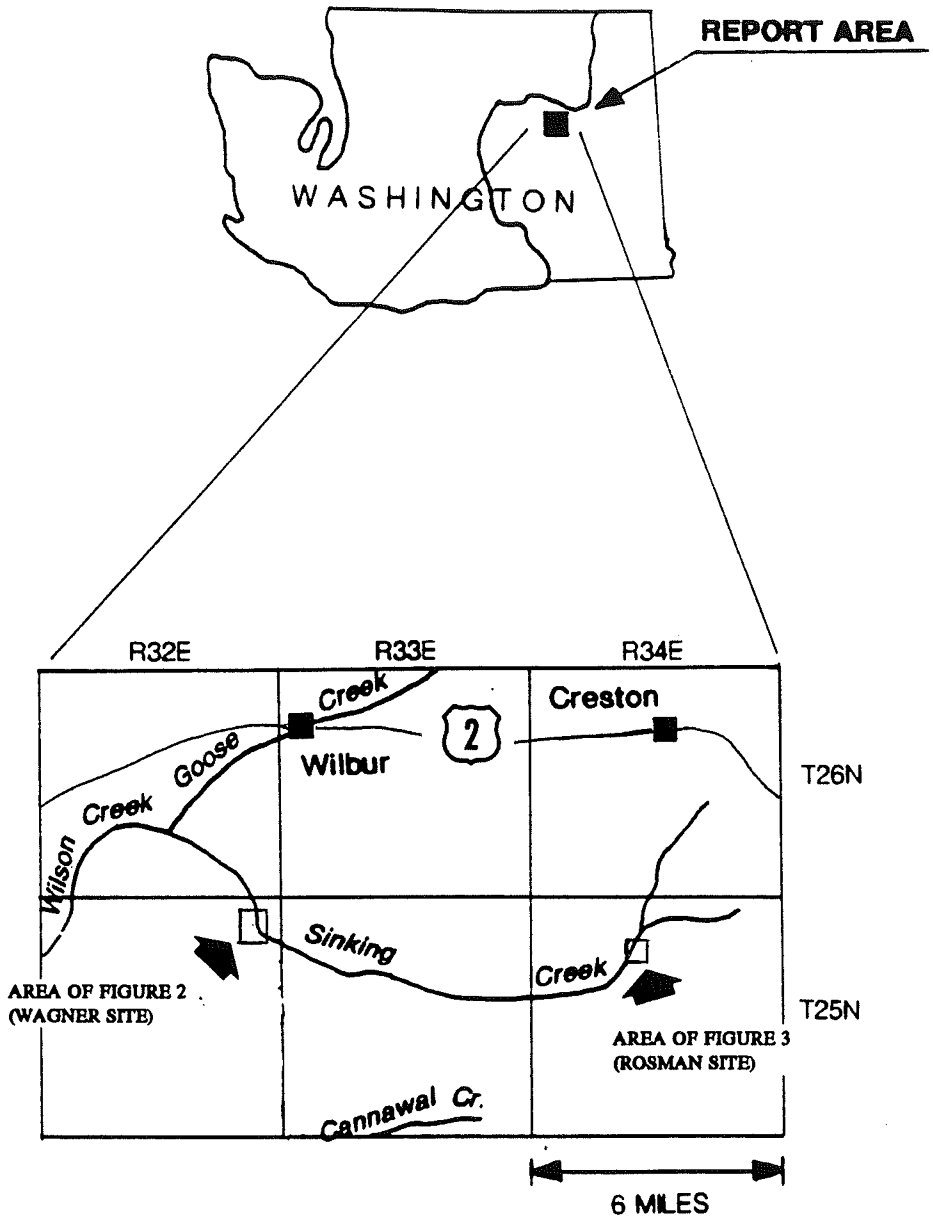

Figure 1. Location of drill holes

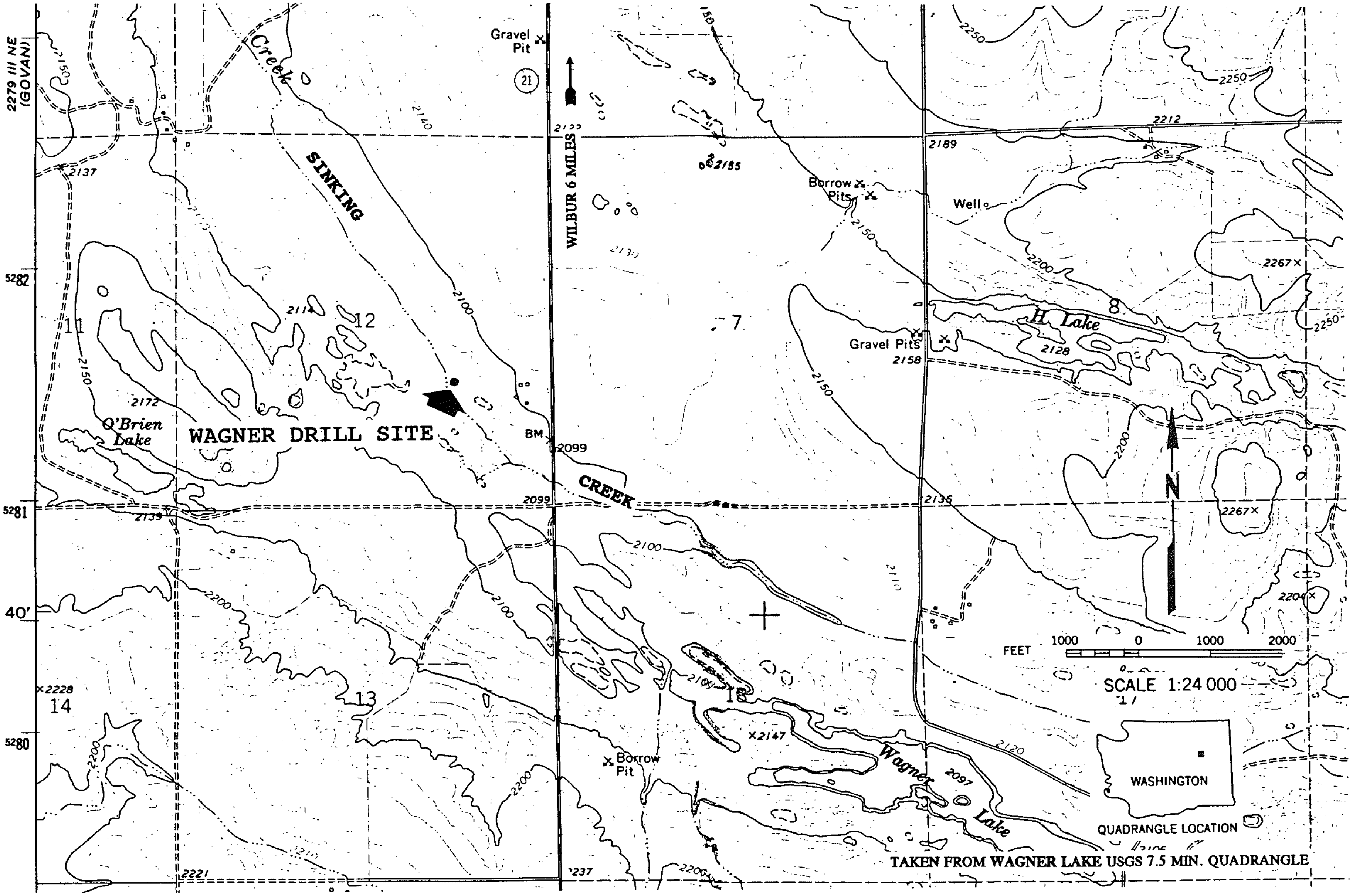

Figure 2. Wagner site

Plate 1. The Wagner site, looking south. The rock-lined, dry channel of Sinking Creek appears in the middle distance. Arrow denotes location of the extinct Wagner Spring.

Plate 2. View looking northwest along the channel of Sinking Creek from the Wagner drilling site. Fragments of a dilapidated concrete containment structure, built for the spring, are visible in the foreground.

level (estimated from U.S. Geological Survey, Wagner Lake 7.5 minute quadrangle).

The Rosman core hole (Figure 3 and Plate 3) is 50 ft. northeast of Baring Spring (or "Rosman Spring" as called by local residents) (T25N/R34E-8N1s) on land owned by John Rosman. The surrounding land is range and hay fields. The site occupies the northern edge of the flood plain of Sinking Creek, roughly 50 ft. from an outcrop of Priest Rapids basalt that marks the northern side of a shallow coulee. At this site, the coulee is roughly 500 ft. wide. Land-surface elevation of the Rosman site is approximately 2210 ft. above mean sea level (estimated from U.S. Geological Survey, Creston Butte 7.5 minute quadrangle). The U.S Geological Survey map erroneously shows Baring Spring 3000 ft. west-southwest of its actual location.

Previous work

The most complete compilations of regional geology, including the Sinking Creek area, are those of Waggoner (1990c) and Stoffel and others (1991). Swanson and others (1979a) focused geologic mapping efforts on identifying basalt flows. Reidel and Hooper (editors, 1989) present the most recent compendium on stratigraphic, structural, and petrologic aspects of the CRBG.

Gephart and others (1979) discuss the factors controlling movement of ground water in the CRBG. Wildrick (1982, 1985, 1990, and 1991) assesses earlier hydrologic studies, well data, aquifer tests, and geology in the Sinking Creek drainage to evaluate the interconnection between basalt aquifers and springs.

Pachis and others (1988), Steele and others (1988), and Tera Corporation (1983) report on the results of drilling and hydrologic testing in basalts, for the purposes of characterizing contaminant transport in fractured basalt and assessing general hydrogeologic conditions in the CRBG. The sites of these investigations are from slightly one mile south-southeast of the Rosman site, to a few miles northeast thereof.

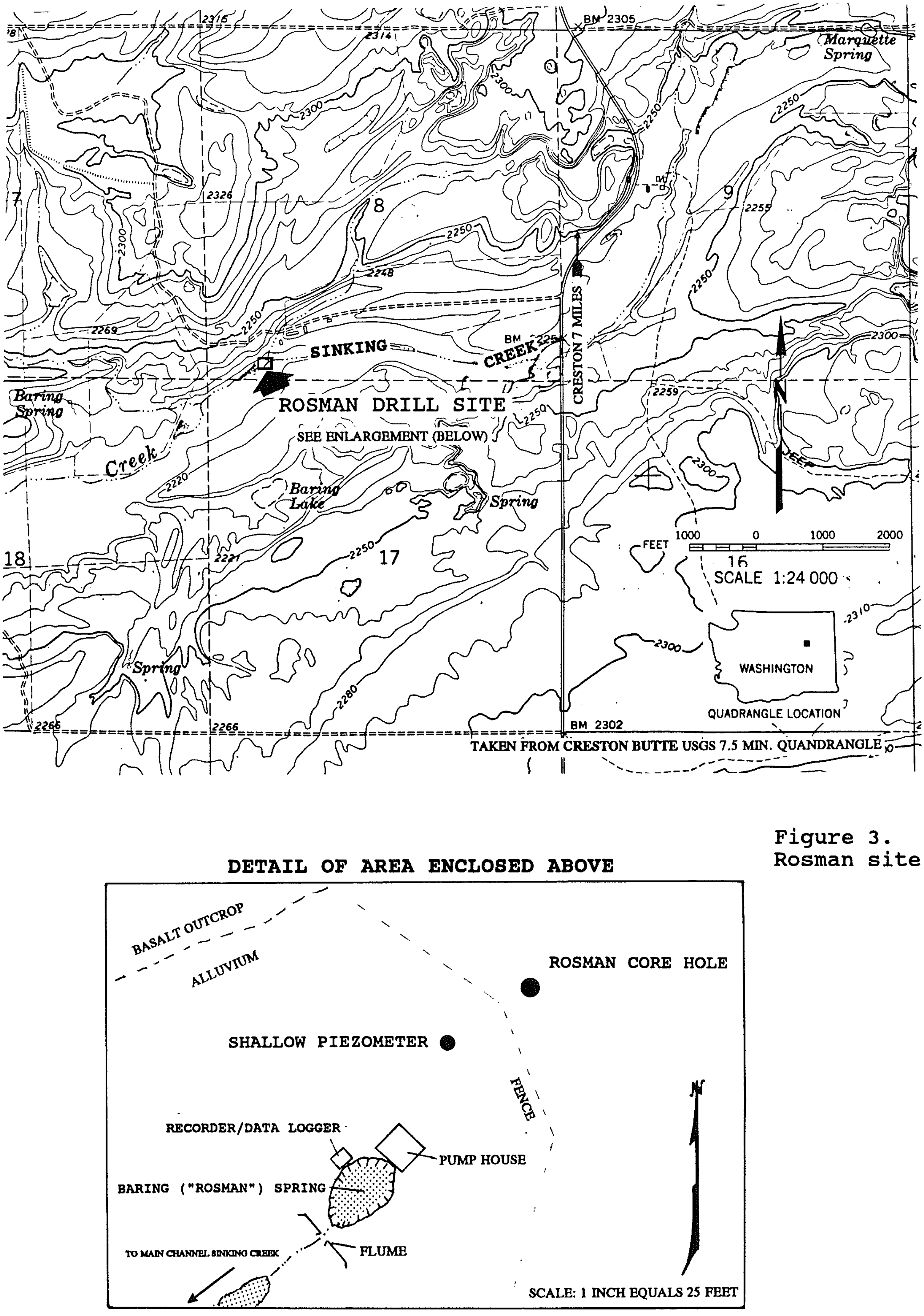

Figure 3.
Rosman site

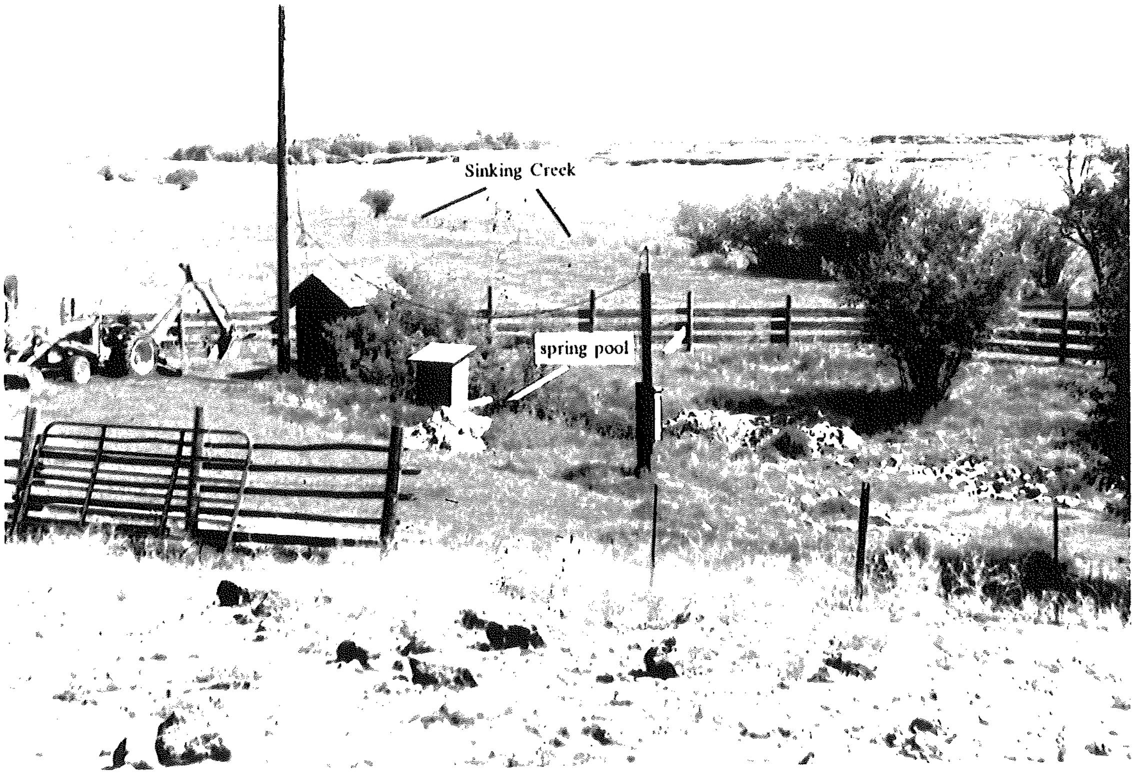

Plate 3. The Rosman site. The photo was taken from the basalt outcrop, looking southeast across the coulee. The pump house for the stock-watering pump and the instrument shelter (left center) are on the edge of the spring pool. An artificially-straightened portion of Sinking Creek appears in the middle distance (outlined, in part, by the line of bushes). The Rosman shallow piezometer hole was drilled near the rear tire of the backhoe. The Rosman core hole was drilled just left of the backhoe on the far side of the wooden fence. The flume shown in Figure 3 had not been installed at the time of the photograph. Note the light-colored pile of diatomite-rich alluvium next to the instrument shelter.

STRATIGRAPHY AND HYDROGEOLOGY

The project area lies near the northern boundary of the lava flows of the Miocene Columbia River Basalt Group (CRBG). Wildrick (1991) summarizes the relationship between stratigraphy and aquifer occurrence in the Sinking Creek area, and describes the nature of geologic materials supporting the creek channel. Figure 4 illustrates the general stratigraphy of the project area. The schematic, as-built diagrams of Appendix A shows the general stratigraphy at the drill sites.

The oldest rock encountered in the drill holes is the Grande Ronde Formation basalt, generally described as a dense, black, mostly aphyric basalt. This unit outcrops several miles to the north of the project area, and was encountered in the bottom 9.5 ft. of the Rosman core hole.

The Vantage Member sedimentary interbed of the Ellensburg Formation separates the Grande Ronde Formation from the overlying Wanapum Formation. In the Rosman hole, this unit occurs at 325.0 ft. below land surface (bls) and is a 0.5-foot-thick, soft, dark gray-green claystone. The Wagner hole is not deep enough to intercept the Vantage Member.

The Roza Member basalt of the Wanapum Formation directly overlies the Vantage Member interbed, and is exposed in the deeper canyons near the Columbia River, north of the project area. The Roza basalt is mostly aphyric in groundmass, but with striking plagioclase phenocrysts up to 1 cm in length that serve to easily identify the member. In the Rosman core hole, some intervals display a glomerophyric texture. The Roza Member was encountered at 142.4 ft. bls to total depth (185.4 ft. bls) in the Wagner core hole. The unit is 141 ft. thick (184.0 ft. to 325.0 ft. bls) at the Rosman site.

Directly above the Roza Member is the Quincy sedimentary interbed. In the project area, the Quincy interbed is usually a thin (1-2 ft.) claystone, is not ubiquitous, and may vary considerably in thickness over short distances. The Quincy is a 0.5-foot-thick, soft, greenish-brown claystone in the Wagner core hole, but is absent in the Rosman core hole.

The Priest Rapids Member of the Wanapum Formation overlies the Quincy interbed horizon, and is the only basalt unit exposed in the study area. The Priest Rapids Member is a medium-dark gray, microphyric basalt. A dense field of interwoven plagioclase laths is barely discernable in hand specimen. Outcrops of the Priest Rapids Member occur near both drill sites.

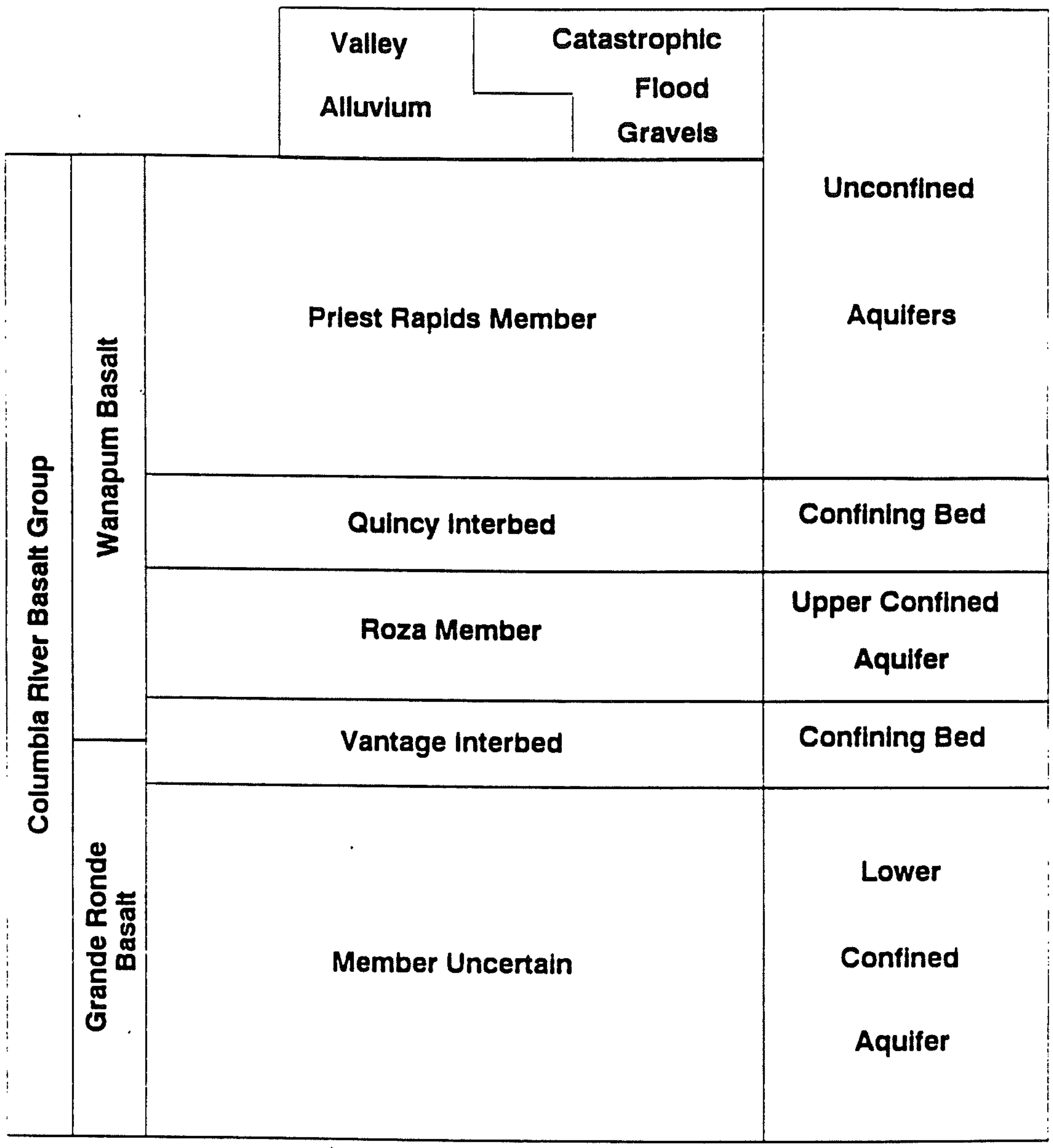

Figure 4. Hydrostratigraphy for the Sinking Creek Area (Modified after Wood, 1987b).

Loess (mostly eolian silt), deposited from late Pliocene through Holocene, overlies the CRBG and is intercalated with catastrophic flood deposits. The largest accumulation of this material is known as the Palouse Formation of "Bull Lake" age (200 ka to 125 ka) (Baker and Nummedal, 1978).

During and following latest stades of Pleistocene glaciation, large channels (or *coulees*) were incised into the basalt and surficial sediments by the erosive force of multiple, catastrophic floods, collectively known as the "Spokane Flood" (Baker and Nummedal, 1978; McDonald and Busacca, 1988). Gravel and sand deposits, left from aggradational stages of the flood, partially fill the coulees in places and mantle some of the higher terrain. Late Pleistocene or Holocene (post-flood) lake deposits cover much of the coulee bottoms. Lake deposits consist of clay, silt, volcanic ash, peat, and diatomite. Elsewhere, post-Flood loess and remnants of pre-flood loess overlie and are interbedded with both flood and lake deposits.

Hydraulic characteristics of basalt

Ground water moves principally through subvertical and subhorizontal fracture systems within basalt flows and within subhorizontal zones of higher permeability at the bases and tops of the flows (Gephart and others, 1979). Fractures originate from cooling of the basalt lava or from later, tectonic deformation. The hydraulic conductivity of fracture systems is related to the intensity of fracturing, the connectivity of the fractures, and the degree of blockage by secondary, in-filling materials, such as clay.

Fault zones in basalt may simultaneously transmit and confine ground water (Gephart and others, 1979). The plane of the fault and slip surfaces will often host gouge and impermeable clay, but the associated, peripheral fracture system may be highly permeable. Thus, fault zones and fracture systems may be sites of considerable vertical leakage of ground water and/or boundaries to horizontal flow (Newcomb, 1961 and 1969, and Pachis and others, 1988).

METHODS OF STUDY AND RESULTS

BASIS FOR SITING DRILL HOLES

Both core holes were located within a few feet of active or extinct springs and the main channel of Sinking Creek. Through the study of the stratigraphy and observation of ground-water levels near the spring sites, we hoped to gain insight into the mechanisms of interconnection between springs and basalt aquifers in the area.

The Wagner hole was drilled within a few feet of the defunct "Wagner Spring", on the banks of Sinking Creek (Plates 1 and 2). The spring had contributed to flow in the creek before 1977 (Clarence Wagner, personal communication). The main objectives at this site were to gather detailed lithologic information from the drilling, and to install at least one piezometer as a local ground-water monitoring point within the Priest Rapids basalt.

At the Rosman site (Figure 3, Plate 3), Baring Spring was not flowing during the time of the project, but maintained a pool that fell steadily during the summer. The spring normally flows during winter and spring. If, as postulated, the basalt aquifers feed this spring, a sufficient hydraulic stress, imparted within a core hole in the basalt several feet from the spring, might induce a measurable response in the pool of the spring. This relationship might be especially notable if the interconnection between spring and aquifer(s) were via a two-dimensional, highly-conductive "conduit" as suspected by Wildrick (1985). A similar structure was detected in hydrologic tests in a nearby well field by Steele and others (1988). Testing would consist of isolating specific intervals of the core hole, in the basalt, with an inflatable packer and injecting a metered amount of water into the isolated interval while monitoring the level of the spring pool.

Alternatively, if no distinct structure exists, leakage between aquifers may be occurring over a large area. If significant, upward or downward flow potential exists in the proximity of the spring, properly-placed piezometers would define this. Wildrick (1991) more recently favors the possibility that basalt aquifers may contribute to, or receive ground water from the broad alluvial aquifer that hosts the spring. Pumping of the spring pool might induce a response in the nearby piezometers.

A second, shallow hole was drilled to near the base of the alluvium at the Rosman site to observe the behavior of the water-table aquifer in the alluvium, both during the injection testing in the Rosman core hole, and during the pumping test of the spring.

DRILLING

All three holes were drilled with a track-mounted, high-speed wireline diamond drill using a "Hydracore 28", Longyear Series 210, hydraulic operating system. Both the Wagner and Rosman core holes were drilled with "N"-size rods and "NQ" diamond bits. Nominal diameters of the holes and core are 2.98 inches and 1.875 inches, respectively.

Surficial materials (alluvium) were drilled to refusal with a hollow-stem auger bit. Drive samples of fine-grained sediments were taken through the auger bit to a depth of 6 ft. bls at the Rosman core hole.

All core was logged in detail and boxed for storage. Particular attention was focused on the number, orientation (with respect to horizontal), width, and filling materials of fractures. Original, lithologic logs for each hole appear in Appendix B.

Steel surface casing was emplaced using the rotary action of the drill and a diamond-impregnated casing shoe. Surface casing for the "N"-size hole has the same nominal dimensions as "H"-size drilling rods (3.5 inches, O.D.), and is essentially reamed into place within the existing "N"-size hole. Project leaders initially intended to remove the surface casing upon completion of the holes, but problems with the drilling equipment made it necessary to cement the casing in place in the Rosman core hole.

A summary of the progress and highlights of each hole follows.

Wagner core hole

The Wagner core hole was spudded on June 11, 1991 using 4-inch and 8-inch auger bits. The hole was drilled in this manner to a depth of 8 ft. bls. Wireline coring methods were then used to drill to a total depth of 185.4 ft. bls. Total depth was reached June 19, 1991. Temporary, steel surface casing, with a diamond shoe, was installed to a depth of 12.0 ft. bls.

The average drilling rate for the Wagner hole was 20.6 ft./day, but days of greater than 30 ft. were common when the rock was competent. Coring runs were typically 4-5 ft. in length (inner tube capacity = 5 ft.), but occasionally less than one foot in fractured basalt. Severely fractured basalt invariably caused jamming of the core barrel and slow drilling. Significant fracturing and resulting slow drilling was encountered in the upper 50 feet of the hole, and in 3 other intervals deeper in the hole, each roughly 5 ft. in length.

Eight feet of loess and alluvium were penetrated at the Wagner site before the Priest Rapids Member basalt was reached. The Priest Rapids Member is a medium-to-dark gray basalt, with widely dispersed vesicles and amygdules 1-2 mm in diameter that diminish in abundance downward. The vesicles and amygdules disappear completely at 77.5 ft. bls, and the rock becomes massive and relatively unfractured. Large vesicles, often in discrete bands or layers, reappear at 123.0 ft. bls, and accompany an increase in fracture abundance. Scoriaceous basalt (flow bottom?) and flow breccia are encountered at 130.6 ft. to 133.9 ft. bls and at thinner horizons down to 141.7 ft. bls.

The Quincy Interbed, is found at 141.7 ft. to 142.4 ft. bls. At this location, the Quincy is a soft, moderately-friable, greenish-brown claystone.

Vesicular, porphyritic basalt of the Roza Member lies directly below the Quincy Interbed. Vesicles in this unit also tend to occur in distinct bands after passing through a uniformly-vesicular flow top. Drilling ceased after penetrating 43.0 ft. of the Roza Member.

Fracture-filling or fracture-coating materials in the basalt of the Wagner hole are mostly iron oxides (hematite, goethite(?), and limonite) and clay. Other minerals identified in hand specimen were pyrite, zeolite(s), manganese oxide, calcite, and possibly chlorite.

Ground water was first encountered between 42.7 ft. and 89.8 ft. bls in the Wagner hole. Because of large amounts of water used during drilling, static-water-level measurements were made only in the morning, prior to drilling activities for the day. On the morning following the last day of drilling, the static water level was 79.98 ft. bls. Figure 5 illustrates static water-levels recorded during the drilling of the Wagner hole.

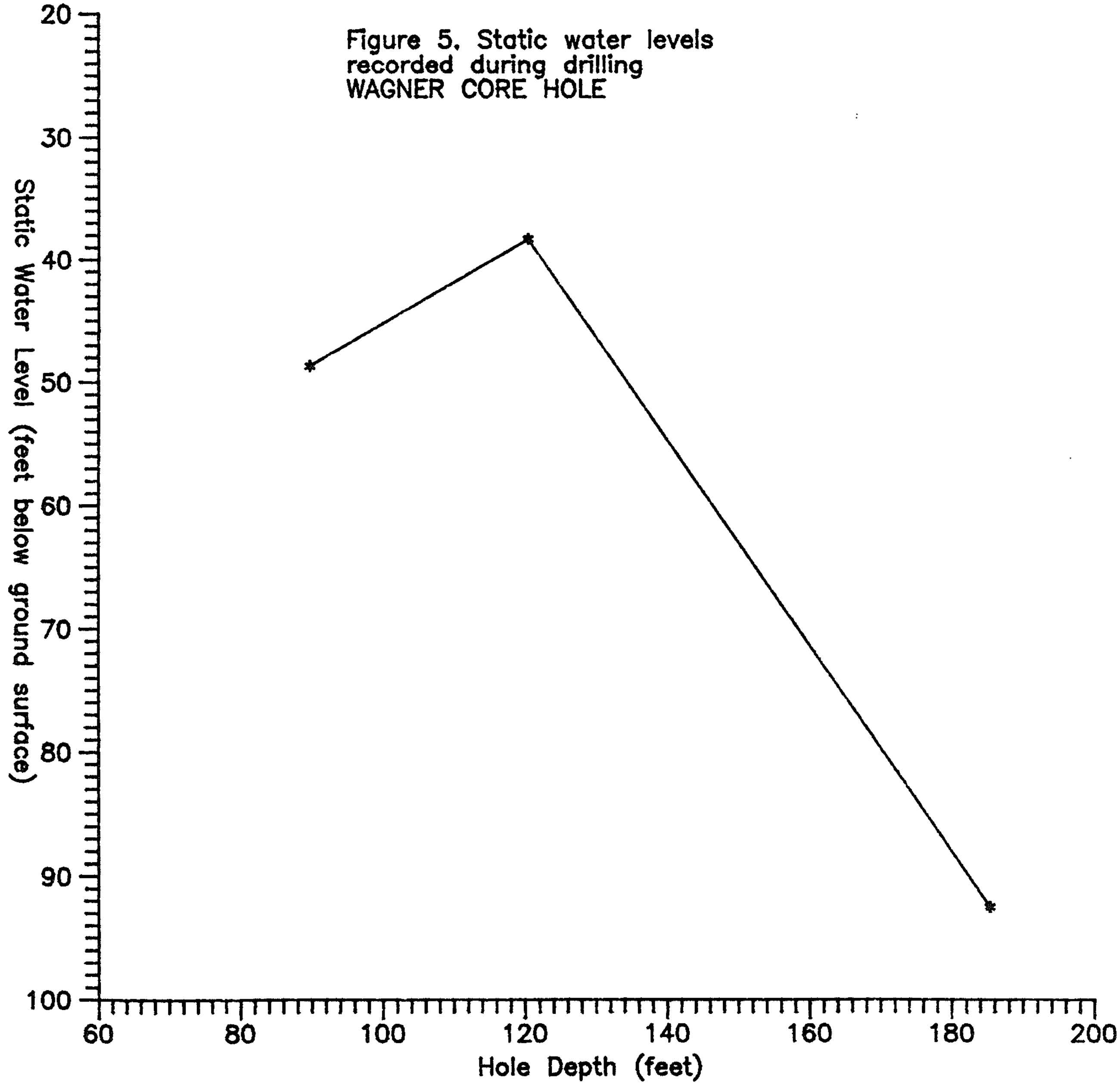
Figure 5. Static water levels
recorded during drilling
WAGNER CORE HOLE
Static Water Level (feet below ground surface)
20
30
40
50
60
70
80
90
100
60
80
100
120
140
160
180
200
Hole Depth (feet)

Rosman Core hole

Drilling began for the Rosman core hole on June 21, 1991. An 8-inch hollow-stem auger was used to drill through the first 10.2 ft. of alluvium. Continuous drive samples were taken from the surface to 6.5 ft. bls, where gravel prohibited any further progress with the sampling tube. Wireline, NX-size core drilling was used from 10.2 ft. to the total depth of 335.2 ft. bls. NX-size surface casing and a diamond casing shoe were installed to a depth of 33.5 ft. bls into Priest Rapids Member basalt. Total depth was reached on July 15, 1991.

Drilling rates averaged 25.8 ft./day, discounting days of testing or of no drilling activity. Many days saw over 40 ft. of drilling. Drilling rates were enhanced when the drillers acquired a new, 10-foot inner tube for holding core, so fewer wireline trips were necessary. Although 10-ft. runs were possible with the new equipment, intervals of fractured basalt caused core-barrel jamming and short runs at many levels (Plate 4). Significant intervals of fracturing occur from; surface to 30 ft. bls, 150 ft. to 177 ft. bls, and 280 ft. to 325 ft. bls.

From the surface, five feet of clay-rich soil and diatomite overlies 5-7 ft. of gravelly alluvium. The lower few feet of the gravel is extremely coarse, and highly conductive of ground water. The base of the gravel lies directly upon highly-fractured basalt of the Priest Rapids Member at 12.4 ft. bls.

The Priest Rapids basalt is almost uniformly vesicular/amygdaloidal throughout, with the exception of isolated horizons of higher vesicle density at widely-separated intervals. Vesicles almost completely disappear from 139.0 ft to 180 ft. bls. The vesicles reappear abruptly at 180 ft., and continue down to the top of the Roza Member basalt (184.0 ft. bls).

The Quincy interbed is absent at this site. In its place, is a highly-vesicular rubble zone representing the flow-top material of the Roza Member basalt.

The Roza Member basalt is encountered from 184.0 ft. to 325.0 ft. bls. The rock is distinguished by its characteristically large plagioclase phenocrysts. Zones of significant fractures in the Roza Member occur from: 225.0 to 236.4 ft. bls, 259.0 ft. to 264.3 ft. bls, and 278.0 ft. to 325.0 ft. bls (bottom of Roza). Horizons

Plate 4. Extremely-fractured and vesicular Roza Member basalt from the Rosman core hole. Note the large, white plagioclase phenocrysts in the lower right of the photograph.

having particularly high concentrations of vesicles occur from: 184.0 ft. to 202 ft. bls; 223.0 ft. to 242.0 ft. bls; 259.5 ft. to 275.0 ft. bls, and; 282.9 ft. to 306.0 ft. bls.

Fracture-filling/coating materials in the Priest Rapids and Roza basalts consist of clays, iron oxides, manganese oxide, zeolite(s), and pyrite. One dark, brown-green material suggested the appearance of serpentine in hand specimen, but x-ray diffraction results indicated the material was probably a clay mineral.

A downward hydraulic gradient is indicated by daily records of static water levels during the drilling of the Rosman core hole (Figure 6). The two outstanding readings at 200.0 ft. bls and 234.0 ft. bls are difficult to explain. It is possible that fractures near these levels were especially conductive, and may have allowed water levels to adjust overnight more quickly to ambient hydrologic conditions than during the periods of inactivity preceding the other measurements. Cuttings from subsequent drilling may have then partially plugged these fractures, thus masking their effect during later measurements. If this assumption is correct, these two lower readings may more closely reflect the composite hydraulic head at their respective hole depths than do the other readings. Supporting this assumption is the fact that static water levels in both the completed Rosman piezometers quickly stabilized at levels significantly lower than those predicted by daily readings taken during drilling.

Rosman shallow hole

During the drilling and hydrologic testing of the Rosman core hole, we decided that a monitoring point in the alluvium between the core hole and the spring would help us further resolve hydraulic interconnection of the basalt-alluvium-spring system and estimate the hydraulic conductivity of the alluvial material. The hole was drilled on July 3, 1991, to a depth of 9.5 ft. bls, and is approximately 16.5 ft. southwest of the core hole (Figure 3). Hollow-stem auger bits of 4-inch and 8-inch sizes were used to drill to total depth. Appendix A illustrates lithologies and as-built specifications for the shallow Rosman hole. Lithologies encountered in this hole are expectedly similar to the Rosman core hole, except that a thicker layer of diatomite was present (from 2.0 ft. to 4.0 ft. bls).

Static water level in the shallow hole was 5.5 ft. bls the day following drilling, and after the hole was purged of cuttings.

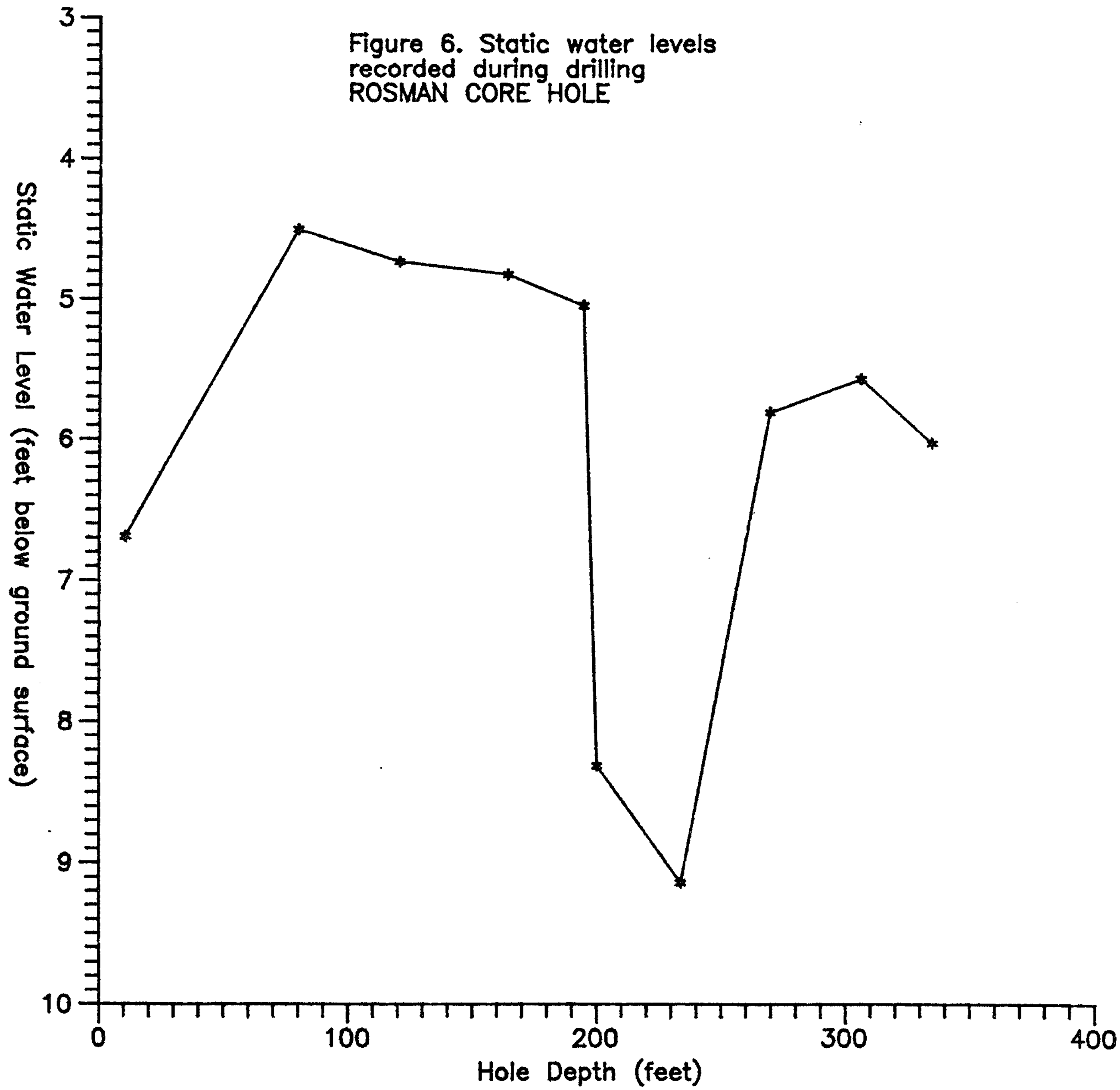
Figure 6. Static water levels
recorded during drilling
ROSMAN CORE HOLE
Static Water Level (feet below ground surface)
3
4
5
6
7
8
9
10
0
100
200
300
400
Hole Depth (feet)

GEOPHYSICAL LOGGING

Washington State University, Department of Geological Engineering was contracted to complete a suite of geophysical logs for the Wagner and Rosman holes. Because of problems with caving, and a possible crooked hole, the Wagner hole was not logged. Caving in the Rosman hole also limited the depth of logging to 319 ft. bls. Functions used in the logging are; natural gamma, flowmeter (relative, vertical fluid velocity), caliper, fluid temperature, fluid resistivity, wall resistivity, and spontaneous potential. Functions using radioactive sources were unavailable. Appendix C is the geophysical log of the Rosman core hole.

Flowmeter and caliper functions exhibit marked deflections at approximately 175 ft. bls in the Rosman hole. This is nine feet above the Priest Rapids Member-Roza Member contact, as interpreted from core. Also present at approximately the same depth are large, positive and negative deflections in spontaneous potential and wall resistivity, respectively. These anomalies also approximately correspond to the flow bottom of the Priest Rapids Member, which is probably the first, significant water-producing zone encountered in the core hole. Gephart and others (1979) also found resistivity and spontaneous potential the most useful functions for identifying basalt interflow zones and water-producing horizons.

HYDROLOGIC TESTING

Injection and pumping tests were conducted at the Rosman drilling site in order to test for hydraulic connection between basalt aquifers and Baring Spring. Accurate hydraulic parameters for the formation were not sought in the initial injection test. Rather, we wished to induce a measurable rise in the pool of Baring Spring by injecting water into an isolated interval of basalt, and thereby demonstrate hydraulic connection between spring and basalt. Alternatively, we would pump the spring pool and try to observe a response in water levels in the basalt aquifer(s). We hoped that, at a minimum, a qualitative relationship might be demonstrable because of the proximity of the core hole to the spring (50 feet).

In the first test, a 24-inch-long inflatable packer was installed at the 45.5-foot-bls level in the Rosman core hole. At the time of the test, the hole depth was 195.0 ft. bls, but was back-filled with grout to 184.0 ft. bls. Water was injected into the isolated interval below the packer at a regulated, metered rate from a large tank truck using a 5-horsepower "trash" pump. The injection rate was monitored by a "Tyme-Flyte" ultrasonic flowmeter and an impeller-type, totaling flowmeter. Plate 5 shows the equipment used in the first injection test. The levels of the spring pool and of the water in the annulus of the core hole (above the packer) were monitored during the test. Head within the isolated interval below the packer was recorded by transducer and data logger. Appendix D is the record of head (in feet) measured within the isolated interval during the test.

During 12 minutes of injection, at a rate of 15 gpm, the hydraulic head in the interval below the packer increased by almost 90 feet; from 24.4 ft. to 114.1 ft. above the level of the transducer. No response was observed in the level of the spring pool. The water level in the interval above the packer rose at a rate that was too rapid to accurately measure with equipment at hand. The latter observation indicates either a poor seal between the packer and the bore wall, or upward movement of water through fractures that intersect the bore and subtend the packer. Approximately 12 minutes into the test, fittings on the injection line leading to the packer failed suddenly and the test was abandoned. A generous fountain of water issued from the hole for several minutes after the injection line broke. Apparently, much of the water injected was not readily accepted by the fracture system in the basalt, and was ejected by force of the overpressured interstices in vicinity of the hole when the pump was turned off. We then surmised that to induce a response in the spring pool, through such a marginally-conductive medium, might require several hours and/or lower injection rates.

The following day, we pumped the pool of the spring itself for two hours at 65 gpm. During this test, water levels in the core hole (above and below the packer) and in the spring pool were recorded. We also monitored the water level in the shallow piezometer that we had installed at the end of the previous day. This piezometer is open to the alluvial, water-table aquifer and is situated roughly halfway between the spring and the core hole (Figure 3). The pumped water was discharged approximately 75 feet south of the spring pool toward the main channel of Sinking Creek. A two-minute interruption occurred 24 minutes into the test because of an unsecured oil plug on the pump engine.

Figures 7-10 show the results of the spring-pumping test. The spring pool itself was lowered 75 mm (2.95 inches) during the two hours of pumping. The pool recovered 88% of its pre-pumping level within 10 minutes of pump shutdown. Superimposed on the pumping response of the spring pool are some slight effects of intermittent withdrawals by a stock-watering pump and an ongoing, seasonal decline in the pool.

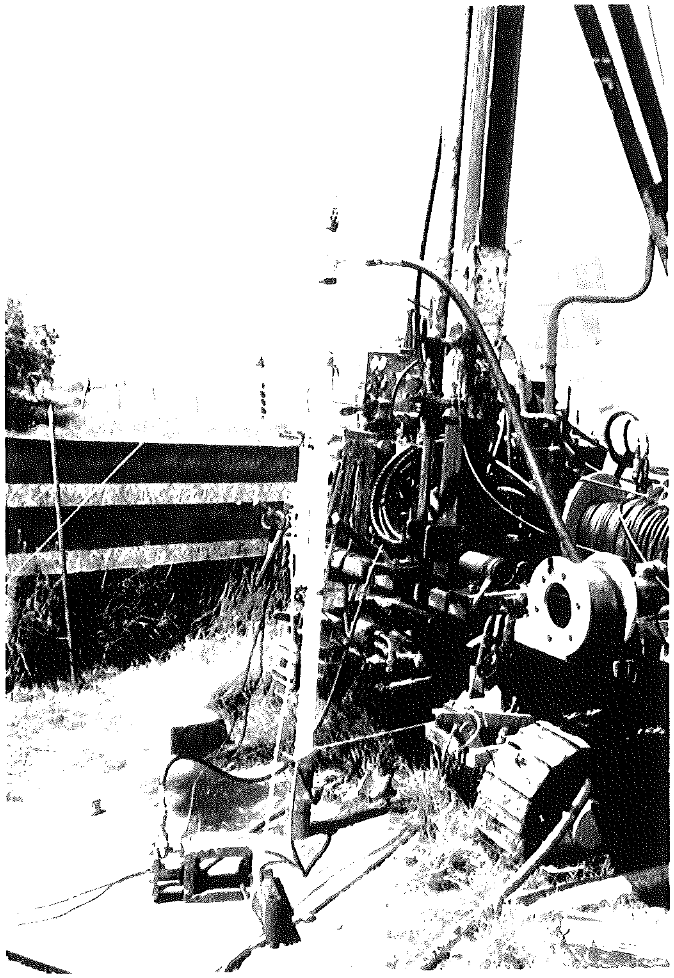

Plate 5. The apparatus used for the first injection test. Shown are the ultrasonic flowmeter (attached to the left side of the vertical injection pipe) and the adapter at the top of the pipe allowing the entry of the transducer tube.

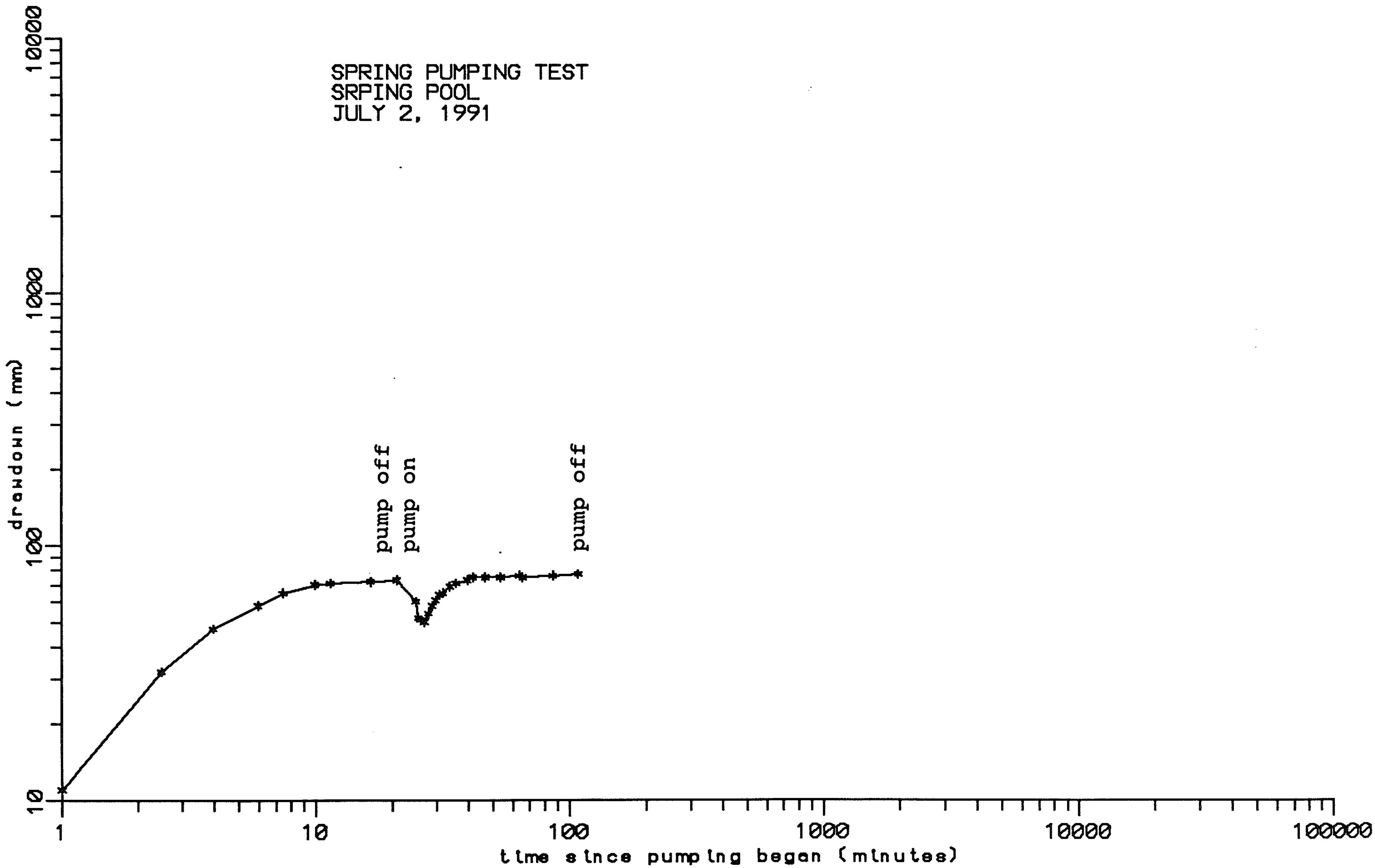

Figure 7. Time-drawdown plot of the spring pumping test--spring pool.

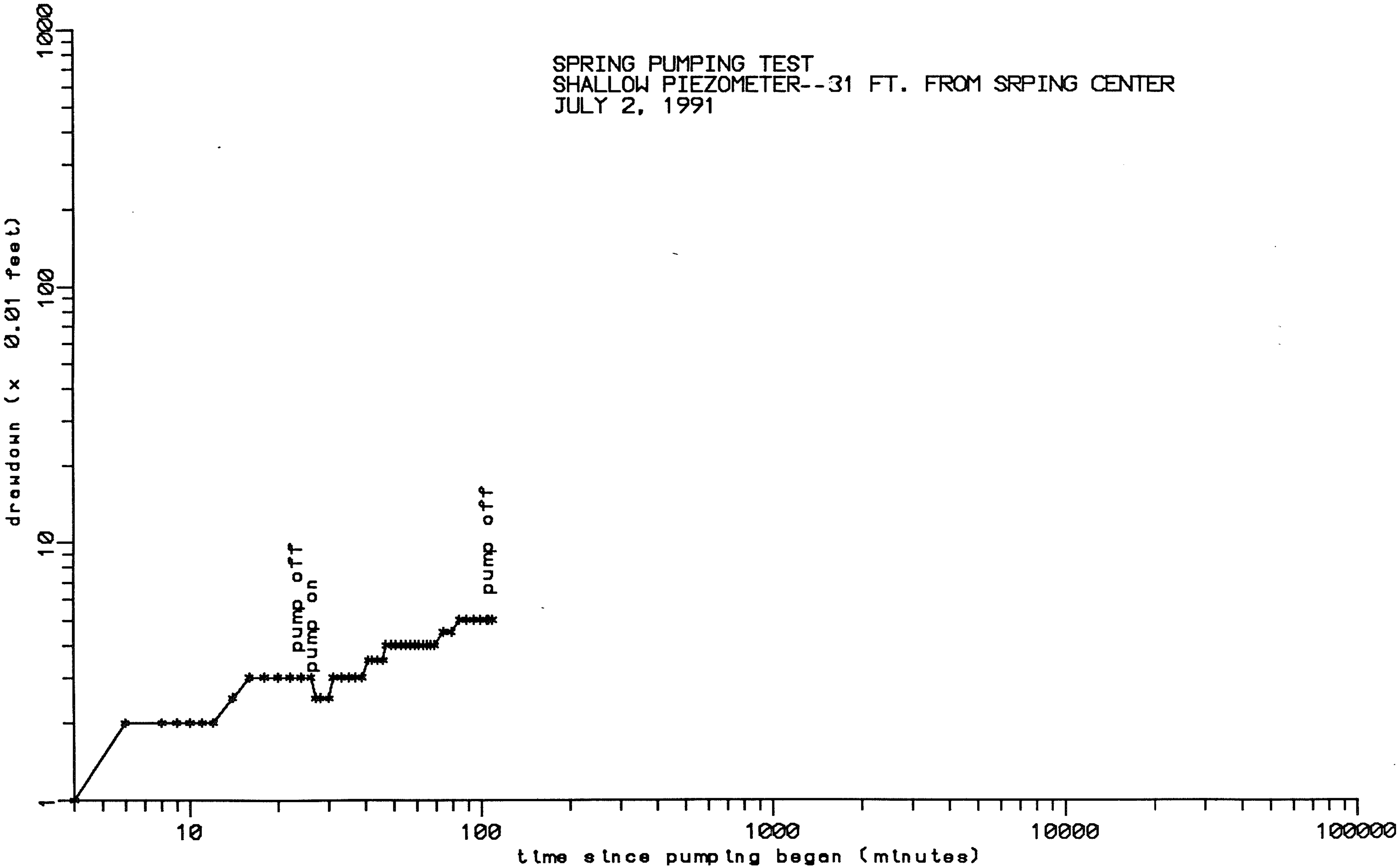

Figure 8. Time-drawdown plot of the spring pumping test--shallow piezometer.

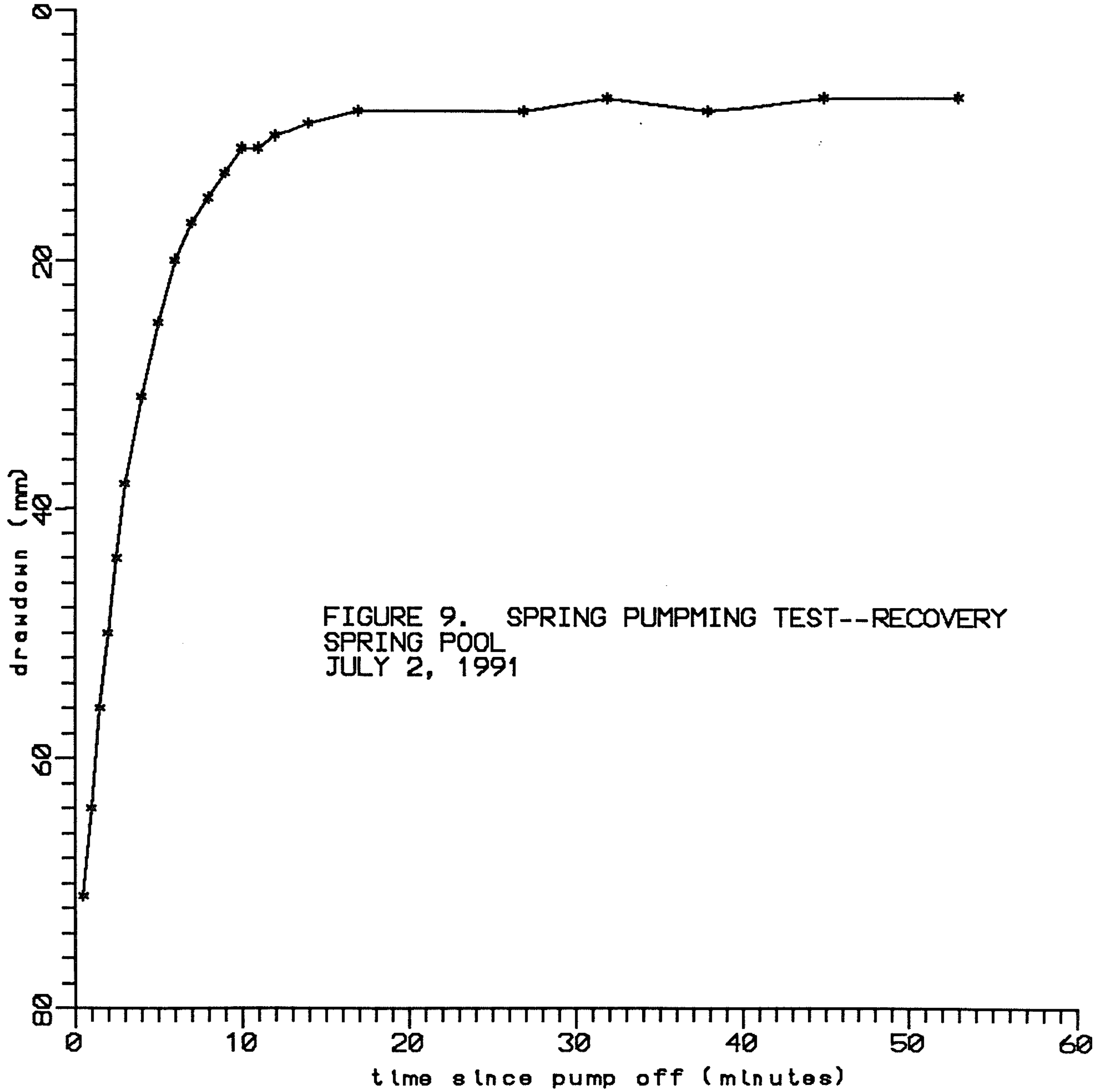

Figure 9. Spring pumping test recovery--spring pool.

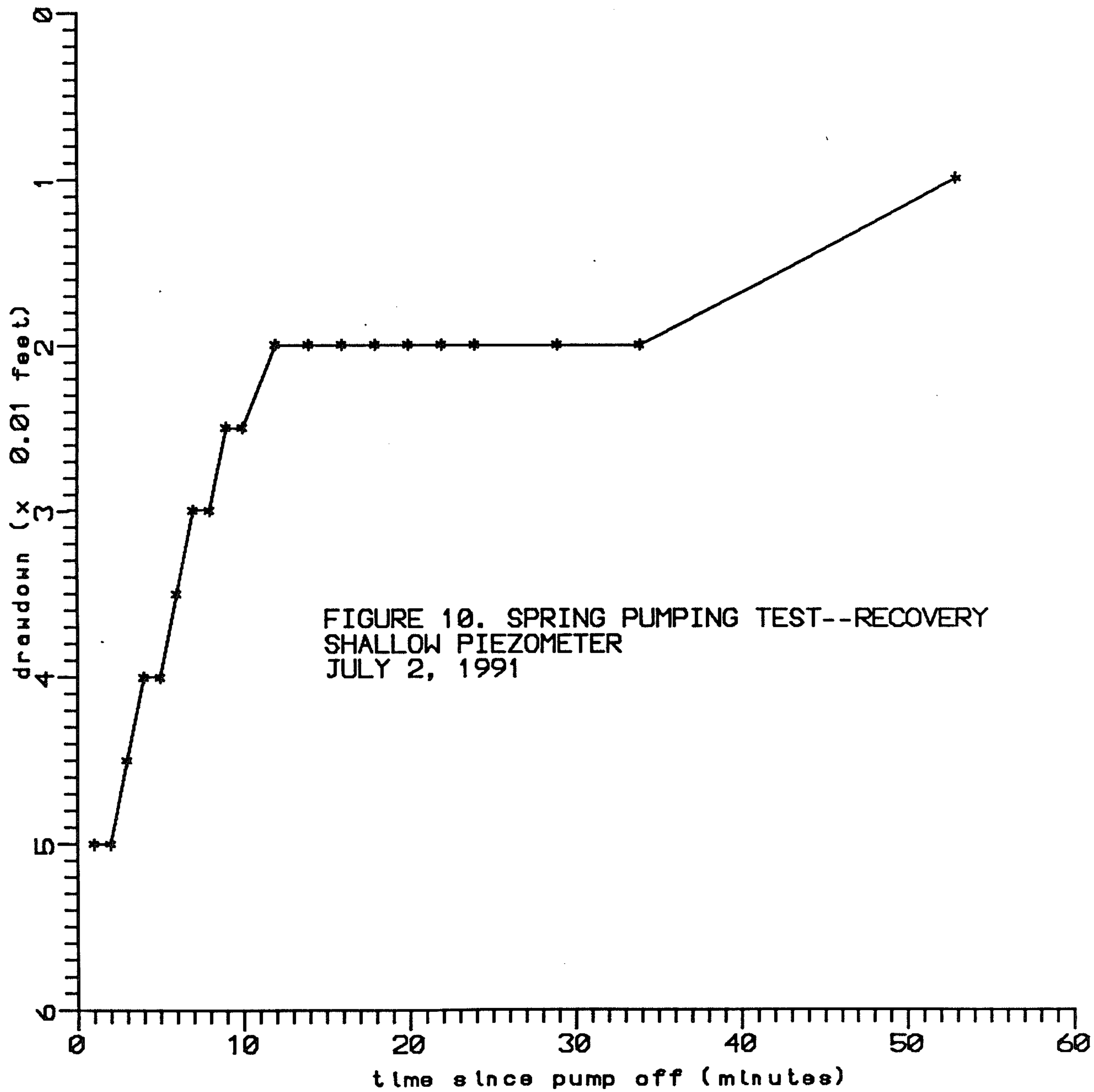

Figure 10. Spring pumping test recovery--shallow piezometer.

Records of spring-pool fluctuations (Appendix E) suggest that the stock-watering pump may intermittently cause a lowering of the pool on the order of a few millimeters (few hundredths of a foot). The seasonal decline rate during the drilling project was on the order of 0.05 ft. in 24 hours.

The water level in the shallow piezometer declined 0.05 ft. during the test, and had recovered to within 0.01 ft. of static level 53 minutes after the pump was shut down. Neither of the water levels in the core hole (above or below the packer) responded to the test.

Rough analyses of the time-drawdown data in Figure 7, assuming non-equilibrium conditions, and comparison with Theis type-curves, indicate a transmissivity for the alluvium of 6000 $ft.^2$/day, a hydraulic conductivity of 1200 ft./day, and a storage coefficient of 0.02. The value for transmissivity is probably well below the average for the alluvium over the entire coulee bottom. Shallow seismic-refraction surveys indicate that the alluvium thickens considerably toward the main channel of Sinking Creek at the center of the coulee (due south of the test area).

A final injection test was attempted in the Rosman hole on July 9, with the hole depth at 200.2 ft. bls. This time, we set the packer at 75.0 ft. bls, within a relatively fracture-free interval. Several highly fractured intervals occur between 75.0 ft. and 200.2 ft. bls. No instruments were installed in the isolated zone below the packer. The injection rate was approximately 15 gpm, as in the first test. We monitored water levels in the spring pool, the shallow piezometer, and the annular space above the packer in the core hole. At six minutes into the test, the packer assembly failed once again and the testing was abandoned for lack of time. During the six minutes of testing, no response was observed in the spring pool or the shallow piezometer.

In summary, two bootless injection tests in the Rosman core hole and a two-hour pumping test of the spring pool failed to demonstrate hydraulic connection between the Priest Rapids basalt aquifer and Baring (Rosman) Spring. These efforts were thwarted by failure of equipment during injection tests, low hydraulic conductivity of the tested intervals, and limited pump capacity. The pumping test did show that the alluvium has high hydraulic conductivity and potentially high transmissivity.

PIEZOMETER INSTALLATION

Because of the small diameter of the core holes, 1-inch, schedule 80 PVC (nominal outside diameter of 1.3 inches) was used as piezometer tubing. Tolerances, therefore, were low, in the core holes, especially in the Rosman core hole where two piezometers were installed and a 1-inch tremie was used to insert pack and sealing materials. Despite this constraint, all of the equipment and seals were installed as planned. The Rosman shallow piezometer, also 1-inch PVC, was installed in an 8-inch auger hole without difficulty. Appendix A shows as-built specifications for the four piezometers.

The injection tests had taught us that although an interval of basalt may contain numerous fractures, it may not necessarily transmit ground water. To ensure communication between water-bearing fractures and the piezometers, 20 ft. to 30 ft. of screen was installed for each piezometer within selected, densely-fractured intervals thought to be water-bearing. Twenty feet of screen was installed for the Wagner piezometer in the Priest Rapids Member basalt (from 113.7 ft. to 133.7 ft. bls), so that the bottom of the screen rests upon a bentonite-pellet seal 7 ft. above the Quincy interbed.

The two piezometers in the Rosman core hole were screened from 157.0 ft. to 177.0 ft. bls (in the Priest Rapids Member basalt), and from 285.0 ft. to 315.0 ft. bls (in the Roza Member basalt). Brief slug tests in both piezometers indicated no intra-bore hydraulic communication between the Priest Rapids Member and the Roza Member.

The shallow piezometer at the Rosman site was screened from 4.5 ft. to 9.5 ft. bls. Piezometer screens in all holes are Schedule 80 PVC, 20-slot. Sand packs were emplaced around all screens with a tremie, except in the shallow hole, where sand was poured through the hollow-stem auger bit.

Upon completion, dedicated transducers were installed in both piezometers in the Rosman core hole. At the time of completion, static water levels in the Rosman piezometers were 5.5 ft. bls in the shallow hole (measured July 3, 1991), 20.7 ft. bls in the Priest Rapids basalt (measured August 8, 1991), and 31.8 ft. bls in the Roza Member basalt (measured August 8, 1991), indicating downward flow potential at this location.

Static water level in the Wagner hole was 70.3 ft. bls a few days after the piezometer was installed.

SUMMARY

The lithologic and hydrologic information gathered at the Wagner and Rosman sites have demonstrated that: 1. The Quincy interbed is absent at the Rosman site, and thus, is not a confining horizon at this location. 2. A downward ground-water flow potential exists between the Priest Rapids basalt and the Roza Member basalt, at the Rosman site. 3. An alluvial aquifer having high hydraulic conductivity (1200 ft./day), and potentially high transmissivity, overlies the Priest Rapids basalt at the Rosman site. 4. Intense fracturing does not uniformly imply increased hydraulic conductivity in the basalt.

Confining layers at the Rosman site, especially between the Roza Member and Priest Rapids Member, are most likely the dense, flow interiors having either few fractures or fractures sealed by secondary minerals.

Two aborted injection tests in the Rosman core hole, and one pumping test of Baring Spring could not establish a direct hydraulic connection between the Priest Rapids Member basalt and the spring, nor between the surficial alluvium and the basalt. However, the results of the study do not preclude the possibility of widespread leakage between the alluvium/spring system and the basalt aquifers near the Rosman site. The pumping test did demonstrate a direct hydraulic connection between the spring and the surficial alluvium.

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APPENDIX A

SITE STRATIGRAPHY

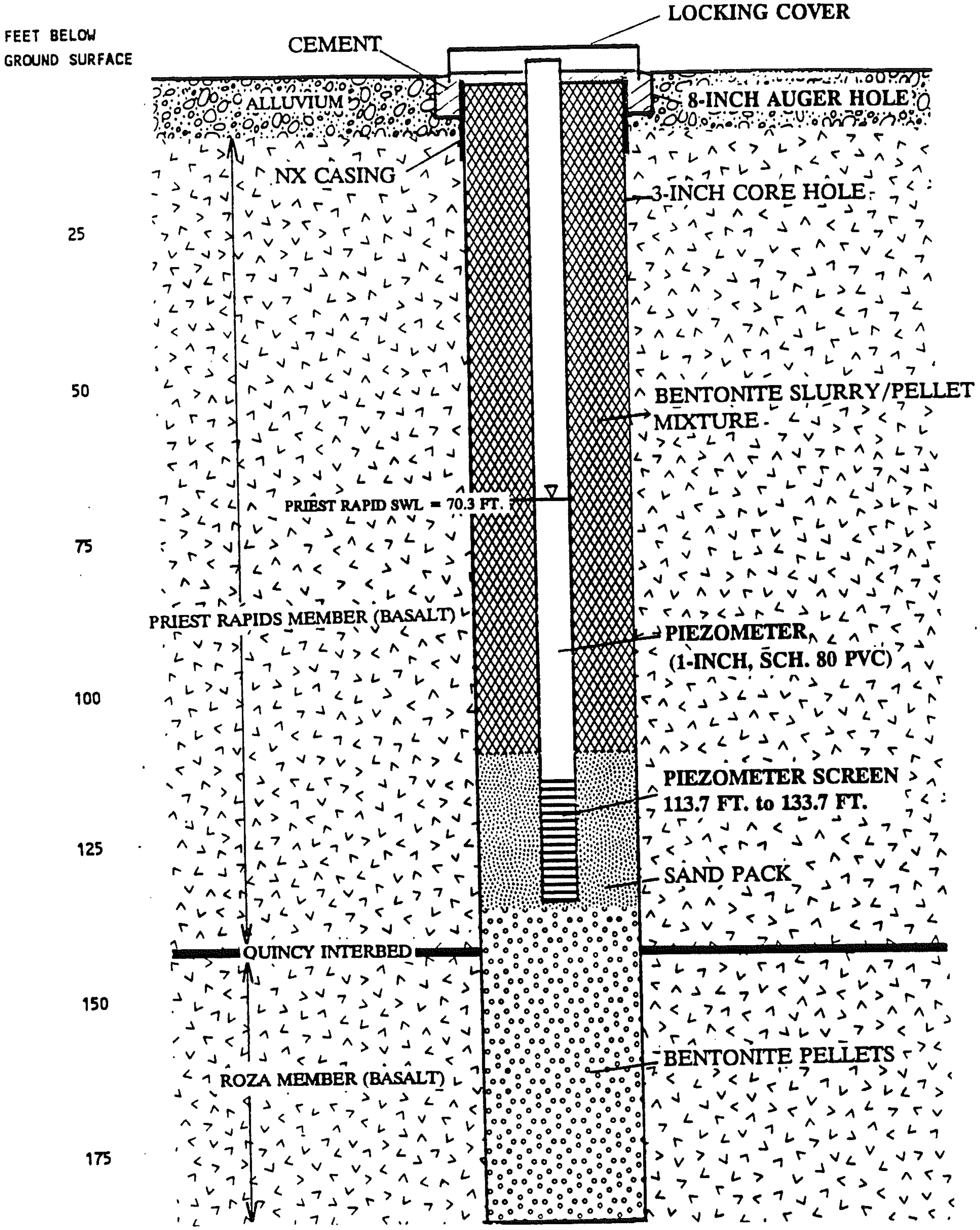
AND

PIEZOMETER AS-BUILT SPECIFICATIONS

WAGNER CORE HOLE

SURFACE ELEVATION = 2090 FT. MSL

25/35-12K2

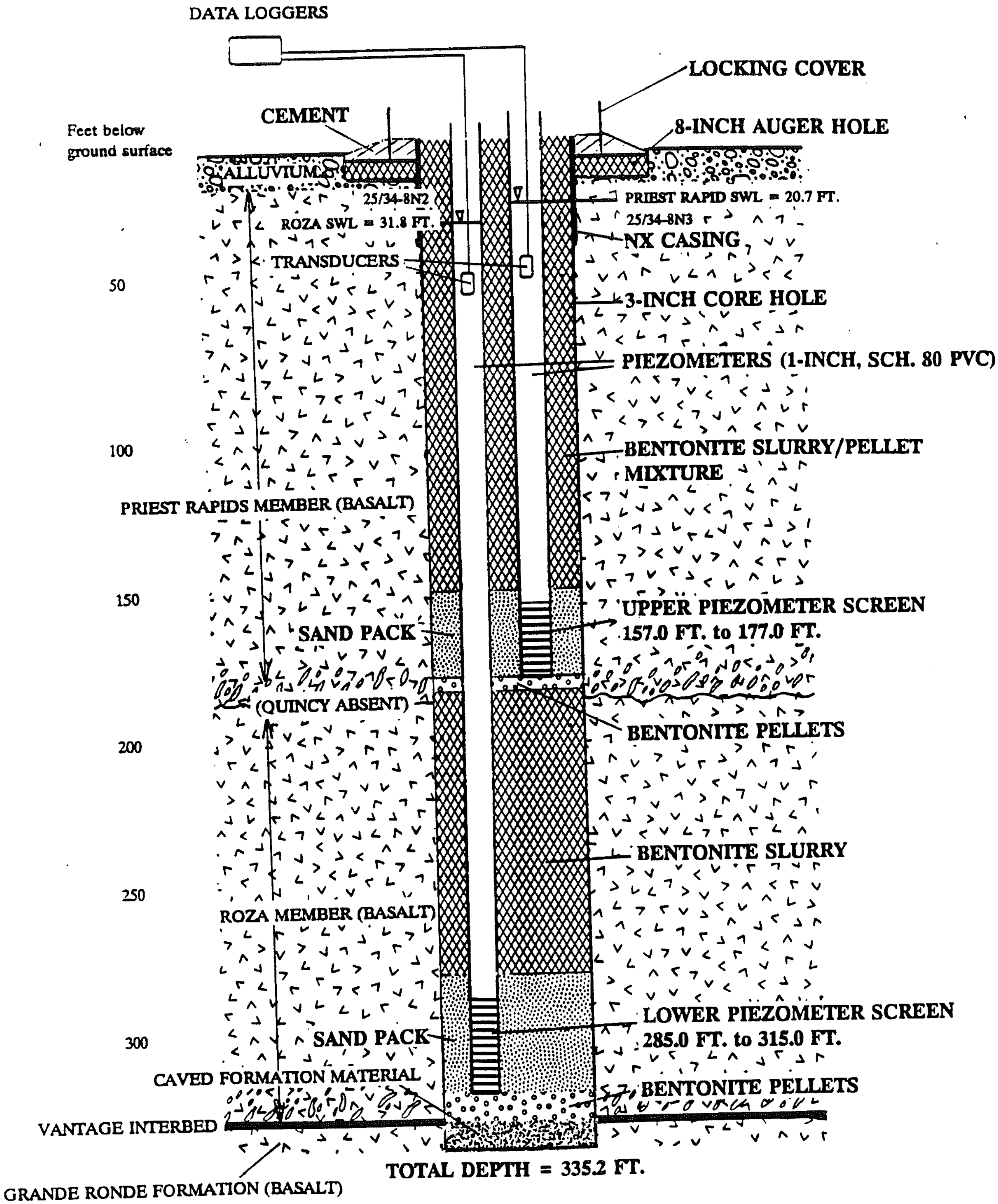


TOTAL DEPTH = 185.4 FT.

One inch equals 25 feet vertically (horizontal not to scale)

ROSMAN CORE HOLE

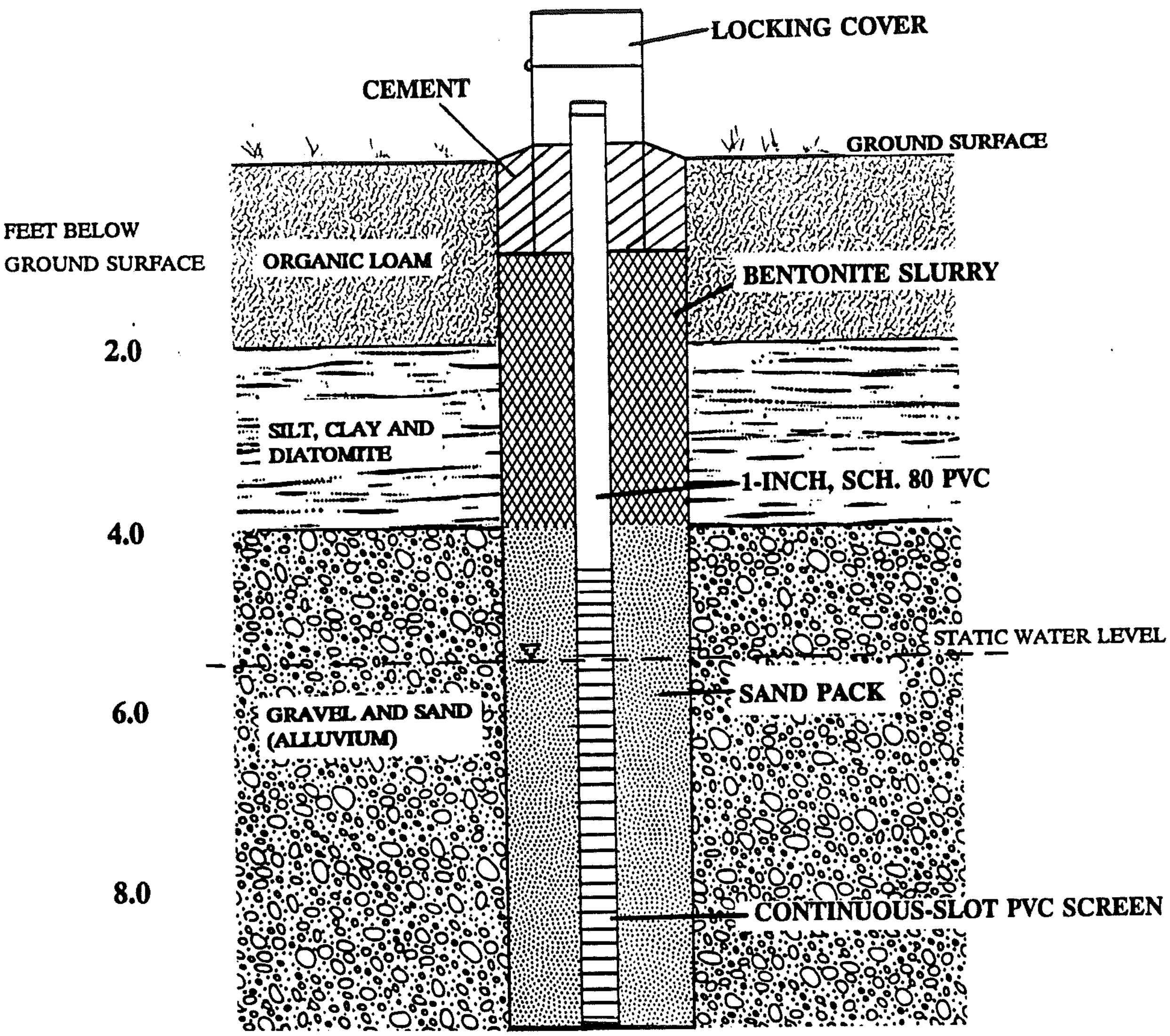
SURFACE ELEVATION = 2210 FT. MSL



One inch equals 50 feet vertically (horizontal not to scale)

ROSMAN SHALLOW PIEZOMETER

25/34-8N4



TOTAL DEPTH = 9.5 FT.

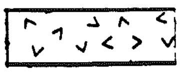
One inch equals 2 feet vertically (horizontal not to scale)

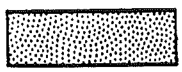
APPENDIX B

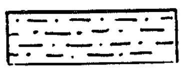
LITHOLOGIC LOGS

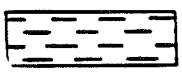
SYMBOLOGY FOR LITHOLOGIC LOGS

Lithologies

 basalt

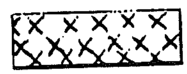
 sand/sandstone

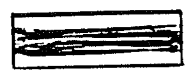
 silt/siltstone

 clay/claystone

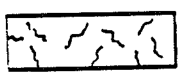
 gravel/sandy gravel

 breccia

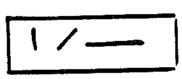
 palagonite and similar material

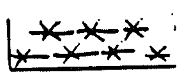
 volcanic glass, devit. glass

Fracturing

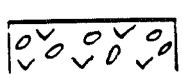
 (in graphic log)

(in "Formation Condition" column)

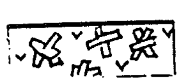
 fractures showing relative, approximate attitudes (with respect to horizontal)

 multiple orientations--pervasive

Other features

 vesicles, spherulites, and amydules (in basalt)

 phenocrysts

 glomerocrysts

DRILL LOG

HOLE NO. R-Rosman Spring ("BARING sp")

PROJECT Sinking Creek
CONTRACTOR Budinger & Associates
DATE STARTED 6/21/91 COMPLETED 7/15/91
LOGGED BY B. BARNETT

TOTAL DEPTH 335.2' LAND SURFACE ELEV. 2210 FT. MSL
INCLINATION VERT. BEARING
COORDINATES T 25N R 34E S 8, SW, SW OTHER
SURVEY REFERENCES

Footage	Run/Box#	Water (gpm)	Pit Loss (gpm)	Fracture Orientation	Fracture Filling	RQD (%)	Casing Schedule
0–0.2	1/1			DRIVE SAMPLES (0–6.5)		0	NX CASING
0.2–1.6	2/1					0	
1.6–3'	3/1					0	
3'–4.6	4/1					0	
4.6–6.5	5/1					0	
6.5–10.2	6/1					0	
10.2–12.0	7/1	SWL @ 5.75' hole at 10.2' 6/24 9:55am				0	
12.0–17.2	8/1			X X X	FeOx, Clay, Zeolite?	0	
17.2–19.2	9/1/2			X X X		0	
19.2–21.5	10/2	lost core in hole @ ~25 ft. lost returns @ same interval (some redrilled core 23.0 to 25.2)		X X X		0	
21.5–23.0	11/2			X X X		0	
23.0–25	12/2			X X			

Graphic Log — Scale 1" = 5' — Basic Geology: rock types, structures, alteration. (Relative Competence)

Lithologic Descriptions, Drilling Notes

0' to 0.5': Sod, organic debris with, BLK, clay/SILT

0.5' to 1.6': SILT/CLAY, DK BRN to BLK, high organic content

1.6 to 3.0': Diatomite & diatomaceous earth,? V. light Brn. to white. Some carbonaceous debris dissem. throughout possible volcanic ash content?

3.0 to 3.4(?) (Poor returns): SILT, MED BRN, (Loess)

3.4 to 4.4(?): Clay, black to dark Brn & basalt gravel. (last of drive samples)

4.4 to 10.2(?) (poor returns): Gravel; basalt clasts, in clay/SILT matrix – some sand(?) clasts are subrounded w/ low sphericity up to 15cm in long dimension

10.2 to 12.4(?): gravel, some sand/silt matrix (poor returns), limonite/FeOx stain throughout, some surfaces (BASALT clasts)

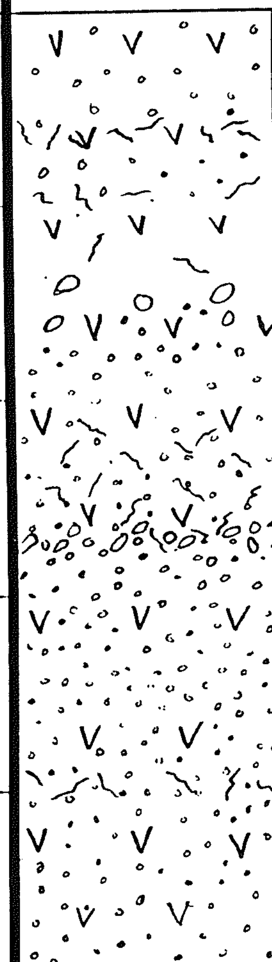
12.4 to 25.0: BASALT, vesicular, BLK, with pervasive fracturing

DRILL LOG

HOLE NO. 2 - Rosman

PROJECT Sinking Creek
CONTRACTOR
DATE STARTED COMPLETED
LOGGED BY BARNETT

TOTAL DEPTH LAND SURFACE ELEV.
INCLINATION BEARING
COORDINATES T R S OTHER
SURVEY REFERENCES

Footage	Hole Condition			Formation Condition			Casing Schedule	Footage	Graphic Log Scale 1" = 5' Basic Geology: rock types, structures, alteration. (Relative Competence)	Lithologic Descriptions, Drilling Notes
	Run/Box#	Water (gpm)	Pit Loss (gpm)	Fracture Orientation	Fracture Filling	RQD (%)				
25.2	13/2/3	6/25 11:15 am SWL 4.56 ft BGS 20 min. after cessation of injection for drilling				0	NX CASING	25		- Started drilling @ 25.2 ft on 6/25 25.0 to : BASALT, BLK, vesicular, dense, interwoven plag. laths ~1mm long. vesicles get smaller become completely un-filled until 3?
28.5	14/3				clay + FeOx goethite	30		30		- vesicles fewer @ 30. …
										- larger vesicles 32.0 to 33.5 1 vesicle filling MnO_2(?) or other soft, BLK mineral
33.5	15/3					0	casing shoe	35		
35.2	16/3					10				- larger vesicles for short interval (stopped drilling from ~45 min at 1:30 pm due to T-storm)
40.2	17/4/5				Serpentine (?)	50	Open NX hole	40		
45.?	18/5				(rel. open)	60		45		46.0 to ~60.5: - fractures mostly lack filling but w/ only occasional zeolite (?) or serpent. (?) coatings.
								50		

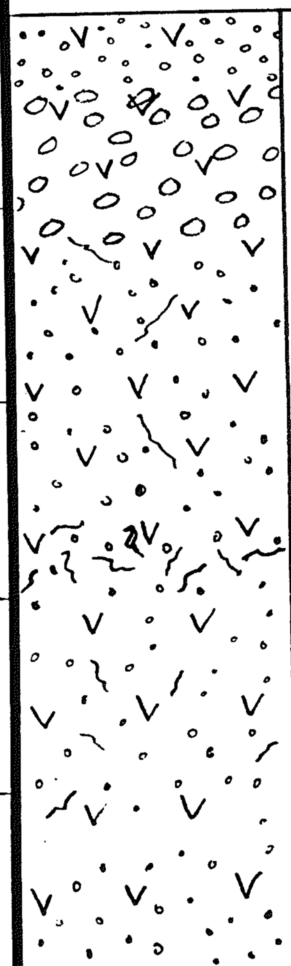
DRILL LOG

HOLE NO. ____________

PROJECT ____________
CONTRACTOR ____________
DATE STARTED ____________ COMPLETED ____________
LOGGED BY BARNETT

TOTAL DEPTH ____________ LAND SURFACE ELEV. ____________
INCLINATION ____________ BEARING ____________
COORDINATES T ___ R ___ S ______ OTHER ____________
SURVEY REFERENCES ____________

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale 1" = 5'; Basic Geology: rock types, structures, alteration. (Relative Competence))	Lithologic Descriptions, Drilling Notes
50.2	19/5/6			/		10		50		52.4-55.6 larger, fewer vesicles
55.2	20/6			═ ; |	pyrite & zeolite(?)	30	↑ NX open hole ↓	55		
60.2	21/6/7			| ; ✕✕✕	large (0.75 cm) healed frcd. w/ serpent(?) or chlorite fill 60.6 to 62.2; serpent. ± chlor.	0		60		
65.2	22/7			∠	↑ almost no filling (open) ↓	<10		65		
70.2	23/7/8			| ; ✕✕✕ ; // 2	serpent. + minor py MnO₂? MnO₂?	50		70		fewer vesicles short interval ~70.8
								75		



DRILL LOG

HOLE NO. 2-Rosman Sp. ("BARING")

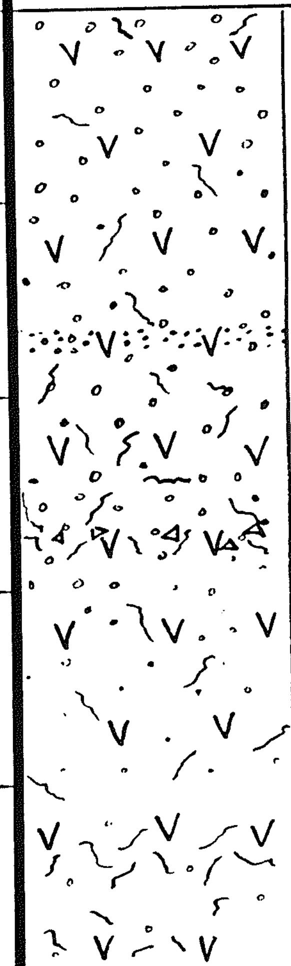
PROJECT ______
CONTRACTOR ______
DATE STARTED ______ COMPLETED ______
LOGGED BY BARNETT

TOTAL DEPTH ______ LAND SURFACE ELEV. ______
INCLINATION ______ BEARING ______
COORDINATES T ___ R ___ S ______ OTHER ______
SURVEY REFERENCES ______

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule
75.2	24/8			(mostly ~30°)	Blk, like soot (MnO2?) some sealed	70	NX open hole
80.2	25/8/9	v. little cave in hole and last 0.7 ft of last run left at bottom. SWL @ 4.50 ft before start drilling			up to 0.5 cm "healed" w/serpent. chlor.(?)	10	
86.1	26/9/10				v. little coating some MnO2? (open); serpent./chlor. mostly healed; minor blue clayey Halloysite(?)	20	
95.2	27/10/11				grn-brn "scale" otherwise open	10	

Footage: 75 – 80 – 85 – 90 – 95 – 100

Graphic Log Scale 1" = 5'
Basic Geology: rock types, structures, alteration. (Relative Competence)



Lithologic Descriptions, Drilling Notes

- 80.2 (stopped drilling on 6/25) (Began using 10 ft. core barrel on 6/26.)
- [notable lack of returns/circul. periodically]
- v. thin horizon of increased vesicle density
- possible Tectonic? breccia, cemented w/ serpentine at ~88.0
- vesicles become fewer – smaller until
- fractures both "open" and "healed" usu. with chlorite or serpentine (?)
- serpentine-filled fract. @ 95.0 (50°) shows possible reverse, dip-slip offset + slicks (?)

DRILL LOG

HOLE NO. 2 - Rosman

PROJECT Sinking Creek

CONTRACTOR

DATE STARTED COMPLETED

LOGGED BY BARNETT

TOTAL DEPTH LAND SURFACE ELEV.

INCLINATION BEARING

COORDINATES T R S OTHER

SURVEY REFERENCES

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale 1" = 5'; Basic Geology: rock types, structures, alteration. (Relative Competence) →)	Lithologic Descriptions, Drilling Notes
100–103.5	27/10/11			// ××××		10		100		fewer vesicles, smaller ↓
103.5–110	28/11/12			×××× ×××× ××× ××××	Blue irridesc. coating; sealed w/clay serpt./chlor.; incipient fracts open space	20	↑	105		incipient fractures w/open space
110–120	29/12/13			××× / ××× ×× ×× ×× ×××	↑ MnO₂ (?) zeolite(?) ↓ Blk sooty; incipient open space	0	NX open hole ↓	110, 115		– Many incipient fractures with open space. Some rotation producing "proto-'breccia'"
120–125	30/13-14	SWL @ 4.53 ft. Before start of drilling	on 6/27	××× ××× ×××		10		120, 125		– stopped drilling @ ~121.0 on 6/26 —mislatch—

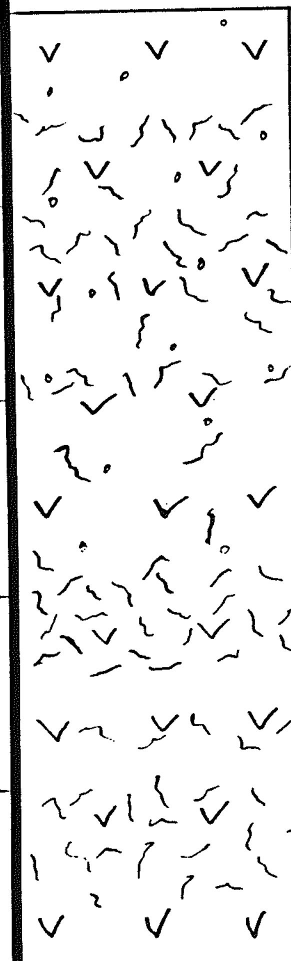
DRILL LOG

HOLE NO. Z-Rosman Sp.

PROJECT ____
CONTRACTOR ____
DATE STARTED ____ COMPLETED ____
LOGGED BY BARNETT

TOTAL DEPTH ____ LAND SURFACE ELEV. ____
INCLINATION VERT. BEARING ____
COORDINATES T ___ R ___ S ____ OTHER ____
SURVEY REFERENCES ____

Footage	Hole Condition: Run/Box#	Water (gpm)	Pit Loss (gpm)	Formation Condition: Fracture Orientation	Fracture Filling	RQD (%)	Casing Schedule	Footage	Graphic Log (Scale 1" = 5'; Basic Geology: rock types, structures, alteration. (Relative Competence))	Lithologic Descriptions, Drilling Notes
								125		Drilling somewhat slower (rock harder)
			1	××××		10				
130.2				××××	large clay-filled fract 1 cm + wide		open NX hole	130		130.2 - 130.8 multiple fracts & incipient fracts. w/open space
	31/14			××××		0				
135.4				××××	Mostly Clay or no fill			135		
	32/15			××××		10				— vesicles disappear ~ 139.0
				××××				140		
141.3				××××	MnO2 or other Blk mineral some incipient					
	33/15-16			××××	Mostly healed	0		145		[driller reports problems with fractured rock blocking inner tube & core barrel]
								150		

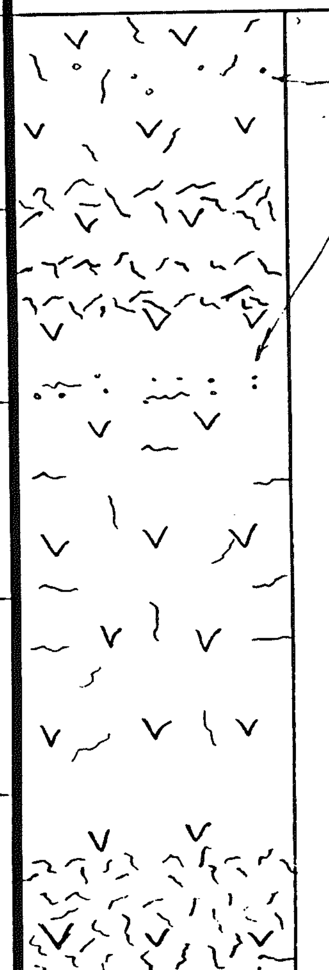


DRILL LOG

HOLE NO. Z-Rosman Sp.

PROJECT Sinking Creek
CONTRACTOR
DATE STARTED   COMPLETED
LOGGED BY BARNETT

TOTAL DEPTH   LAND SURFACE ELEV.
INCLINATION   BEARING
COORDINATES T   R   S   OTHER
SURVEY REFERENCES

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale 1" = 5'; Basic Geology: rock types, structures, alteration. (Relative Competence))	Lithologic Descriptions, Drilling Notes
150.2	34/16	150.9 – Jammed core barrel			Pyrite 150.9 to ~154.0 + Blk, sooty mineral ↓	0		150		~V. small vesicles throughout, but concentr. in some short intervals - very subtle.
	35/16-17		1	xxx xxx xxx	some part. healed	0	open NX hole	155		
154.4	36/17	Jamming core barrel				30				~157.0 driller reports light brn cuttings in return flow. prob fract.-fill material. drilling rate has slowed somewhat
157.8	37/17-18			— / —	Pyrite; v little fill - some grn-blue coatings	20		160		- Pyrite in fracts. mostly pseudo-morphic after Fe_3O_4 – occurs in "spots" on fract surfaces (photo @ 168.0)
164.7	38/18-19			— / —	↓ Pyrite			165 / 170		- Stopped drilling at 164.7 on 6/27; ~164.0 ft - driller noted metal shavings in returns "could be bit deterioration". turned out to be pyrite from fracts
172.?	39/19	Poor recovery - barrel jammed		xxx xxx xxx	Red-brn (FeOx?) + clay	6		175		severely fractured ~172.5 to ~175.5 - friable, coating of FeOx(?) paleo-water table? – Lack of returns

DRILL LOG

HOLE NO. Z-Rosman Sp.

PROJECT Sinking Creek

CONTRACTOR

DATE STARTED   COMPLETED

LOGGED BY BARNETT

TOTAL DEPTH   LAND SURFACE ELEV.

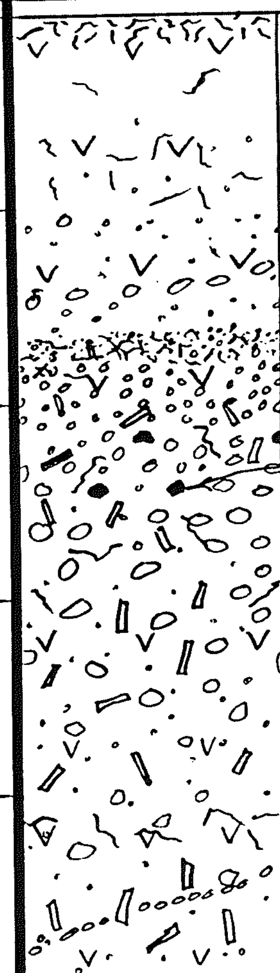
INCLINATION   BEARING

COORDINATES T   R   S   OTHER

SURVEY REFERENCES

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage
175–177.3 (175.9)	40/19	poor recovery	barrel jam	x x x x	Red-Brn clay – small apertures	0; 0		175
177.3–185.2 (180)	41/19-20		1		serpent/clay? ~1 cm healed; thick (~1cm) gry-white clay; red-Brn clay in fract.	10	NX open hole	180
185.2–195.2 (185, 190)	42/20-21				open + serpent./clay; clay – blue-grn. 0.5cm; Blue – HALLOY?; open + FeMnOx; serp./clay Blue/BLK + zeolite? ~1cm; MnO2 + clay + Blue-grn coatings; clay zeolites	10		185; 190
195.2–200 (195)	43/21	started here on 7/8 SWL @ 5.44' BGS inside packer — 5.18 BGS in annulus.			zeolites MnO2	30		195; 200

Graphic Log, Scale 1" = 5' (Basic Geology: rock types, structures, alteration. (Relative Competence))



Lithologic Descriptions, Drilling Notes

- driller reports lack of returns except at end of runs
- 180.0 Vesicles – some layers of larger vesicles. at angle of ~45°
- red-Brn clay fracts, minor palagonite, compressed vesicle layer (photo) chalcedony – no Quincy – ?
- extremely fractured, friable
- 184.0 very vesicular

ROZA MBR at ~184.0

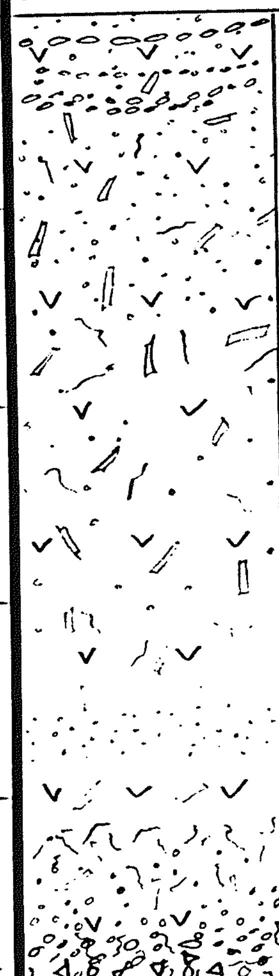
- Some vesicles filled w/ clay fracture-filling material near fract. Some will allow passage of air through core
- 184.0 to 225.0: BASALT, PORPHYRITIC w/ Plag. up to 1cm long.
- larger vesicles progressively Downward, some coated w/ MnO_2 + Blue/grn mineral – some partially in-filled w/ same – small (< 1mm) vesicles throughout
- 6/28 Stopped drilling at 195.0 to cement hole for injection test. found that cement was up to 184.0 ft, but after redrilling only a small bridge was present
- stopped drilling again at 200.2' to test interflow zone 7/8.

DRILL LOG

HOLE NO. Z-Rosman

PROJECT Sinking Creek
CONTRACTOR
DATE STARTED COMPLETED
LOGGED BY BARNETT

TOTAL DEPTH LAND SURFACE ELEV.
INCLINATION BEARING
COORDINATES T R S OTHER
SURVEY REFERENCES

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale 1" = 5'; Basic Geology: rock types, structures, alteration. (Relative Competence))	Lithologic Descriptions, Drilling Notes
200 / 200.2	44/21-22	SWL @ 8.31' BGS before activity (no annulus) - packer + 75' of 2" PVC in hole but packer not inflated.			clay-serpent.	40	open NX hole	200		Conduct injection test on 7/9 - resumed drilling at 200.2' Thin, irregular horizons of larger (0.25 cm) vesicles.
205					serpent. MnO2, but mostly open			205		
					large, sert. w/ Serpt. , MnO2 Zeolite					
210 / 210.5	45/23				healed clay/serp. MnO2 + open?	50		210		
215					MnO2 Red/Brn + open? Zeolite + open?			215		Very competent 215.7 to 223.0
217.7										vesicles locally more abund. in bands
220	46/23-24					50		220		223.0 vesicles begin increasing in number.
		drilling water change color [illegible]			mostly serp. healed					225.0 to 225.3 vesicles increase along with dense fracturing and Tectonic (?) or flow breccia.
224.4 / 225								225		

DRILL LOG

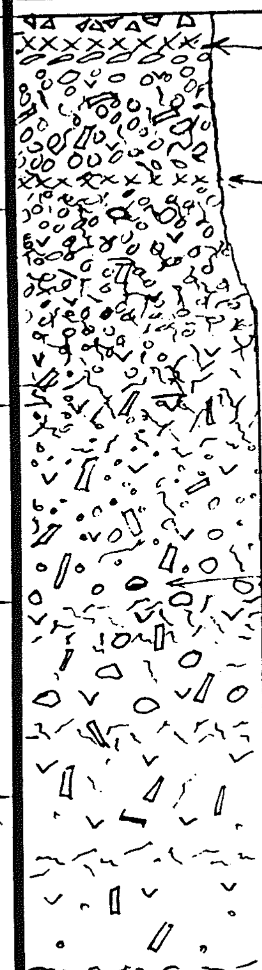
HOLE NO. Z-Rosman

PROJECT ____
CONTRACTOR ____
DATE STARTED ____ COMPLETED ____
LOGGED BY BARNETT

TOTAL DEPTH ____ LAND SURFACE ELEV. ____
INCLINATION ____ BEARING ____
COORDINATES T ___ R ___ S ____ OTHER ____
SURVEY REFERENCES ____

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage
	47/24-25	- driller reports blocking - 1		ΔΔΔ ×××× ××× 7 = ×××	BLK clay ... GRN/BRN CLAY; CLAY; green/white clay - some open	0	Open NX hole	225–230
232.1	48/25	stopped here on 7/9; SWL in hole at 9.14 Bgs @8:58am 7/10		××× ××× ××× ××× ××× ×××	serpent. + grn/brn to white clay; red/brn clay >3cm	0		230–235
233.9	49/25-26	Driller reports more consistent returns - pump Q ≈ 7 gpm		××× ×××× ××××		10		235–240
240.2	50/26			×××× ××××		0		240–245
244.4	51			××× (mostly healed) ×××	mostly healed	20		245–250

Graphic Log Scale 1" = 5' — Basic Geology: rock types, structures, alteration. (Relative Competence)



Lithologic Descriptions, Drilling Notes

Vesicles at base of "glass" horizon preferent. aligned w/ contact

225.4 to 225.8 - Clay, Black (Devitr. glass?) fracture filling? Resinous luster on fresh surface. Some BLK-grn glass still present. Both glass and "BLK clay" display conchoidal fract. pattern.

225.8 - 229.0 Vesicular porphyritic BASALT - densely fractured

229.0 - 229.2: clay, grn-brn to blk, devit. glass

229.2 to 236.4: BASALT, vesicular, porphyritic, intensely fractured-fragmented.

236.4 to 243.3 BASALT, vesicular, not as fractured/fragmented as overlying interval. Vesicles become larger but fewer with depth this interval

243.3 to 259.5: BASALT, PORPHYRITIC, Med-dark gray w/ Plag. phenos up to 1cm.

some vesicles partly clay-filled (PHOTO)

DRILL LOG

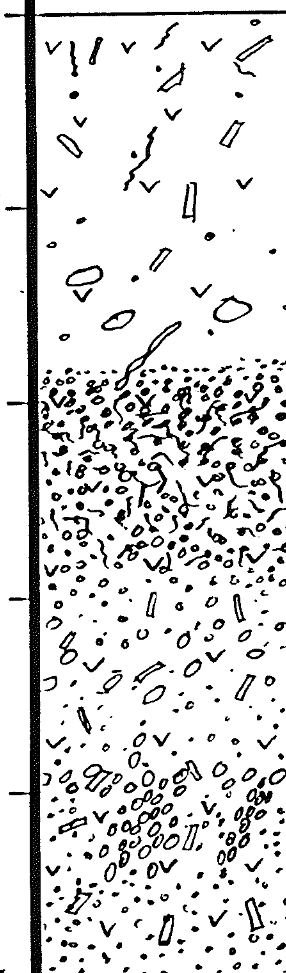
HOLE NO. 2 - Rosman Sp.

PROJECT Sinking Creek
CONTRACTOR Budinger [?]
DATE STARTED ______ COMPLETED ______
LOGGED BY BARNETT

TOTAL DEPTH ______ LAND SURFACE ELEV. ______
INCLINATION ______ BEARING ______
COORDINATES T ___ R ___ S ______ OTHER ______
SURVEY REFERENCES ______

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Lithologic Descriptions, Drilling Notes
250 – 250.2								
250.2 – 254.1	52/27	short runs due to blockage/fracts.			mostly clay 2mm; healed; open(?) + MnO_2 serp.	40	Open NX hole	259.5 to 264.3 BASALT, very vesicular, possibly scoriacous, extremely fractured, fragmented; vesicles gradually diminishing downward beyond this interval (porphyritic)
254.1 – 260.2	53/27-28				light gry/brn clay; mostly open(?)	70		large vesicles; pipe vesicle (5 cm in length); 259.0 to 264.3: Vesicular basalt, very fractured/fragmented
260.2 – 264.1	54/28					0		264.3 to 290.8: BASALT, Vesicular, porphyritic; 264.5 — Some vesicles wholly or partly clay-filled.
264.1 – 270.2	55/28-29				very few fracts mostly horiz.	50		Large & small vesicles — seems like two distinct populations/modes
270.2 – 275	56/29-30	Stopped here on 7/10; SWL on 7/11 5.80' BGS @ [illegible] am			MnO_2 + open	50		- vesicle "trains" - near-vertical bands of vesicles larger than most; very porous - after drying exterior, interior of core retained moisture (possibly minor permeability)

Graphic Log, Scale 1" = 5' (Basic Geology: rock types, structures, alteration. (Relative Competence))

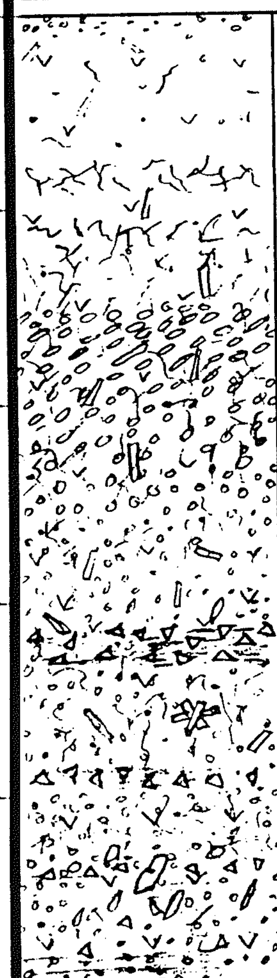


DRILL LOG

HOLE NO. 2-Rosman

PROJECT Sinking Creek
CONTRACTOR
DATE STARTED ______ COMPLETED ______
LOGGED BY BARNETT

TOTAL DEPTH ______ LAND SURFACE ELEV. ______
INCLINATION ______ BEARING ______
COORDINATES T ___ R ___ S ___ OTHER ______
SURVEY REFERENCES ______

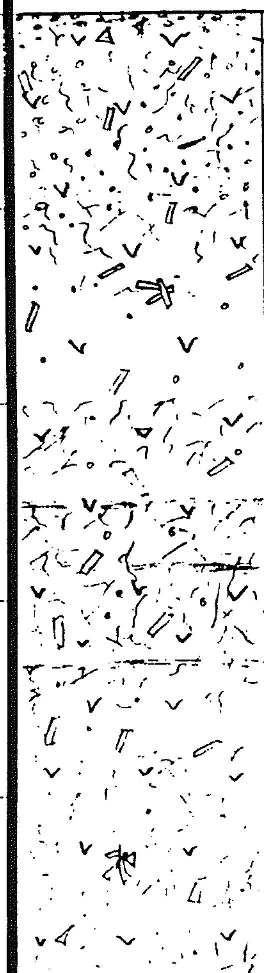
Footage	Hole Condition: Run/Box#	Water (gpm)	Pit Loss (gpm)	Formation Condition: Fracture Orientation	Fracture Filling	RQD (%)	Casing Schedule	Footage	Graphic Log Scale 1" = 5' Basic Geology: rock types, structures, alteration. (Relative Competence)	Lithologic Descriptions, Drilling Notes
	56/29-30			= + xxx xxx	serpent. clay	50	↑ Open NX hole ↓	275		vesicles fewer 276.4. intensely fractured 278~~40~~
280.2	57/30	↑ Short runs due to fracturing ↓		xxx xxx xxx xxx	white clay; open? + clay	0		280		
282.9	58/30			xxx xxx xxx	white clay	20		285		vesicles reappear 282.9 – some flattened and inclined – diminish with depth & become smaller
285.9	59/30	← Poor recovery		xxx xxx	open? + clay	0				
287.4	60/30-31	Drilling very slow much Broken rock poor recovery ↓		xxx xxx		0		290		290.8 to 292.8?: Volcanic glass & flow breccia. frags of phyric basalt with glass/clay rinds. (PHOTO) – some glomeroporphyritic texture w/Plag. in phyric basalt frags.
291	61/31			xxx xxx xxx		0				294.0 – 294.5 Breccia, volcanic glass-clay filled vugs. gray-green
293.5	62/31			xxx xxx xxx		0		295		
296.5	63/31			xxx xxx xxx	gray-grn clay	0				298.5 to 325.0: spiracles, glass and elongate vesicles – long axis vertical w/some sections of phyric basalt, porphyritic. locally non-vesicular
298.6								300		

DRILL LOG

HOLE NO. Z-Rosman

PROJECT Sinking Creek
CONTRACTOR
DATE STARTED ______ COMPLETED ______
LOGGED BY BARNETT

TOTAL DEPTH ______ LAND SURFACE ELEV. ______
INCLINATION ______ BEARING ______
COORDINATES T ___ R ___ S ______ OTHER ______
SURVEY REFERENCES ______

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale 1" = 5'; Basic Geology, rock types, structures, alteration)	Lithologic Descriptions, Drilling Notes
300	64/31	Stopped at 301.5 on 7/11		xx x	"vesicle"/tubes filled w/ grn/gry clay - rubble	0		300		"glass" with white "pisolites" - "vein" of green-brown clay (spiracle?) and white clay along boundary of "vein" and surrounding basalt frags suspended in clay/glass matrix.
301.5		No SWL measurement								
		Drilling faster less blockage								
	65/31	Driller added polydrill to help w/ cuttings (flocculant)			clay-filled spiracle?	0 (photo)	PIEZOS			vesicles diminish ~ 306-307 - downward
305				xxx xxx				305		pyrite in cuttings/returns? (seen in fracts)
306	66/32	polymer			pyrite	0				Stopped at 306.7 on 7/12
307.7		(mistake on first run - failed to trip out of hole)								306.7 to 307.7 contains some "redrilled" cuttings
	67/32			x x	open - black, glass like	10				still getting good return flow
310				xx x			Open NX hole	310		
310.6	68/32	SWL on 7/15 = 5.5 ft BGS 10:08 am		xx x		0				
311.7						0				
313.5	69/32			xx x						"glass"/clay horizons (spiracle?) essentially rubble 310.7 - 316.5
314.2	70/32	poor recovery (~50%)		x x x		0				
315	71/32			x x x	light blue-grn. coating + BLK glass like	0		315		
316				x x x			CAVED			
		return flow light gray-grn.		x x x						
320	72/33			xxx	open + blue clay coating	0		320		
				x x x						
				x x x						
325				xxx	much pyrite			325		

DRILL LOG

HOLE NO. 2-Rosman

PROJECT SINKING Creek

CONTRACTOR

DATE STARTED 6/21/91 COMPLETED 7/15/91

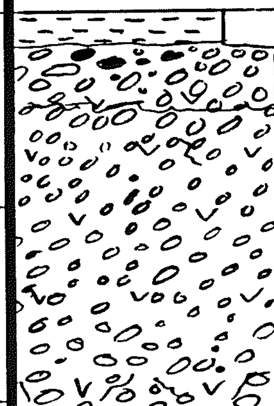
LOGGED BY BARNETT

TOTAL DEPTH 335.2' LAND SURFACE ELEV.

INCLINATION BEARING

COORDINATES T R S OTHER

SURVEY REFERENCES

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale 1"=5'; Basic Geology: rock types, structures, alteration. (Relative Competence))	Lithologic Descriptions, Drilling Notes
325.2		drilling rate increase						325		325.2 to 325.5? Clay, dark gray-grn. VANTAGE HORIZON. Bright gray-green returns ~320 to 330 — some loss of recovery ~325-330? Some saprolitic clay at ~325.4-325.6. - weathered basalt. Some vesicles clay-filled
	73/33-34				3cm. Horizont. Fract filled w/ hard dk grn. clay	30	open NX hole			
330								330		
					mostly open - no fill.					325.5 to 335.2:- BASALT, MED. gray, vesicular, aphyric w/ <1mm plag. laths densely interwoven. GRANDE RONDE FM.
335 / 335.2	T.D.	SWL on 7/16 3:30am = 98.66 ft BGS.				T.D.		335	335.2 = T.D.	Stopped drilling on 7/15 @ 335.2 - T.D.
340								340		
345								345		
350								350		

1.2 / 2.7 from 153 - 180

DRILL LOG

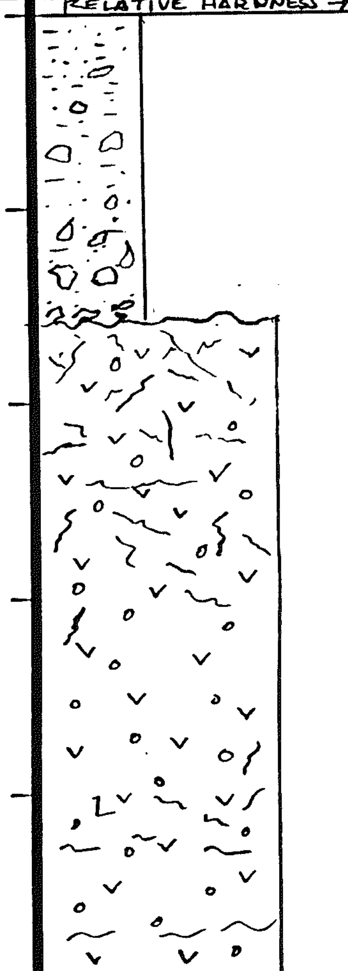
HOLE NO. 1-WAGNER SP.

PROJECT SINKING CREEK
CONTRACTOR BUDINGER & ASSOC.
DATE STARTED 6-11-91 COMPLETED 6-19-91
LOGGED BY BARNETT / covert

TOTAL DEPTH 185.4 FT. LAND SURFACE ELEV. 2090 FT. MSL
INCLINATION VERTICAL BEARING
COORDINATES T25N R 32E S SE,SE 12 OTHER
SURVEY REFERENCES

Footage	Run/Box#	Water (gpm)	Pit Loss (gpm)	Fracture Orientation	Fracture Filling	RQD (%)	Casing Schedule / Hole Construction
0–8		dry					8" Aug. / 8" Auger; HQ casing
	1/1			(dips) 40°, 10° (70°)		0	
	2/1					0	
10	3/1					0	
	4/1					0	Shoe
	5/1					0	
	6/1						
15.3	7/1	driller reports water levels fluctuating between 13-15 ft. throughout day on 6-14-91				0	NX hole
18.0	8/1					44	
20.6	9/2					60	
22.8	9/2					0	
25	9/2					0	

Graphic Log Scale 1" = 5 FT. Basic Geology: rock types, structures, alteration. (Relative Competence) RELATIVE HARDNESS →



Lithologic Descriptions, Drilling Notes

0.0 to 8.0: Loess, silt, mixed with basalt frag./gravel some cobble-sized, med. Brn

8.0 to 30.6: BASALT, DARK BRN to BLK, Aphyric, Amygdules of clay min. (?) ± FeOx evenly dist. throughout but only <1% of volume. Amyd. ~ 1-2 mm, gives rock a "speckled" appearance (Priest Rapids mbr.) (?) Densely fractured to ~16.0 ft. Densely fractured in some intervals throughout

DRILL LOG

HOLE NO. 1-WAGNER Spring

PROJECT
CONTRACTOR
DATE STARTED COMPLETED
LOGGED BY BARNETT / eovert

TOTAL DEPTH LAND SURFACE ELEV.
INCLINATION BEARING
COORDINATES T R S OTHER
SURVEY REFERENCES

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Lithologic Descriptions, Drilling Notes
25	9/4							25	
	10/2/3			vert predom.	FeOx, clay minor zeolite	10			Fracturing ~26.5 - 30
30	11/3					0	NX open hole	30	Dence fracturing ~31.5 - 33.0
	12/3					0			Started drilling ~10:30 on 6/17 hole at 42.7 ft. water injected into hole infiltrates quickly - drilling about 15 ft./hr.
35	13/3	dry			Chlorite (serpent?) zeolite ± calcite ?	0		35	
	14/4/4	E-tape detects no water at 10:30 am on 6/17/91 - hole at 42.7 ft.				<10			
40	15/4					~20		40	DENSE FRACTURING 42 → 44 Some VERTICAL
43.4	16/4	← start of 6/17				0			
45	17/5				MnO_2 FeO_x	40		45	
48.1	18/5/6								
50								50	

Graphic Log Scale 1" = 5' Basic Geology: rock types, structures, alteration. (Relative Competence)

DRILL LOG

HOLE NO. 1_WAGNER SP.

PROJECT ______
CONTRACTOR ______
DATE STARTED ______ COMPLETED ______
LOGGED BY BARNETT / Covert

TOTAL DEPTH ______ LAND SURFACE ELEV. ______
INCLINATION ______ BEARING ______
COORDINATES T ___ R ___ S ______ OTHER ______
SURVEY REFERENCES ______

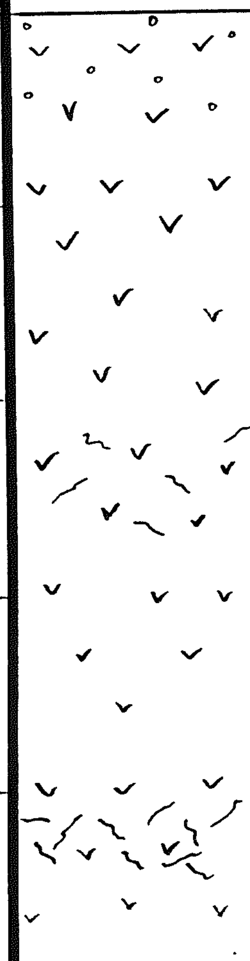
Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale 1" = 5'; Basic Geology: rock types, structures, alteration. (Relative Competence))	Lithologic Descriptions, Drilling Notes
	18/5/6					80		50		Photo of "Halloysite" @ 54.9'
	19/6			most common ~50° widths 0.5 to 1.0 mm	Blue, clay-like (Halloysite?) esp. 54-57 some chlor. or serpent. some int.	70		55		
59.0	20/6/7				chlorite/FeOx	40	open NX hole	60		
63.6	21/7					60		65		Photo of "healed" fractures w/ clay/chlor. @ 66.6' w 1-2 mm apertures max.
68.7	22/7	- inner tube blocked -				0				
	23/7/8							70		
74.2	24/8							75		

DRILL LOG

HOLE NO. 1-WAGNER St.

PROJECT ____
CONTRACTOR ____
DATE STARTED ____ COMPLETED ____
LOGGED BY BARNETT / Covert

TOTAL DEPTH ____ LAND SURFACE ELEV. ____
INCLINATION ____ BEARING ____
COORDINATES T ___ R ___ S ___ OTHER ____
SURVEY REFERENCES ____

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale 1" = 5'; Basic Geology: rock types, structures, alteration. [Relative Competence])	Lithologic Descriptions, Drilling Notes
75	25/8			most separated fracts: ~ ⊕ to 45° MANY healed fracts. > 45°		90	open NX hole	75		77.5 - amygdules no longer present (now within dense flow interior? colonnade?) - drilling very evenly & fast - but cannot keep enough water for drilling. Hole is using water (?)
79.5	26/9					90		80		
84.8	27/9/10	Static water @ 48.67 ft. In am. before drilling		most fracts. ⊕		40		85		
89.8	28/10			Minor Pyrite in fracts @ 90.9 & 93.9 (PHOTO) Most fract filled w/ chlor. or serpent(?)	←	80		90		→ Stopped drilling @ 89.8' on 6/17/91. Static water on 6/18 stood at 48.67 ft. BGS. Started Drilling @ ~ 9.30. Stopped to replace wireline at ~10 00 am. Begin drilling again at 11:13
94.9	29/10	Jammed core barrel						95		
95.1	30/10/11			many "healed" fracts	Chlorite/Serp.?	40				- fracts mostly "healed". 99.8' densely fractured core with slickensides indicating reverse, dip-slip movement (Photo)
100								100		

DRILL LOG

HOLE NO. 1 - WAGNER SP.

PROJECT Sinking Cr.
CONTRACTOR
DATE STARTED COMPLETED
LOGGED BY BARNETT / covert

TOTAL DEPTH LAND SURFACE ELEV.
INCLINATION BEARING
COORDINATES T R S OTHER
SURVEY REFERENCES

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log Scale 1" = 5' Basic Geology: rock types, structures, alteration. (Relative Competence)	Lithologic Descriptions, Drilling Notes
100								100		Drilling rate approx. 12 ft./hr. Recovery ~ 100%
	31/11					80				
105.4	32/11/12			fracts. are ~ every 0.8'; Φ ≈ ~55° most common	Pyrite abundant in fracts 91.0 to 111.1	80	open NX hole	105 / 110		
110.4	33/12				chlor./serpent.	80				
115.4	34/12/13					50		115		~116° to 122°: BASALT CONTAINS remnant phenocrysts ~1mm (olivine → chlorophaeite ? or iddingsite); - MOSTLY "Healed" fracts 117.9-118.9
120.4	35/13	Jammed core barrel				0		120		- stopped drilling ~3:00 pm At 120.7 ft. started ~9:00 am on 6/19. Swl = 38.29 ft.
120.7	36/13					60				at 123° Vesicles/Amygdules reappear
125								125		

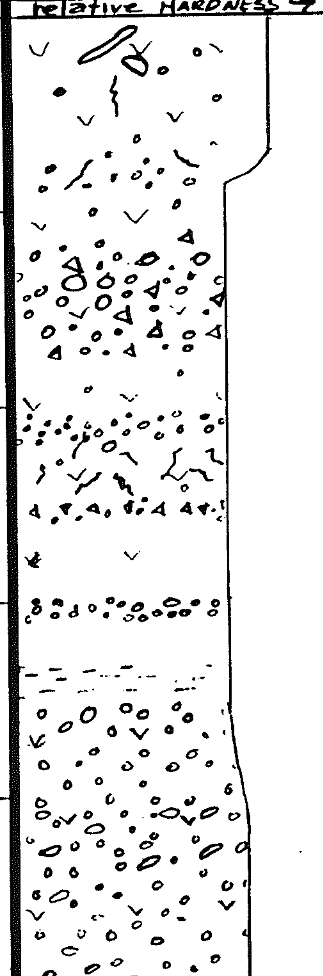
DRILL LOG

HOLE NO. 1-WAGNER. SP

PROJECT ____
CONTRACTOR ____
DATE STARTED ____ COMPLETED ____
LOGGED BY BARNETT / Covert

TOTAL DEPTH ____ LAND SURFACE ELEV. ____
INCLINATION ____ BEARING ____
COORDINATES T ___ R ___ S ___ OTHER ____
SURVEY REFERENCES ____

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale 1" = 5'; Basic Geology: rock types, structures, alteration. (Relative Competence)) — relative HARDNESS →	Lithologic Descriptions, Drilling Notes
125 (125.4)	37/13/14		1	large	vesicles	50		125		large vesicles coated with blk, botryoidal mineral w/ light brn streak; (flow bottom (Priest Rapids)
130 (130.4)	38/14					0	NX open hole	130		130.6 to 133.9: Scoriaceous BASALT and flow breccia vesicles filled w/ limonite & other FeOX's (Photo)
134.2 / 135	39				chlor./ serpent/ other blk min.	30		135		ABUND. FRACTS 135.6 to 137.0; Bx + vesicles; drilling rate ~ 20 ft./hr.
140 (140.4)	40					0		140		vesicular 139.8 - 140.4; 141.7 to 142.4: claystone, med. grn-brn, possibly fused clay and/or glass at base of flow, Quincy "interbed"?
144.8 / 145 (145.4)	41/16	JAMMED	inner tube			0		145		142.4 to 185.4 BASALT, vesicular (flowtop) w/ palagonite esp. in vesicles (photos) (BEGIN ROZA MBR.) Also Halloysite(?) Bright Blue-grn coating on vesicles ?
	42/16					40				
150								150		

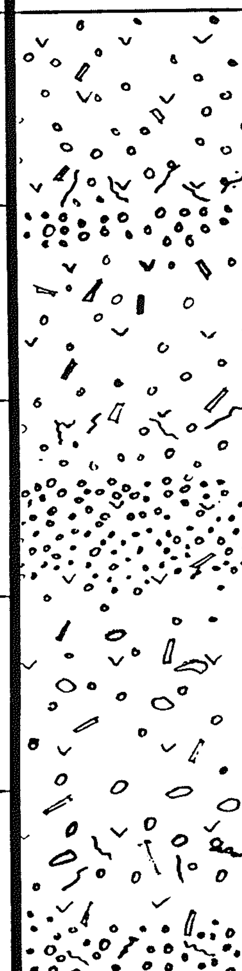


DRILL LOG

HOLE NO. 1- WAGNER Sp

PROJECT SINKING CREEK
CONTRACTOR
DATE STARTED COMPLETED
LOGGED BY BARNETT / COVERT

TOTAL DEPTH LAND SURFACE ELEV.
INCLINATION BEARING
COORDINATES T R S OTHER
SURVEY REFERENCES

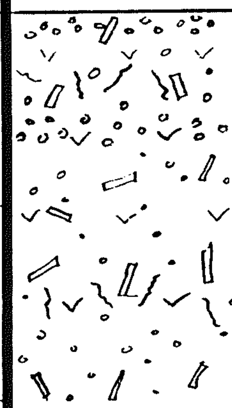
Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log (Scale 1" = 5'; Basic Geology: rock types, structures, alteration. (Relative Competence))	Lithologic Descriptions, Drilling Notes
150	43 16/17					20		150		(contd) locally vesicles are smaller but more concentrated (eg. 155.5 and 162.5) <u>Plagioclase pheno.</u> become more prominent downward; up to 1.5-cm-long plag. laths. Aphyric groundmass.
155 (155.4)	44/17					30	NX open hole	155		(ROZA FLOW TOP)
160 (160.4)	45/17/18					10		160		
165 (165.4)	46/18					50		165		165.0 – 178.0: vesicles larger, fewer -Some vesicles >3.5 cm
170 (170.4)	47/18/19					50		170		- LARGER VESICLES
175								175		

DRILL LOG

HOLE NO. 1-WAGNER SP

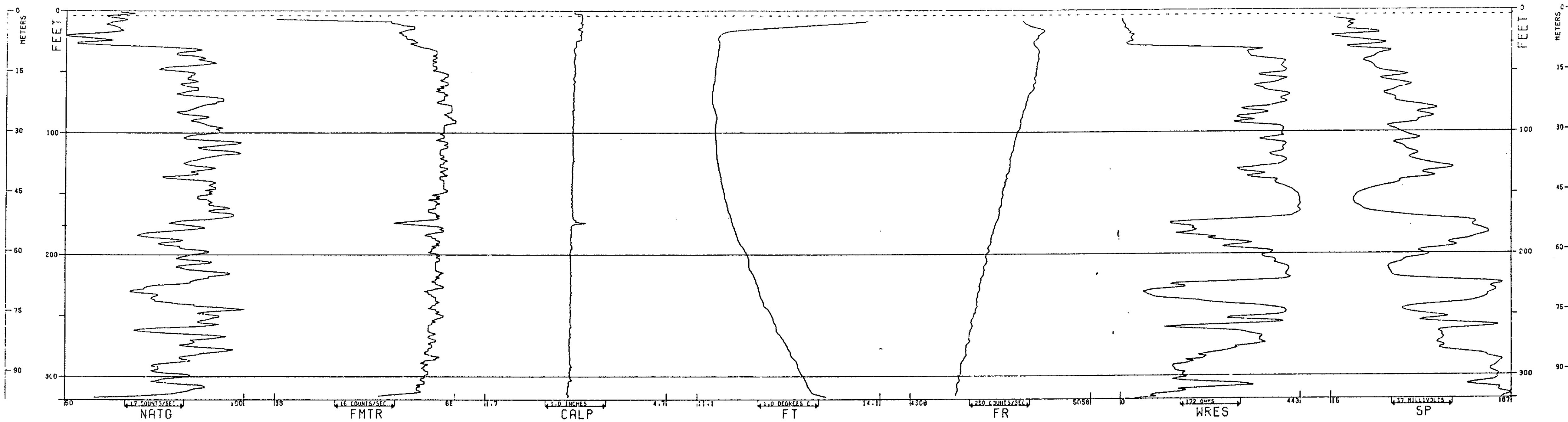
PROJECT ______
CONTRACTOR ______
DATE STARTED ______ COMPLETED ______
LOGGED BY BARNETT / Covert

TOTAL DEPTH ______ LAND SURFACE ELEV. ______
INCLINATION ______ BEARING ______
COORDINATES T ___ R ___ S ___ OTHER ______
SURVEY REFERENCES ______

Footage	Hole Condition: Run/Box#	Hole Condition: Water (gpm)	Hole Condition: Pit Loss (gpm)	Formation Condition: Fracture Orientation	Formation Condition: Fracture Filling	Formation Condition: RQD (%)	Casing Schedule	Footage	Graphic Log Scale 1" = 5' (Basic Geology: rock types, structures, alteration. (Relative Competence))	Lithologic Descriptions, Drilling Notes
175 / 175.3	48/19						Open NX hole	175		
180 / 180.0	49/19/20							180		SMALLER VESICLES
185 / 185.4								185	T.D. = 185.4 Ft.	– Stopped drilling @ 185.4' on 6/19 – SWL @ 79.98 on 6/20 10:30 am Began preparing to move off site
190								190		
195								195		
200								200		

APPENDIX C

GEOPHYSICAL LOG OF THE ROSMAN CORE HOLE



WASHINGTON STATE UNIVERSITY

COLLEGE OF ENGINEERING

GEOLOGICAL ENGINEERING SECTION
WELL LOG PROCESSING SYSTEM

NAME OF WELL	ROSMAN
DATE LOGGED	07/17/91
STATE	WASHINGTON
COUNTY	LINCOLN
LOCATION	25N/34E-08N1
SURFACE ELEVATION	2207
TOTAL DEPTH LOGGED	0-319
DEPTH TO WATER LEVEL	4
CASING & LINERS(P=PVC):	
0- 30= 3	

LEGEND

LOG TITLES

- NATG - - NATURAL GAMMA
- GG - - - GAMMA GAMMA
- NN - - - NEUTRON NEUTRON
- NG - - - NEUTRON GAMMA
- FT - - - FLUID TEMPERATURE
- FR - - - FLUID RESISTIVITY
- CALP - - CALIPER
- SP - - - SPONTANEOUS POTENTIAL
- WRES - - WALL RESISTIVITY
- FMTR - - FLOW METER, + = DOWN
- SV-* - - SONIC VELOC
- SA-* - - SONIC AMPLITUDE
- SW-* - - SONIC WAVEFORM
- SN - - - SHORT NORMAL
- LN - - - LONG NORMAL
- CONS - - CONSTRUCTION
- * TRANSMIT-RECEIVE GAP (0=10")
- * P,S,T WAVES, C=CASING

BELOW WATER LEVEL: - - - -
DENSITY (GG-LOG) INCREASES --→
POROSITY (NN-LOG) INCREASES ←--

NOTE: SCALE MAY CHANGE ABOVE WATER LEVEL

CONSTRUCTION SYMBOLS

FORMATION
GRAVEL
GROUT
BENTONITE
SCREEN

07/22/91 KRS

ROSMAN CORE HOLE--BELOW PACKER
FIRST INJECTION TEST
JULY 2, 1991

Terrascience Systems Ltd., Terra8 Series Data Printout

Terra8 Data Collection Report

Firmware Version: 0
Time of Data Dump: 07/02 12:24:52.54
User Comment: Injection test of Priest Rapids basalt. Rosman corehole
Default Scan Interval: 00/00 00:00:30.00
Number of Logs to Memory: 122
Remaining Data Memory: 22379
Filename: d:\sinkcrk\drilling\rosman.wel\prelim1.dat

Terra8 Channel Setup:
Number of Declared Analog Channels = 1

Ch#	Description	Units	Delay	M	B
1	50 psi transducer	ft	100	22.550	1.910

Terra8 Channel Setup:

Number of Declared Digital Channels = 0

Ch#	Description	Units	Delay	M	B

APPENDIX D

DATA FROM FIRST INJECTION TEST

Terrascience Systems Ltd.. Terra8 Series Data Printout

Time		Analog#01 - Feet of water above transducer
07/02	10:03:35.90	7.547
07/02	10:04:07.37	25.024
07/02	10:04:09.39	25.024
07/02	10:07:25.58	44.755
07/02	10:07:29.87	44.755
07/02	10:08:42.04	64.712
07/02	10:49:07.67	24.460
07/02	10:49:12.25	24.573
07/02	10:49:16.19	24.460
07/02	10:49:18.76	24.460
07/02	11:22:36.58	24.234
07/02	11:22:41.20	24.460
07/02	11:22:57.77	24.347
07/02	11:23:27.34	24.347
07/02	11:23:57.34	24.347
07/02	11:24:27.34	24.460
07/02	11:24:57.34	24.460
07/02	11:25:27.39	24.347
07/02	11:25:57.34	24.347
07/02	11:26:27.34	24.460
07/02	11:26:57.34	24.460
07/02	11:27:27.34	24.460
07/02	11:27:57.34	24.347
07/02	11:28:27.39	24.234
07/02	11:28:57.34	24.460
07/02	11:29:27.34	24.347
07/02	11:29:57.34	24.347
07/02	11:30:27.34	24.460
07/02	11:30:57.34	24.347
07/02	11:31:27.39	24.460
07/02	11:31:57.34	24.460
07/02	11:32:27.34	24.347
07/02	11:32:57.34	24.347
07/02	11:33:27.34	24.460
07/02	11:33:57.34	24.347
07/02	11:34:27.39	24.347
07/02	11:34:57.34	24.460
07/02	11:35:27.34	24.347
07/02	11:35:57.34	24.347
07/02	11:36:27.34	24.460
07/02	11:36:57.34	24.460
07/02	11:37:27.39	24.460
07/02	11:37:57.34	24.347
07/02	11:38:27.34	24.460
07/02	11:38:57.34	24.460
07/02	11:39:27.34	24.460
07/02	11:39:57.34	24.347
07/02	11:40:27.39	24.347
07/02	11:40:57.34	24.347

Terrascience Systems Ltd., Terra8 Series Data Printout

	Time	Analog#01	
07/02	11:41:27.34	24.347	
07/02	11:41:57.34	24.460	
07/02	11:42:27.34	24.347	
07/02	11:42:57.34	24.347	
07/02	11:43:27.39	24.347	
07/02	11:43:57.34	24.460	
07/02	11:44:27.34	24.347	
07/02	11:44:57.34	24.460	
07/02	11:45:27.34	24.347	
07/02	11:45:57.34	24.347	
07/02	11:46:27.39	24.347	
07/02	11:46:57.34	24.460	
07/02	11:47:27.34	24.460	
07/02	11:47:57.34	24.460	
07/02	11:48:27.34	24.460	
07/02	11:48:57.34	24.234	
07/02	11:49:27.39	24.234	
07/02	11:49:57.34	24.460	
07/02	11:50:27.34	24.460	
07/02	11:50:57.34	24.460	
07/02	11:51:27.34	24.460	
07/02	11:51:57.34	24.460	
07/02	11:52:27.39	24.347	
07/02	11:52:57.34	24.347	
07/02	11:55:14.01	24.347	
07/02	11:55:43.34	24.347	
07/02	11:56:13.34	24.234	
07/02	11:56:43.55	24.347	
07/02	11:57:01.30	37.764	**BEGIN INJECTION TEST**
07/02	11:57:07.31	90.644	
07/02	11:57:12.32	83.879	
07/02	11:57:17.31	87.938	
07/02	11:57:22.31	89.404	
07/02	11:57:27.32	87.487	
07/02	11:57:32.31	88.727	
07/02	11:57:37.31	89.968	
07/02	11:57:42.32	90.757	
07/02	11:57:47.31	92.448	
07/02	11:57:52.32	92.899	
07/02	11:58:02.31	96.056	
07/02	11:58:12.31	98.198	
07/02	11:58:22.31	101.581	
07/02	11:58:32.31	102.708	
07/02	11:58:42.31	104.512	
07/02	11:58:52.31	103.723	
07/02	11:59:02.31	103.949	
07/02	11:59:12.31	105.753	
07/02	11:59:22.31	105.865	
07/02	11:59:42.31	109.248	
07/02	12:00:02.30	108.008	

Terrascience Systems Ltd..   Terra8 Series Data Printout

	Time	Analog#01	
07/02	12:00:22.30	109.135	
07/02	12:00:42.31	110.037	
07/02	12:01:02.31	108.684	
07/02	12:01:22.31	110.714	
07/02	12:01:42.31	109.473	
07/02	12:02:02.31	109.361	
07/02	12:02:22.31	111.165	
07/02	12:03:02.31	111.954	
07/02	12:03:42.31	111.841	
07/02	12:04:22.31	112.292	
07/02	12:05:02.31	111.165	
07/02	12:05:42.31	112.969	
07/02	12:06:22.31	112.292	
07/02	12:07:02.31	113.983	
07/02	12:07:42.31	114.885	
07/02	12:08:22.31	114.096	**INJECTION SYSTEM FAILURE**
07/02	12:09:22.31	16.116	
07/02	12:10:22.31	15.553	
07/02	12:11:22.31	15.214	
07/02	12:12:22.31	14.876	
07/02	12:13:22.31	14.651	
07/02	12:14:22.31	14.538	
07/02	12:15:22.31	15.553	

APPENDIX E

RECORD OF BARING ("ROSMAN") SPRING WATER LEVELS

BARING ("ROSMAN") SPRING (25N/34E-8N1s) WATER LEVELS

DATE	TIME	WATER LEVEL (MM below datum)	COMMENTS
JUNE 24	10:00	-----	staff gage reading (in feet) = 6.91
24	12:00	-----	staff gage reading (in feet) = 6.89
24	15:00	-----	staff gage reading (in feet) = 6.90
25	9:30	-----	staff gage reading (in feet) = 6.86
25	11:00	00154	withdrawing water for drilling.
25	11:51	00153	
25	pm?	-----	instrument reset
26	9:15	00152	
26	14:33	00155	
26	14:48	00156	
26	15:48	00150	pumping from pool for drilling had ceased about 15:38
26	16:23	00149	
27	8:34	00156	
27	10:07	00157	
27	10:42	00162	pumping from pool for drilling
27	11:45	00165	"
27	12:46	00469	instrument reset (00165 = 00469)
27	15:06	00470	
27	16:18	00472	just stopped drilling
28	8:30	00477	before drilling started
28	13:23	00480	drilling for 3 hrs.--pump running

JUNE 28	15:20	00476	stopped drilling 1 hr. ago--T-storm in vicinity
JULY 1	9:20	00500	staff gage = 6.67
2	9:15	00510	staff gage = 6.63
2	15:00	00514	injecting water into core hole over last 3 hrs.
2	16:55	00513	no activity for 2 hrs.
3	9:36	00522	pump on intermittently
8	9:57	00589	no activity
8	12:28	00591	stock pump on intermitt.
8	17:25	00593	no activity
9	9:09	00607	stock pump running
9	10:28	00607	6 minutes into injection test
9	11:04	00608	35 min. after test ended
9	14:19	00604	drilling since 11:30
9	16:08	00604	drilling stopped 1/2 hr ago
10	9:02	00615	no activity
10	11:20	00617	stock pump running
10	17:17	00619	drilling stopped >1 hr. ago
11	9:53	00629	no activity
11	13:46	00637	drilling since 10:45
11	16:06	00640	drilling stopped 1\2 hr. ago--stock pump running
12	9:47	00650	drilling water faucet left on all previous night
15	9:35	00689	no activity--storm moved in at 9:40
15	12:38	00697	drilling--withdrawing water since 10:30
15	15:54	00700	drilling stopped 20 min. ago

JULY 16	10:03	00706	no activity
16	13:58	00708	5 min. after purging core hole
16	14:52	00708	just finished tripping out of core hole
17	9:12	00720	stock pump on intermitt.
17	13:00	00723	"
18	12:06	00737	no activity
19	9:03	00749	"
22	15:22	00796	"
23	9:31	00805	"
23	14:36	00808	"
24	9:47	00819	" An instrument reading of 00820 corresponds to a measurement of 4.68 ft. from nail on "upper board" to spring-pool surface
24	16:27	00822	no activity--storms in area
25	10:05	00830	no activity
25	12:37	00831	purging core hole
26	10:03	00839	stock pump on intermitt.
26	14:17	00841	"
29	14:15	00860	no activity
30	9:57	00863	stock pump on intermitt.
30	13:21	00864	"
31	12:03	00866	
31	15:08	00867	stock pump on intermitt.--float of instrument may be nearing bottom of stilling well.

AUGUST 1	9:51	00866	no activity at site--local farmer reports that some irrigators have shut down, and springs in town are beginning to flow.
1	12:10	00866	no activity--4.82 ft. to nail on upper board.
1	14:25	00866	no activity **END OF RECORD**