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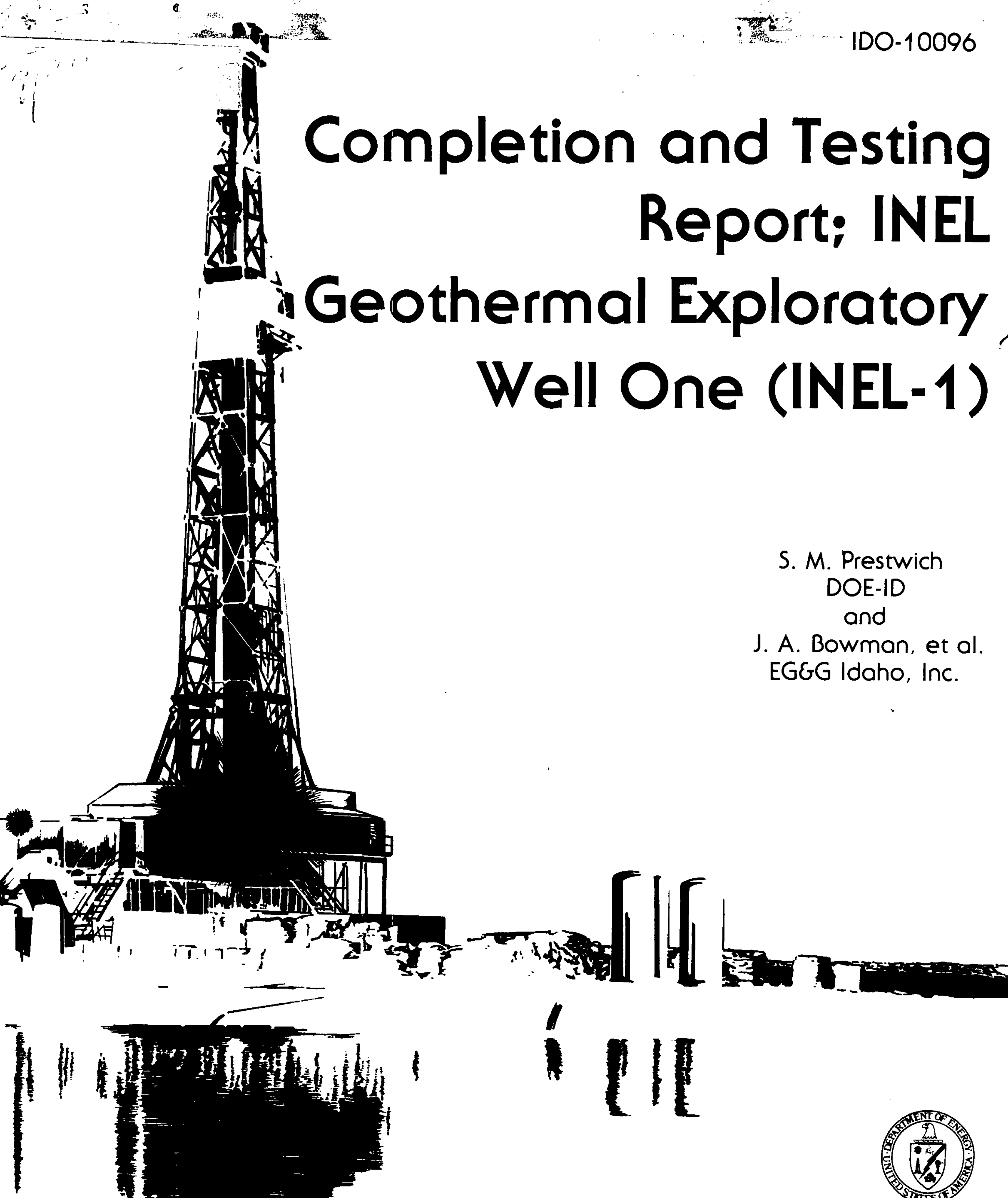
Completion and Testing Report; INEL Geothermal Exploratory Well One (INEL-1)



S. M. Prestwich
DOE-ID
and
J. A. Bowman, et al.
EG&G Idaho, Inc.

Idaho Operations Office
February, 1980

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S. M. Prestwich, DOE-ID

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February 1980

U.S. Department of Energy

Idaho Operations Office

550 Second Street

Idaho Falls, Idaho 83401

Jeg

ABSTRACT

INEL Geothermal Exploratory Well One (INEL-1) was drilled in search of a geothermal resource beneath the Snake River Plain for use at the Chemical Processing Plant (CPP) on the Idaho National Engineering Laboratory site. The drilling site was selected as the most promising location within reasonable distance of the CPP. The resource was thought to be located at a depth near 7500 ft (2300 m). Neither significant production nor high temperatures were noted at that depth, and the well was then drilled to 10,333 ft (3150 m) with similar findings. Rock cores, geophysical logs, and hydrologic tests of the well to date indicate that no useful geothermal resource exists at this location. This report presents information on the drilling, completion, and testing of INEL-1.

ACKNOWLEDGMENTS

Acknowledgment is made of those who provided information and technical assistance in support of this project. Listed by organization, contributors were:

DOE-ID -- S. M. Prestwich and L. L. Mink

DOE-NV -- J. B. Cotter and J. N. Fiore

EG&G Idaho, Inc. -- J. A. Bowman, S. Petty, D. Goldman, W. Niemi, D. M. Callan, and R. E. McAtee

USGS -- J. T. Barraclough and D. J. Doherty

Although others helped, these persons made special contributions to this project and the preparation of this report.

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COMPLETION AND TESTING REPORT; INEL GEOTHERMAL EXPLORATORY WELL ONE (INEL-1)

INTRODUCTION

This report describes the drilling, completion, and testing of the INEL Geothermal Exploratory Well One (INEL-1). The well was drilled in search of a hydrothermal resource beneath the Idaho National Engineering Laboratory (INEL) for use at the Chemical Processing Plant (CPP). In order to be useful, the resource was expected to yield 500 gpm (31.5 L/s) of water at 300°F (149°C).

The site for INEL-1 was chosen by the U.S. Geological Survey (USGS) in the most favorable location within 6 mi (10 km) of the Chemical Processing Plant (CPP). The location is NE 1/4, NW 1/4, Sec. 1, T3N, R29E, in Butte County, Idaho, as seen in Figure 1.

The site was prepared by EG&G Idaho, Inc. Brinkerhoff-Signal Drilling Company performed the drilling and completion under contract to the Department of Energy Idaho Operations Office (DOE-ID). Technical direction and drilling supervision were provided by Fenix And Scisson, an operating contractor of the Department of Energy Nevada Operations Office (DOE-NV), at the request of DOE-ID. DOE-ID funded the entire operation, and EG&G provided logistic support, budgeting, and procurement administration. The USGS provided geological consultation and funded aquifer testing during the drilling operation.

SITE PREPARATION

The drill site was prepared by clearing and grading a 500-ft (152-m) square area, excavating a reserve pit and a water storage pit, constructing a cellar, drilling a 36-in. (91-cm) hole, cementing 30-in. (76-cm) conductor pipe to a depth of 40 ft (12 m), and building an access road from Lincoln Blvd. A water well was drilled, and power and telephone lines were installed. Trailers were provided for the USGS, DOE-ID, DOE-NV, Fenix and Scisson, and EG&G.

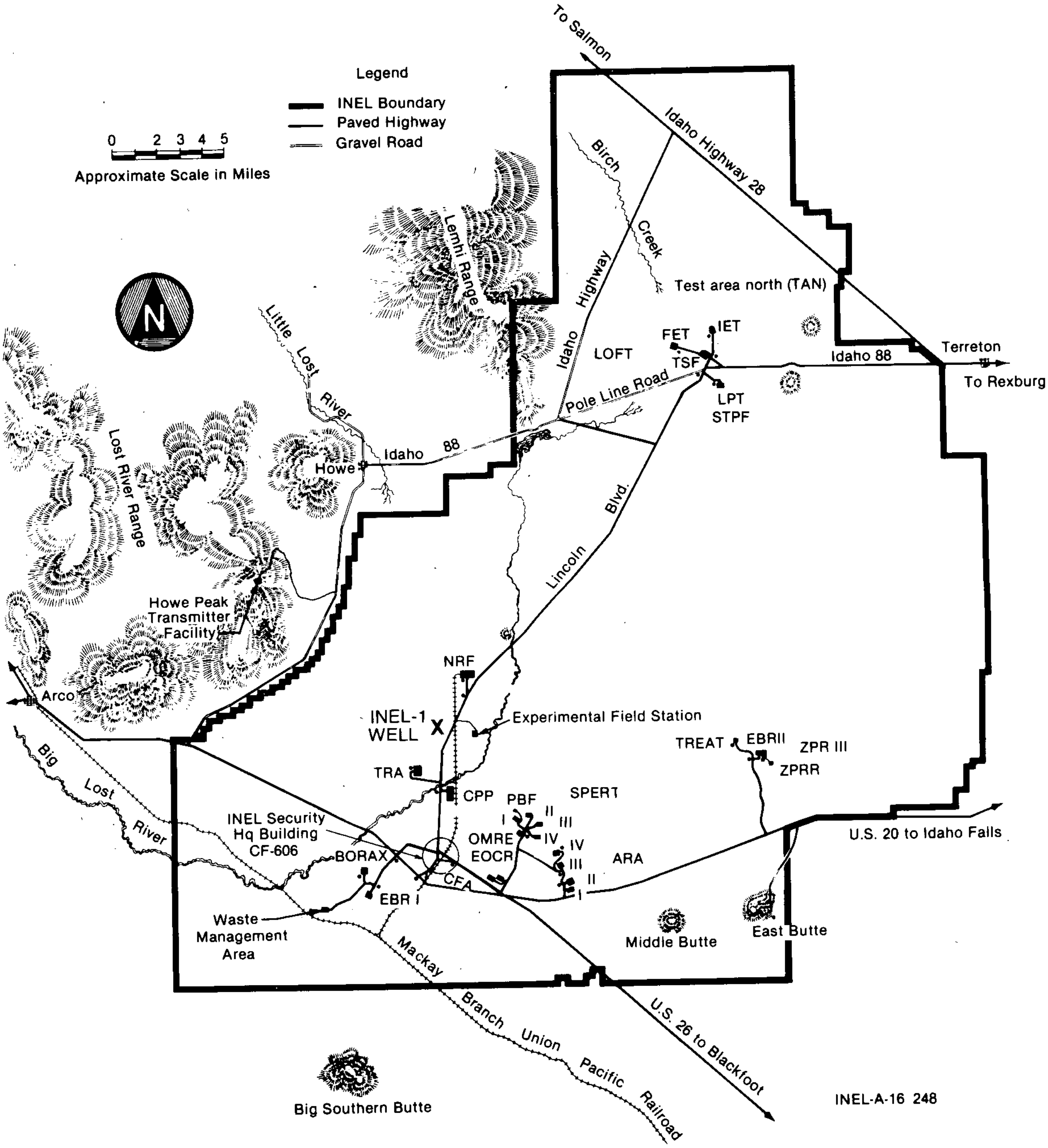

Figure 1. INEL-1 well location on the Idaho National Engineering Laboratory site.

DRILLING AND OPERATIONS SUMMARY

Drilling

Drilling commenced on February 15, 1979. A 26-in. (66-cm) surface hole was dry-drilled to 1524 ft (465 m), various geophysical logs were obtained, and 20-in. (51-cm) casing was set and cemented to surface. The blowout prevention equipment (BOPE) for the intermediate hole was installed and tested successfully. The 17-1/2-in. (44-cm) intermediate hole was then drilled to 3560 ft (1085 m), cores and geophysical logs were obtained, the aquifer was tested, and 13-3/8-in. (34-cm) casing was set and cemented to the surface. The BOPE for the main hole was installed and tested successfully.

The 12-1/4-in. (31-cm) main hole was also drilled with water to 10,333 ft (3150 m); periodic high-viscosity mud sweeps were made to keep the hole clean. Cores and geophysical logs were obtained and an aquifer test was attempted, using a nitrogen gas lift technique. After this test, a 9-5/8-in. (24-cm) liner was hung from 3262 to 6796 ft (994 to 2071 m). The liner was cemented only at the top and bottom to provide later access to the intermediate aquifer. A bottom-hole core was obtained, increasing the depth of the open hole by 32 ft (10 m) at a reduced diameter of 8 in. (20 cm). The rig was released on May 27, 1979.

Appendix A contains excerpts from the Daily Drilling Reports. Figure 2 summarizes drilling and operations. Drilling depths are referenced in the kelly bushing (KB), which was 20 ft (6.1 m) above ground level (GL).

Testing

After the rig moved away, several tests of the aquifer were attempted. In early June, air-lift testing was performed, followed by sampling of the fluid near the bottom of the borehole. On the second trip out, the sampler stuck at the bottom of the liner. It was decided to call in a workover rig, which performed the fishing job and a swab test. After the swab test, the hole was circulated from 10,000 ft (3050 m) in an attempt to clean remaining wall cake with water.

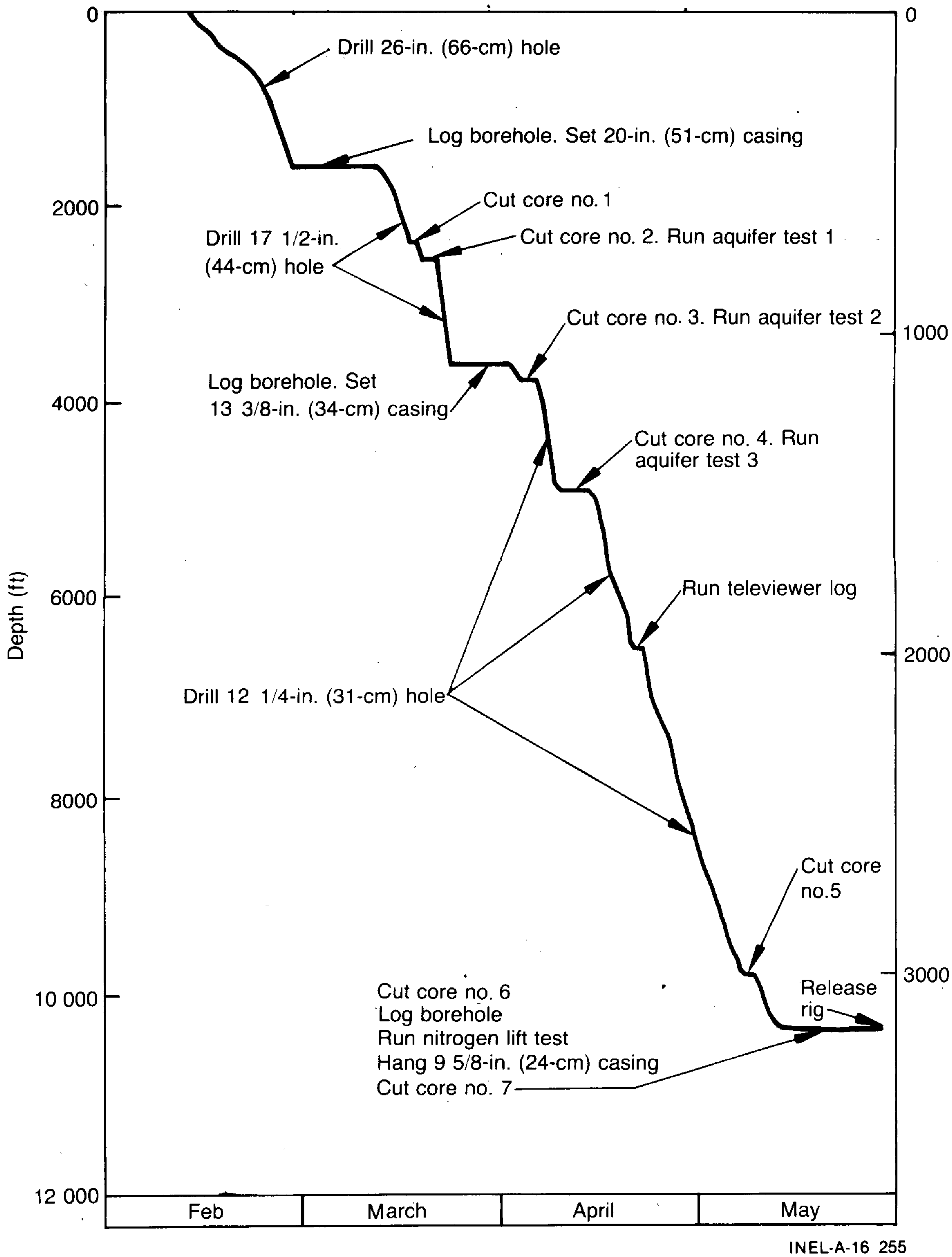

Figure 2. INEL-1 well drilling and operations summary.

Information derived from these operations led to the decision to augment production from the intermediate aquifer behind the 9-5/8-in. (24-cm) liner where tests and previous logs had indicated the possibility of production at temperatures between 150 and 200°F (66 and 93°C). The 9-5/8-in. (24-cm) liner was perforated with 730 holes between 4200 and 6300 ft (1280 and 1920 m). These perforations provided access to the intermediate aquifer during the subsequent pump test.

The final test of INEL-1 was made with a submersible pump set at 1300 ft (396 m). The results of the tests performed on INEL-1 are discussed in a later section of this report.

SURFACE AND CONTAINMENT EQUIPMENT

Cellar

A reinforced concrete cellar (Figure 3) 8 by 10 by 8 ft (2.4 by 3 by 2.4 m) deep contains the wellhead. The casing head is welded to the 20-in. (51-cm) casing.

Blowout Prevention

For drilling below the 20-in. (51-cm) casing, the BOPE (Figure 4) included: a 20-in. spoolpiece, a 20-in. drilling spool, a 20-in. single gate blowout preventer, a 20-in. Hydril type GK blowout preventer, and a 20-in. Grant rotating head.

For drilling the main hole, the BOPE (Figure 5) included a 20- by 12-in. (51- by 30-cm) WKM expansion spool bolted to the casing head, above which were: a 12-in. (30-cm) WKM Master gate valve, a 12-in. drilling spool, a 12-in. double-gate blowout preventer, a 12-in. Hydril type GK blowout preventer, and a 12-in. Grant rotating head.

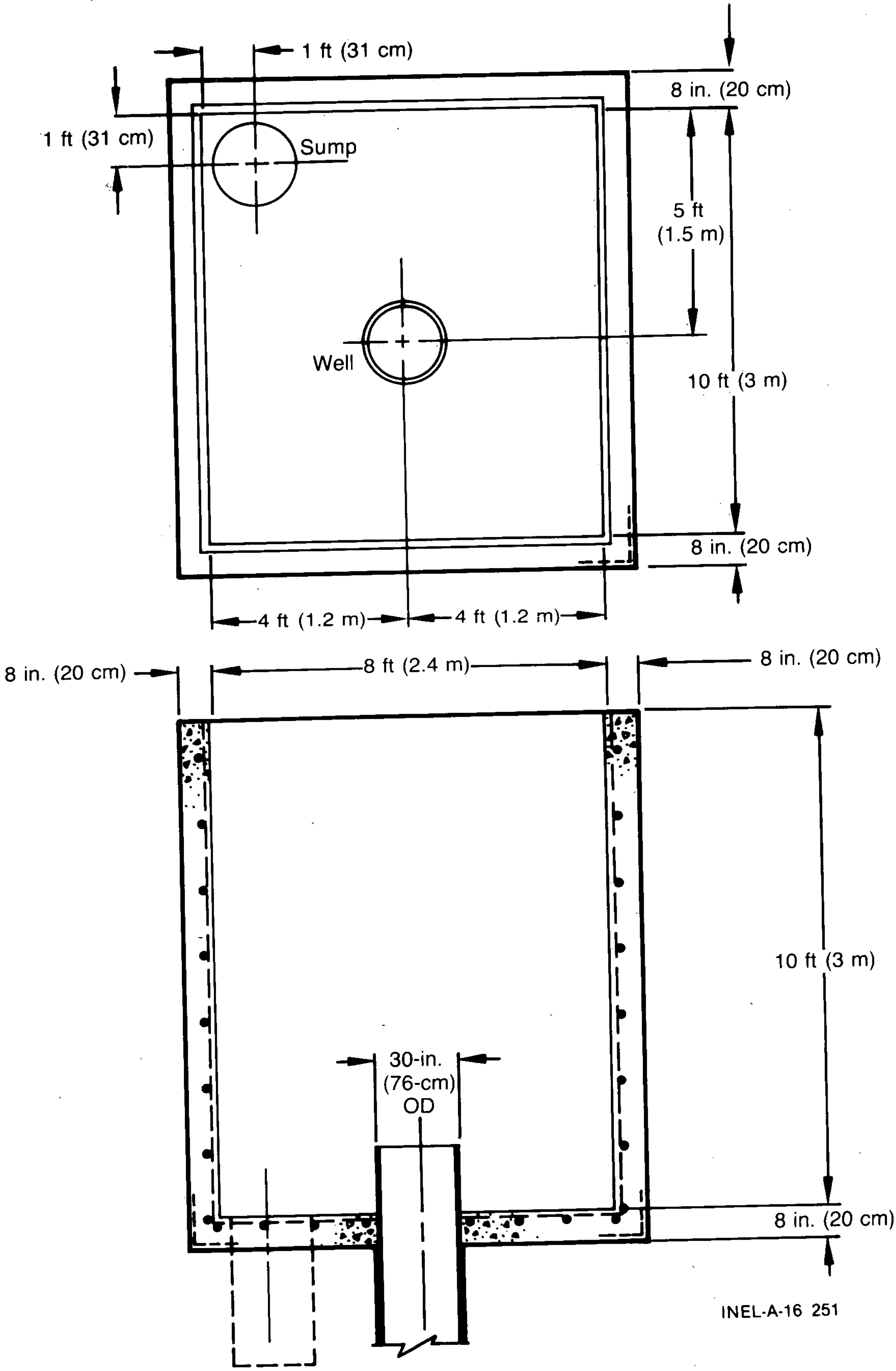

Figure 3. Concrete cellar construction.

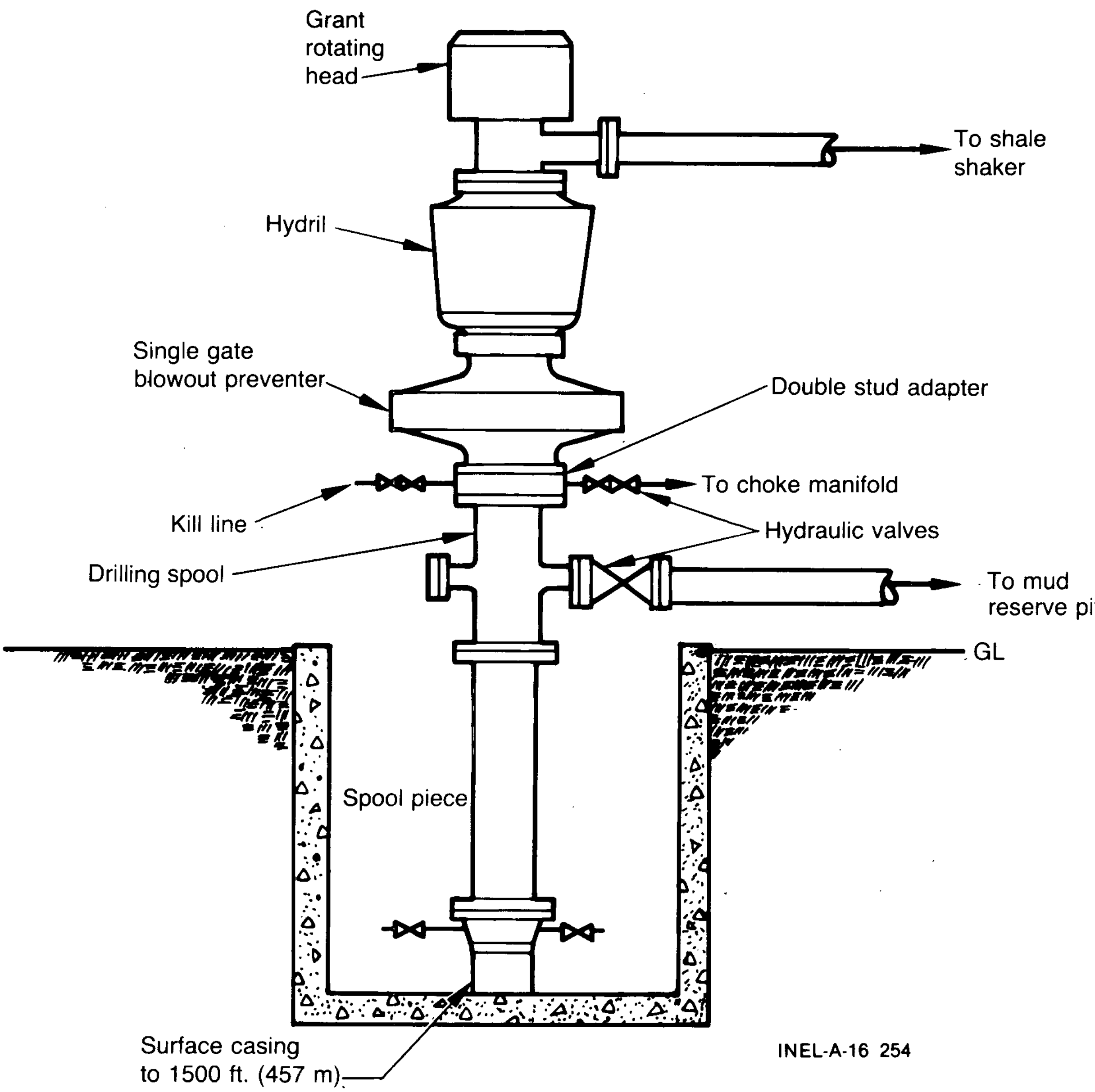

Figure 4. INEL-1 well BOP wellhead equipment (2000 psi minimum rating) for drilling below the 20-in. (51-cm) casing shoe.

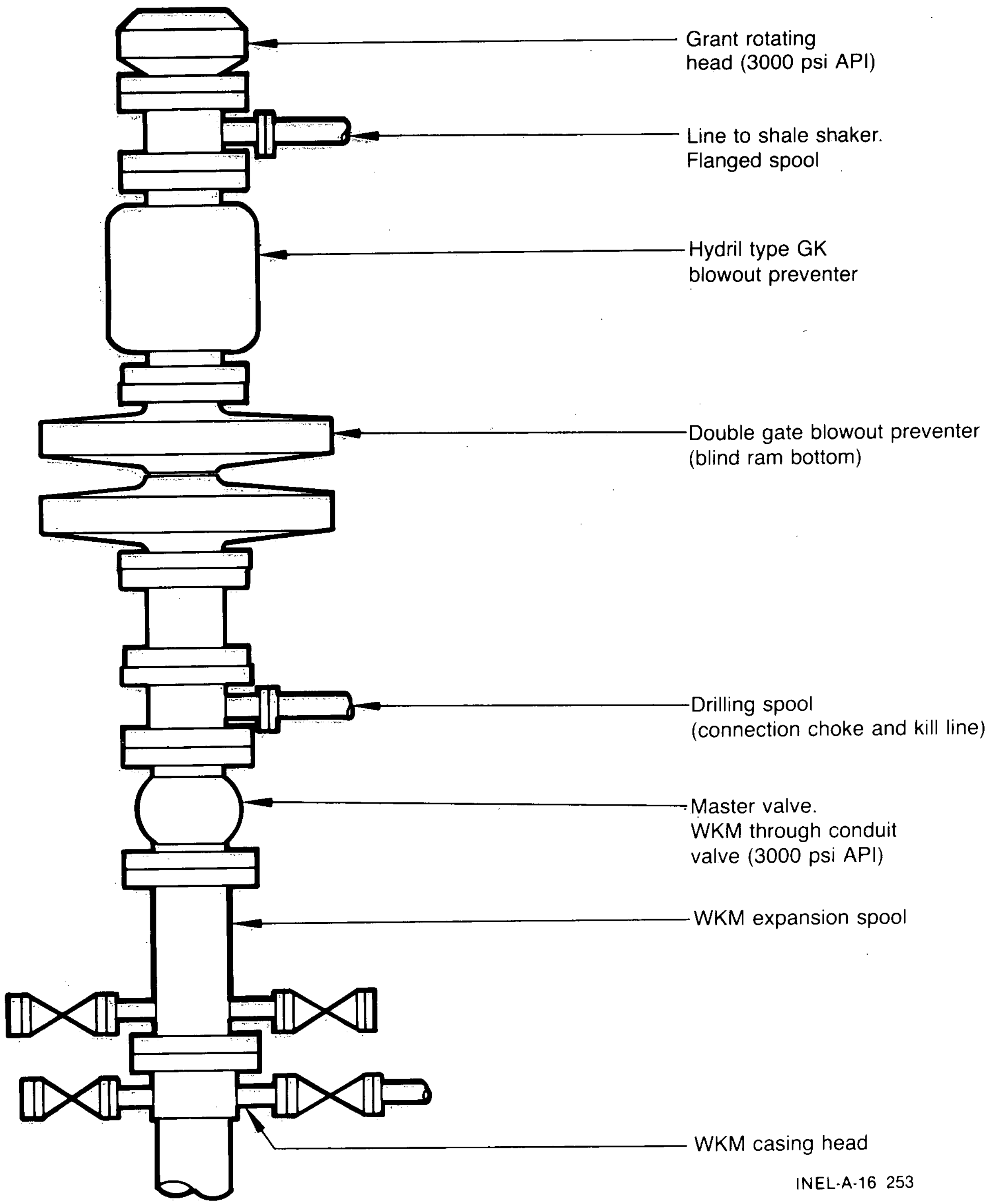

Figure 5. INEL-1 well BOP wellhead equipment for drilling below the 13-3/8-in. (34-cm) casing shoe.

Wellhead

After completion of the hole, the BOPE was removed, leaving only the expansion spool and the Master gate valve (Figure 6). The Master gate valve is equipped with API 3000 (ANSI 900) flanges.

Drilling Recorder

A drilling recorder, used during all drilling operations, indicated depth, weight on bit, rotary rate, penetration rate, and pump pressure.

Deviation Survey

Deviation surveys were made periodically. Deviations recorded were usually less than one degree, with a maximum of three degrees at 9294 ft (2833 m). The directional log indicates that the bottom of the hole is located 83 ft (25 m) south and 5 ft (1.5 m) east of the surface hole.

DOWNHOLE EQUIPMENT AND SERVICES

Conductor

Two joints of butt-welded 30-in. (76-cm) conductor pipe were set to a depth of 40 ft (12 m) and cemented to the surface.

Casing

Twenty-four joints of 20-in. (51-cm) K-55 133# ST&C casing and 14 joints of H-40 94# ST&C casing were set to a depth of 1511 ft (460 m) and cemented to the surface with 8696 ft^3 (246 m^3) of Class G cement with 20% silica flour, 25 sacks Kolite, and 8% Gypseal.

Eighty-seven joints of 13-3/8-in. (34-cm) P-110 72# ST&C casing were set to a depth of 3559 ft (1085 m) and cemented to the surface with 4781 ft^3 (135 m^3) of the same cement formulation.

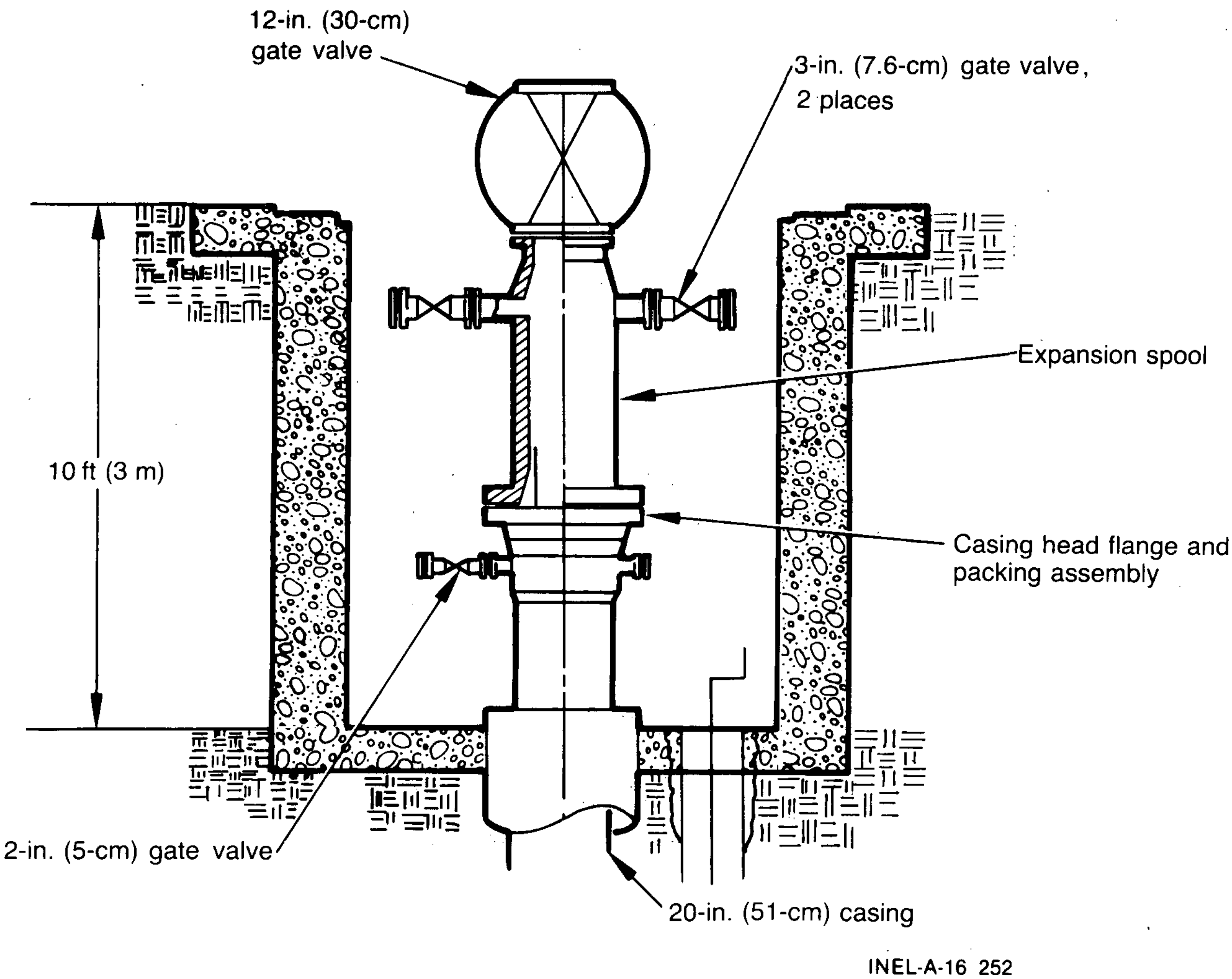

Figure 6. INEL-1 well wellhead equipment installed on completed well.

Liner

Eighty-four joints of 9-5/8-in. (24-cm) S-95 special drifted 40# LT&C casing liner were hung from a liner hanger set at 3262 ft (994 m). The casing liner extended to a depth of 6976 ft (2126 m). The liner was cemented with 434 ft^3 (12 m^3) of Class G cement in two stages, one at the bottom and one at the top, with the intention of keeping the midsection free of cement. Subsequently, this liner was perforated with 730 quarter-inch (6-mm) holes between 4200 and 6266 ft (1280 and 1910 m) in seeking production from the intermediate aquifer. Figure 7 shows the subsurface well status.

Lithologic Logging

A service company provided mud logging services, sampled cuttings, and monitored drilling fluid temperature and hydrogen sulfide content. Lithologic characteristics were determined by periodically analyzing drill cuttings and cores when they were acquired. A discussion of INEL-1 lithology is presented in the Hydrogeology section of this report.

Drill Bit Summary

A dry hole digger drilled 40 ft (12 m) of 36-in. (91-cm) hole and set the 30-in. (76-cm) conductor pipe.

For the surface hole, five 26-in. (66-cm) bits were used. Three were mill tooth bits, and were used to drill to a depth of 610 ft (186 m). The other two were journal-bearing bits used to drill to a depth of 1526 ft (465 m).

The intermediate hole was drilled with three 17-1/2-in. (44-cm) journal-bearing bits to a depth of 3563 ft (1086 m).

The main hole was drilled with six 12-1/4-in. (31-cm) bits to a total depth of 10,333 ft (3150 m).

Appendix B presents the drill bit record taken from the Daily Drilling Report.

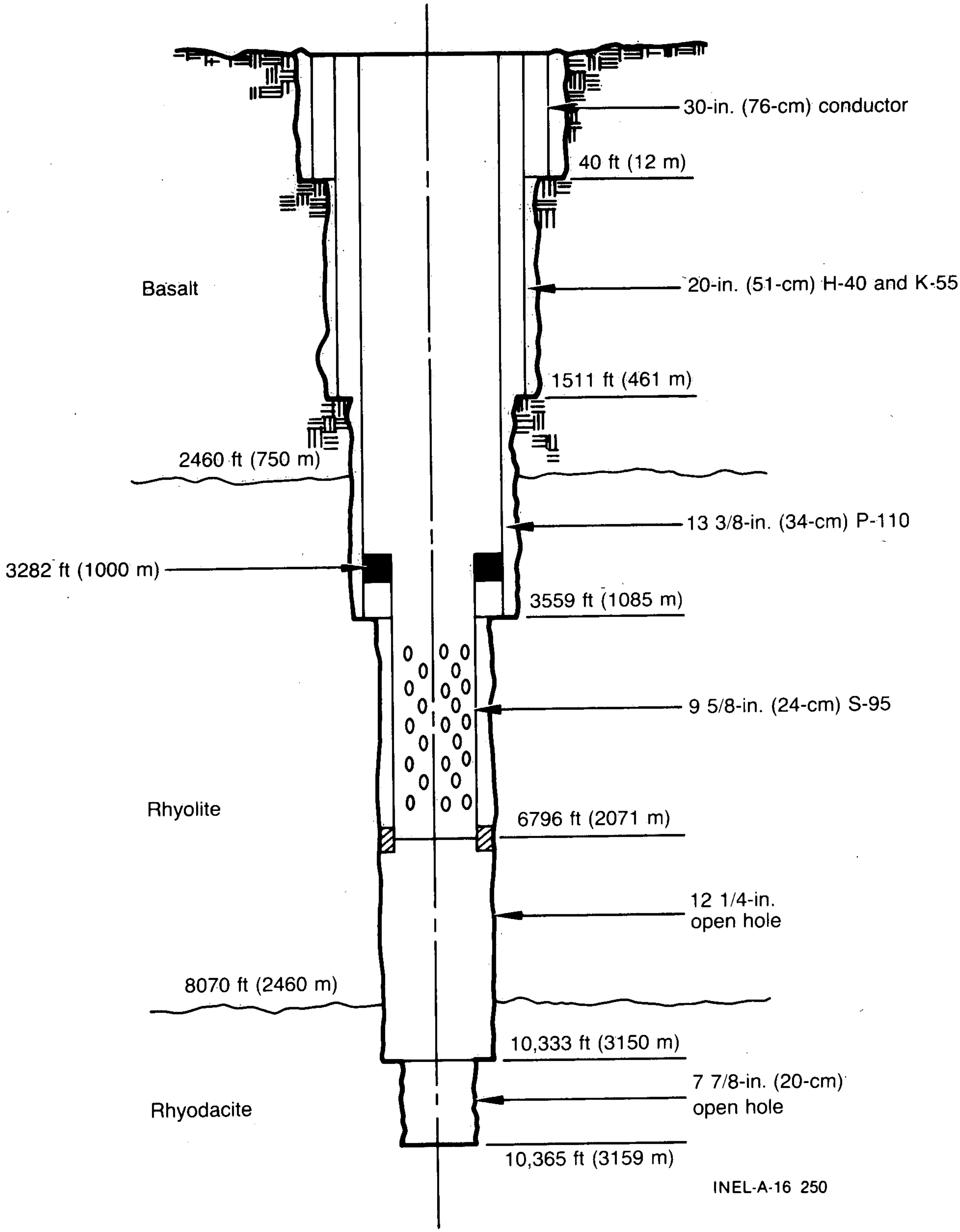

Figure 7. INEL-1 well subsurface status.

Drilling Fluids

The 26-in. (66-cm) hole was drilled with gel until returns were lost at 136 ft (41 m). From there to the first casing point, a wide range of lost circulation material was tried with no success, and the surface hole was essentially dry drilled with water.

The intermediate hole was drilled with conventional gel/lime drilling fluid. The main hole was drilled with water. At least once each tour, a high-viscosity sweep with drilling fluid was made to remove the cuttings and keep the borehole clean.

Coring

Cores were acquired at selected intervals during drilling. Seven cores were cut, analyzed, and sent to the core library at the University of Utah Research Institute. The coring summary is presented in Appendix C.

Geophysical Logging

Various geophysical logs were obtained of INEL-1 to determine the condition of the hole at certain stages of the drilling operation (Appendix D). The Hydrogeology section of this report discusses the information derived from the logs.

DRILLING PROBLEMS

The driller encountered lost circulation at 136 ft (41 m). The problem was severe, and no lost-circulation drilling fluid additives alleviated the condition, although many were tried. The hole was essentially "dry drilled" with water to the first casing point below 1500 ft (457 m). A considerable amount of time was spent reaming the surface hole before casing could be set. The subsequent cementing operation took eight stages; the top of the first stage was indicated at 180 ft (55 m).

At a depth of 698 ft (213 m) the drilling jars twisted off, leaving a 200-ft (61-m) fish in the hole. An overshot was employed and the fish was landed on the first attempt.

HYDROGEOLOGY

Geology of the INEL-1 Region

Basaltic lava flows interbedded with silty to sandy alluvial and lacustrine sediments, rhyolitic air-fall ash deposits, and ash-flow tuffs constitute the upper 3000 ft (900 m), approximately, of the eastern Snake River Plain in the vicinity of the INEL. Rocks below this depth had been identified by deduction from geological models and limited geological data, and had not been drilled until INEL-1. Drilling data from INEL-1 support the hypothesis that upper crustal rocks beneath the basalt-sediment layer of the eastern Snake River Plain are chiefly rhyolitic tuffs and ash-flows that formed collapsed calderas. Precambrian, Paleozoic, and Mesozoic sedimentary rocks found in mountain ranges north and south of the eastern Snake River Plain may also be present locally below the volcanic cover of the Plain. (From USGS Open File Report 79-1248.)

Lithology of INEL-1

The surface formation at INEL-1 was fresh basalt with abundant fractures, causing extreme lost circulation problems and slow drilling until casing was set at 1511 ft (461 m). Circulation was first lost at 137 ft (42 m) and not regained until pipe was set. After several days of mixing mud additives in an attempt to regain circulation, it was decided to drill ahead with water until a casing point was reached. While drilling ahead, crews were pumping nearly a half-million gallons of water (1890 m^3) a day into the formation, indicating the extensive nature of the fracture network. After the surface casing was set, no other major problems were encountered in drilling to T.D. at 10,333 ft (3150 m).

Although few samples were available from the surface hole, geophysical log data and correlation from nearby core holes indicate that basalt flows with occasional interbedded lacustrine sediments are located in this zone (Figure 8). The basalts encountered upon drilling out from surface casing were very fresh olivine-rich tholeites, with abundant plagioclase. They exhibited a diktytaxitic texture, and were occasionally glomeroporphyritic with clusters of olivine phenocrysts. Small amounts of pyroxene were seen, and the opaque minerals were generally illmenite or magnetite. These basalts are believed to be upper Quaternary in age. Similar basalts found at Craters of the Moon, 35 mi (56 km) to the southwest, have been dated at less than 2000 years ago.

At approximately 1650 ft (503 m) the samples showed a subtle change to an older, intensely altered and mineralized basalt. The rocks were serpentinized to an almost greasy luster, and were highly mineralized with zeolite, chlorite, hematite, calcite, and silica. These basalts are the oldest found in this area, probably middle Pliocene-Pleistocene in age. It should be noted that no firm age dates were available for this report and ages are given on a correlative basis. The USGS will age date cores taken, and this information will be available in a later USGS report.

A relatively thick bed of Tertiary lacustrine sediment was encountered at 2160 ft (658 m). Core no. 1 showed a gray-green claystone, calcareous and occasionally silty. Below this sediment at 2440 ft (744 m), Tertiary rhyolite was found. Core no. 2 showed it to be a welded ash flow tuff, with abundant flattened pumice fragments, rich in quartz and potassium feldspar. This tuff continued to 5750 ft (1753 m) showing sporadic zones of highly fractured, intensely propylitized and mineralized rock. At this depth, interbeds of nonwelded tuffs, reworked tuffs, air-fall ash, and volcanic breccia along with more welded tuffs were encountered. This lithology continued to 9000 ft (2743 m) where the welded tuffs began a gradual change to dacite, showing an increasing amount of plagioclase. The actual top of the dacite was picked from the density log at 9460 ft (2883 m), with no further changes encountered to a total depth of 10,333 ft (3150 m).

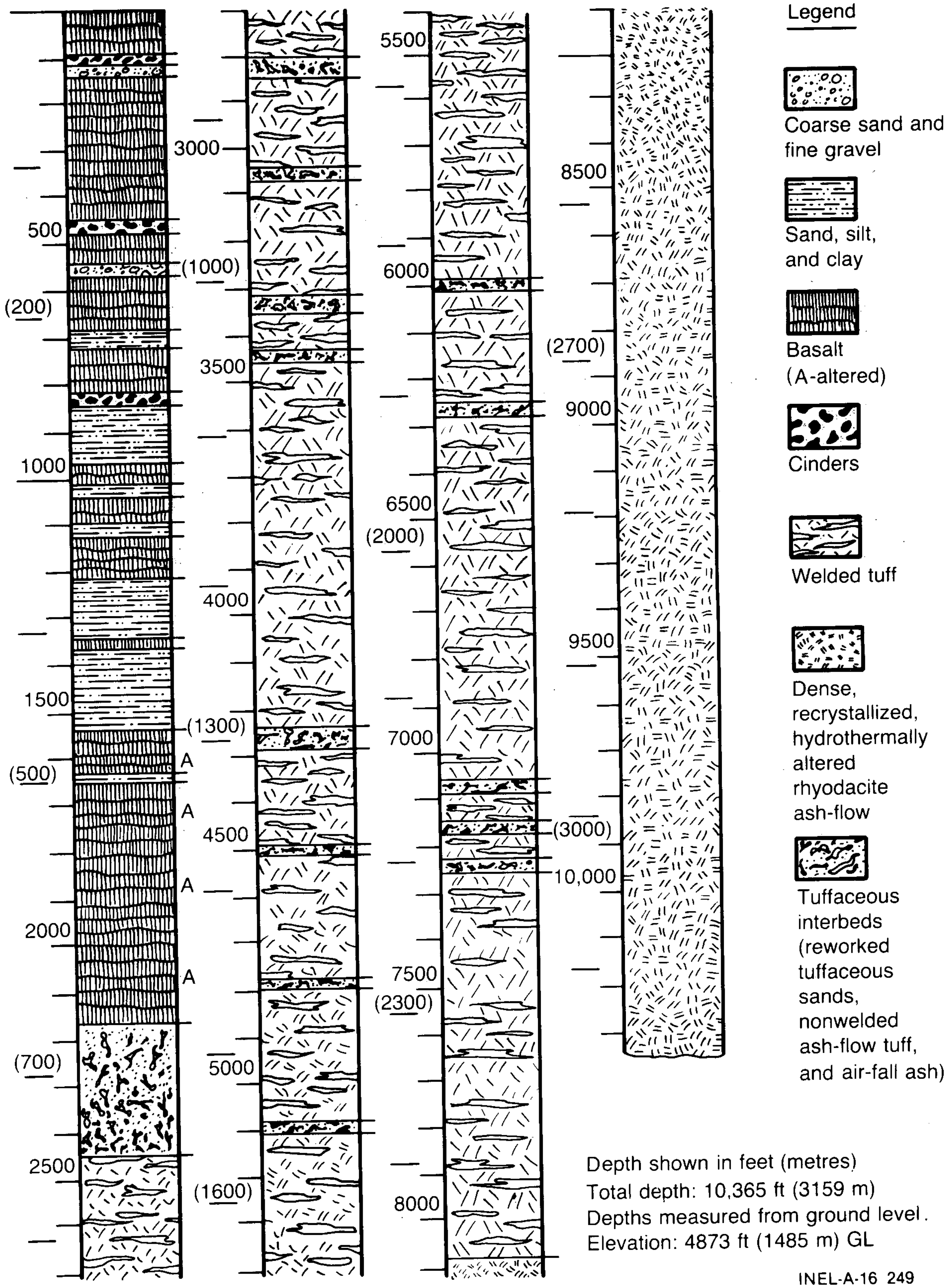

Figure 8. Generalized lithologic log from INEL-1 well.

Geophysical Logging

Geophysical logging was performed at various stages in the construction of INEL-1. Logs run in the top 1511 ft (461 m) of the hole may be unreliable due to incompatiblity of the logging tools with the large diameter of the borehole. The lithology of this portion of the hole was determined from drilling speed, some return of cuttings, and correlation with nearby wells. Correlation was made between lithology found from cuttings and cores, and compensated neutron density, dual induction, natural gamma, caliper, and temperature logs.

At 1558 ft (475 m) a sharp lithologic change in both the natural gamma and sonic logs indicates the end of a section of sediments, altered basalt, or ash, the top of which occurs at approximately 1470 ft (448 m) as indicated by drilling speed. All geophysical logs show interbedded dense and more porous rocks, probably basalt with weathered interbeds or ash-fall tuff from 1562 to 2170 ft (476 to 661 m). There, the logs show a typical clay-type response on natural gamma corresponding with clay and siltstone in the cuttings record. Below 2480 ft (756 m), denser, less porous materials alternate with more porous rocks. This marks the start of the section of rhyolitic, welded tuffs with softer reworked ash beds, air-fall and less consolidated tuffs. Between 3465 and 4160 ft (1056 and 1268 m) occurs a section of tight, low porosity rock with possible fractures near 3650 ft (1113 m).

Below this dense zone are sections of washed-out borehole with indications of higher porosity. These washouts could be attributed to nonwelded tuffs, reworked tuffaceous sand, or cinder. They correspond to temperature anomalies seen in the May 1 temperature log made prior to emplacement of the liner. This region is also included in the region of highest productivity found from pump testing on April 14 and 15. Temperatures in this region reach a maximum of 150°F (65°C). Similar washed-out areas occur at 6000 ft (1829 m) and 6250 ft (1905 m) with small temperature anomalies. As determined from cuttings, this section is largely welded tuffs to 5751 ft (1753 m) where, in general, the ash units are reworked or air-fall deposits with less competence than the overlying welded tuffs.

From 7070 to 7231 ft (2155 to 2204 m) a zone of interbedded porous and dense rock is indicated on sonic, neutron, and resistivity surveys. The caliper log shows washing-out of the borehole. This region coincides, in general, with a temperature anomaly at 7280 ft (2219 m) seen in the June 13 temperature log run immediately after nitrogen-lifting the well. Nitrogen-lifting would remove water from the borehole and induce movement of water into the well to replace it, emphasizing thermal anomalies. Corresponding anomalies in the neutron log and borehole compensated sonic log are also apparent. Areas of higher porosity coinciding with temperature anomalies also occur at 7500 ft (2286 m) and 7110 ft (2167 m). Temperature in this region reaches 190°F (88°C). At 8081 ft (2463 m) a region of slightly different signature on the sonic and neutron logs may indicate a change in lithology. This does not show on the natural gamma or in any of the temperature surveys, and so may not correspond to any hydrologic change.

The lower section of the borehole is fairly uniform from 8081 ft (2463 m) down. Cuttings indicate a transition from rhyolite to dacite starting at 9050 ft (2758 m). Temperature anomalies are apparent from 9600 to 9750 ft (2926 to 2972 m), possibly in regions of fractured rock which do not show up on geophysical logs. An isothermal condition at the bottom of the borehole indicates a zone of stagnant water, possibly drilling fluid.

In general, the geophysical logs indicate only a slight possibility for water production below the liner with the possible exception of the zone between 7070 and 7231 ft (2155 and 2204 m). This could be either a fractured and altered zone, or a zone of reworked tuff with higher porosity and less competence than surrounding tuffs as indicated by washing out of the borehole. There are no other indications of higher porosity in the lower section of the borehole except for the temperature anomalies near 9700 ft (2957 m).

Bottom hole temperature as high as 302°F (150°C) was recorded during temperature logging on May 24, 1979. However, this temperature was not repeated in later surveys and a maximum-reading thermometer showed a bottom hole temperature of 288°F (142°C) at the time of this log. Later logs showed the same bottom hole temperature of 288°F (142°C).

TESTING OF INEL-1

Prior to the drilling of the INEL-1 well, very little information on the geology and hydrology of the eastern Snake River Plain was available for the rock units below a depth of 1500 ft (457 m). The well, located in the west-central part of the INEL, was instrumental in gaining hydrologic information about these lower units. Several attempts were made during and after drilling of INEL-1 to evaluate the hydraulic characteristics of the borehole. These attempts include nitrogen-lifting, air-lifting, swabbing, and pump testing.

Aquifer Test 1

From March 23 to March 24, 1979, an aquifer test was run on a 695-ft (212-m) section of the INEL-1 well. The test interval consisted of strata between 1511 and 2206 ft (460 and 672 m) below GL. At the time of the test, the well was cased with 20-in. (51-cm) O.D. casing from the surface to a depth of 1511 ft (460 m) and originally continued as a 17-1/2-in. (44-cm) open hole from 1511 to 2518 ft (460 to 767 m).

The borehole penetrated a repetitive sequence of basalt and sediment from the surface to a depth of 2445 ft (745 m). A thick, predominantly sediment section was traversed from 1220 to 1530 ft (372 to 466 m). This section probably acts as a confining layer and separates the Snake River Plain aquifer into two distinct zones. A thick section of rhyolitic welded tuff was encountered below 2445 ft (745 m) and had not been breached when drilling was terminated for Test 1. Upon removal of highly viscous drilling mud from the borehole, caving sediments filled the hole from 2518 to 2206 ft (767 to 672 m). The rhyolites were then temporarily sealed and probably did not contribute water to the aquifer test. Therefore, the test interval consisted of strata present in the now-designated lower basalt zone of the Snake River Plain aquifer.

A 30-hp submersible pump was installed at a depth of 802 ft (244 m) below GL. A 1-in. (2.5-cm) diameter measuring line was installed to 828 ft (252 m) below GL to facilitate water-level measurements. The static water level was about 330 ft (100 m) below GL. Pumping started at 0814 on March 23, 1979. The average pumping rate was about 125 gpm (8 L/s). The test terminated at 0814 on March 24, 1979. The maximum drawdown from the test was 218 ft (66 m). The calculated 14-1/2-hr specific capacity is 0.57 gpm/ft of drawdown (1.8×10^{-4} L/s·m). The coefficient of transmissivity was determined to be 224 gpd/ft (2.77 m^2/d).

Aquifer Test 2

Following Aquifer Test 1, drilling continued to a depth of 3713 ft (1132 m) and a 13-3/8-in. (34-cm) casing was set from the surface to a depth of 3559 ft (1085 m). The borehole continued from 3559 to 3663 ft (1085 to 1116 m) as a 12-1/4-in. (31-cm) open hole and a 7-7/8-in. (20-cm) cored interval from 3663 to 3713 ft (1116 to 1132 m). Aquifer Test 2 was performed on this 154-ft (47-m) section of the INEL-1 well from April 6 through April 8, 1979.

The rock strata penetrated by the renewed drilling were dominated by rhyolitic welded tuff with a few thin tuffaceous interbeds of varying compositions. Cores demonstrated that fractures present in the samples had been filled by secondary mineralization and that the rhyolitic rocks were very dense. Water contribution to the test through the bottom of the corehole was, therefore, assumed to be negligible.

The 30-hp submersible pump used in Aquifer Test 1 was installed at a depth of about 840 ft (256 m) below GL. A 1-in. (2.5-cm) diameter measuring line was installed to 807 ft (246 m) below GL to facilitate water-level measurements. Pumping began on April 6. The average pumping rate was about 20 gpm (1.25 L/s) for the entire test. The static water level was about 290 ft (88 m) below GL. Maximum drawdown was about 459 ft (140 m) after pumping for 43 hours. From this information, the specific capacity was determined to be 0.04 gpm/ft (1.28×10^{-5} L/s·m). The coefficient of transmissivity was determined from recovery data as 14.3 gpd/ft (0.18 m^2/d).

A comparison of the data obtained from Aquifer Test 2 to the data obtained from Test 1 shows that the permeability and the amount of water recoverable from the rhyolite-dominated aquifer are at least an order of magnitude lower than the same parameters in the overlying lower basalts of the Snake River Plain aquifer.

Aquifer Test 3

Following test 2, the borehole was deepened by means of drilling a 12-1/4-in. (31-cm) open hole from 3663 to 4839 ft (1116 to 1475 m) and a 7-7/8-in. (20-cm) cored hole from 4839 to 4879 ft (1475 to 1487 m). The well casing completion was similar to that of Test 2 and the rocks penetrated were also very similar rhyolitic welded tuff with tuffaceous interbeds. The open 1320-ft (402-m) section of the well was investigated by Aquifer Test 3. The test was performed from April 13 to 15, 1979, and included the strata analyzed in Aquifer Test 2.

The 30-hp submersible pump was set at about 840 ft (256 m) below GL. A 1-in. (2.5-cm) diameter measuring line was installed at a depth of approximately 810 ft (247 m) below GL to facilitate water level measurements. At 1246 on April 14, pumping for Aquifer Test 3 began, and after an hour was nearly at a constant rate of 75 gpm (4.7 L/s). Initial static water level was approximately 290 ft (88 m). Drawdown during the last 17 hours of the test reached a maximum of 359 ft (109 m). The calculated specific capacity for this zone is 0.20 gpm/ft (6.4×10^{-5}L/s·m). The coefficient of transmissivity was determined from the recovery curve and from a semilog plot of the drawdown data. In both cases, the values were identical at 77 gpd/ft (0.95 m^2/d). After approximately 2 hours, the drawdown data indicated that very little, if any, further drawdown would occur. This relationship indicates that the effective radius of a cross-sectional area covered by the cone of depression had increased to a point where recharge from the aquifer to the pumping well was nearly equal to its pumping rate.

The hydrologic parameters determined for the rhyolitic rocks in this test are considerably higher than those determined from Test 2 and are mostly due to additional footage in the Test 3 zone. However, the results of Test 3 indicate that the hydrologic parameters of the rhyolitic rocks are about three times smaller than those for the lower basalts of the Snake River Plain aquifer and indicate only limited potential.

Nitrogen-Lift Testing

Nitrogen-lifting was attempted during drilling to assess the open borehole interval from 3560 to 10,333 ft (1085 to 3150 m). Nitrogen was introduced through the open-ended drill stem hung in the 13-3/8-in. (34-cm) casing.

The nitrogen-lifting was useful in cleaning the hole, but did not provide adequate hydraulic data to assess formation characteristics. Flow measurement was extremely difficult because nitrogen built up in the large annular space producing periodic bubbles with surge-type discharge. In addition, access to the eductor pipes at the pressurized wellhead was difficult. The wellhead assembly required to accommodate the equipment precluded measurement of fluid level in the annulus. The method and circumstances did not permit quantitative assessment of response.

Air-Lift Testing

Air-lift testing was carried out June 10-11, 1979. The drilling rig had been moved off the hole at this time after reaching total depth. The interval open to testing was that section of the hole below the 9-5/8-in. (24-cm) casing between 6804 and 10,364 ft (2074 and 3159 m). Water level was 295 ft (90 m). Air was introduced through a string of 2-in. (5-cm) tubing hung inside the 13-3/8-in. (34-cm) casing. Several attempts were made on June 10th, gradually increasing the length of tubing until it reached 1000 ft (305 m). The well was permitted to recover overnight and a further test was attempted. Static fluid level before this test was 673 ft (205 m) and showed a trend of slow recovery of 1.6 ft/hr (0.5 m/hr).

The response to air-lifting was a two-minute pulse of water. When flow stopped, the wellhead assembly was removed and recovery measurements were commenced. After 20 minutes the water level was 668 ft (204 m) and it slowly recovered to 620 ft (189 m) after 48 hours.

The recovery response to air-lifting was analogous to a "slug" test because the pumping period was extremely short. For this reason, the method of Cooper, Bredehoeft, and Papadapulos was applied as the most appropriate means of analyzing available recovery data. This method indicated an apparent transmissivity of less than 100 gpd/ft (1.25 m^2/d).

The very slow recovery following air-lift testing suggested the possibility of wellbore damage in addition to low hydraulic conductivity in the section tested. To assess this possibility, an attempt was made to obtain selective samples of borehole fluid using a Schlumberger Repeat Formation Tester on June 15, 1979. The samples recovered at 10,107 ft (3081 m) and 10,307 ft (3142 m) verified the presence of drilling fluid. The residence time since drilling stopped and the 288°F (142°C) borehole temperature measurement suggested that formation damage might be an important influence on yield.

Swab Testing

In an attempt to clean and stimulate the borehole, swabbing was carried out July 10-13, 1979. This method was selected to minimize the possibility of pushing contaminated drilling fluid into the formation. The swabbing was carried out in tubing with a packer set near the foot of the 9-5/8-in. (24-cm) liner. Limited information on the hydraulic characteristics of the open interval, 6804 to 10,364 ft (2074 to 3159 m), can be drawn from the response to swabbing.

Initial fluid level was 361 ft (110 m) below GL. Successive swabbing runs were made, swabbing the tubing dry to a depth of 5512 ft (1680 m). Fluid level recovered in 12 hours to a depth of approximately 1503 ft (458 m). The recovery data indicated an apparent transmissivity of less than 100 gpd/ft (1.25 m^2/d). Following swabbing, the hole was circulated with water through tubing hung to 10,170 ft (3100 m). Approximately 115,000 gal (435 m^3) were circulated, representing approximately two borehole volumes.

Pump Testing

Both the air-lifting and swabbing operations indicated that only very poor yield could be expected from the barefoot segment of the borehole. It was decided to try to improve the yield by perforating the 9-5/8-in. (24-cm) liner opposite indicated productive zones between 4200 and 6273 ft (1280 and 1912 m). Perforating was carried out on August 14, 1979 by Schlumberger. Lower fluid temperatures were anticipated in this interval than in the deeper, uncased section. Table 1 shows the perforated intervals and anticipated fluid temperatures obtained from pre-liner temperature logs.

A preliminary estimate of the potential yield from the perforated well based on earlier testing of the uncased interval by USGS indicated that relatively poor production could be anticipated. The predicted drawdowns at rates of 100 gpm (6.1 L/s) and 500 gpm (31.5 L/s) are summarized in Table 2. These predictions were made using extension of the linear drawdown trend indicated in the USGS April 14-15 test and applying a ratio technique. The predictions assume no hydraulic boundaries are intersected and that the perforated interval responds as efficiently as the open wellbore would.

A pumping test was performed September 11, 1979 to evaluate the perforated well. The pump used for this test was rated at 400 gpm (25.2 L/s) with intake set at 1280 ft (390 m). Although the preliminary predictions indicated that the water level would fall below 1280 ft (390 m) at 400 gpm (25.2 L/s), this pump selection was accepted because the terms of reference for a practical source well called for a yield of 500 gpm (31.5 L/s) with reasonable lift costs.

TABLE 1. INEL-1 WELL PERFORATED ZONE INTERVALS AND ANTICIPATED FLUID TEMPERATURES

Perforated Zone, ft (m)	Anticipated Temperature, °F (°C)
4210-4225 (1283-1288)	146 (63)
4240-4270 (1292-1302)	147 (64)
4300-4315 (1311-1315)	147 (64)
4490-4520 (1369-1378)	151 (66)
4775-4790 (1455-1460)	154 (68)
5085-5100 (1550-1555)	156 (69)
5230-5245 (1594-1599)	160 (71)
5995-6010 (1827-1832)	166 (74)
6220-6235 (1896-1900)	168 (76)
6260-6275 (1908-1913)	169 (76)

TABLE 2. PREDICTED INEL-1 WELL DRAWDOWNS

Pumping Rate, gpm (L/s)	Predicted Drawdown from Static Water Level, ft (m)			
	1 day	30 days	150 days	210 days
100 (6.1)	490 (150)	520 (160)	520 (160)	520 (160)
500 (31.5)	2450 (750)	2550 (780)	2600 (790)	2600 (790)

Fluid level in the well was monitored by a nitrogen line set near the pump impellers with pressure read from a Heise gauge. Initial fluid level was 371 ft (113 m) below ground level. After 7.3 minutes of pumping at 400 gpm (25.2 L/s), the available drawdown was exhausted, terminating the test. Recovery measurements were collected for 100 minutes, after which recovery was complete. Drawdown and recovery measurements indicate that the apparent transmissivity is less than 100 gpd/ft (1.25 m^2/d). All test indicators point to a very poor producing well.

CHEMICAL LOGGING

Chemical logging studies were conducted at INEL-1. Calcium-alkalinity ratios as a function of drill depth assisted in the definition of warm and hot water aquifers penetrated by the drill. This section describes the correlations between chemical logs and geophysical logs and evaluates the chemical data collected from the flow tests, nitrogen-lift, swab test, and the final circulation test of INEL-1.

Correlation of the calcium-alkalinity log and the compensated neutron log between 4590 and 5250 ft (1399 and 1600 m) was significant. This zone has the highest porosity within the borehole. The chemical log indicates that the borehole area having the highest porosity is the area of highest formation water flow. From the depth of 6230 to 9840 ft (1900 to 3000 m), the porosity decreases and the chemical log gives no indication of any water flow. Below 9840 ft (3000 m), the neutron log shows no areas with any significant porosity. The chemical log, however, indicates the possibility of hot water at low flow rates, possibly from small fractures which are not detected by the neutron log.

Comparison of the calcium-alkalinity and the caliper log indicates that the areas where the calcium-alkalinity ratio is highest correlate well with the washout areas of the borehole. It indicates that the formations with the greatest flow are located 4590 and 5575 ft (1399 and 1699 m). Flow tests between 3400 and 4890 ft (1036 and 1490 m) produced water at a temperature of approximately 122°F (50°C) and the resource was estimated to be capable of a flow of approximately 100 gpm (6.3 L/s).

The lithologic log defines the fracture zones and contact points between different zones. Comparison of the calcium-alkalinity log with the lithologic log correlates well between 4590 and 5900 ft (1400 and 1800 m) and 9840 ft (3000 m). Since the chemical log depends on drill fluid dilution by an aquifer to show change, it is inferred that these are the water-producing zones in INEL-1. The wellbore between 5900 and 9840 ft (1800 and 3000 m) has a number of high-porosity fractured zones not defined by the chemical log. It is assumed that these zones did not produce enough water to affect the chemical composition of the drill water and consequently the chemical log.

INEL-1 was flow tested at several depths and water samples were obtained. Chemical analysis data from the four flow tests support the following conclusions: (a) most of the water produced from the well comes from the intermediate zone, (b) the water from the intermediate and lower zone is of the low-chloride bicarbonate type, and (c) data evaluation supports the existence at one time of vapor-dominated geothermal systems in the Snake River Plain.

Air-lifting of water from INEL-1 was conducted after well completion to induce flow from the formations at the bottom of the borehole. Samples were then collected using a downhole sampler. The very low fluoride and silicon concentrations indicate that the samples contained only the water used for drilling. This indicates that very little, if any, formation water was produced at the bottom of the borehole.

APPENDIX A

DAILY DRILLLING REPORTS

APPENDIX A

TABLE A-1. DAILY DRILLING REPORTS, FEBRUARY TO MAY 1979

February 15	INEL-1 spudded at 11:00 a.m. Drilled lava from 40 ft (12 m) to 97 ft (30 m). Survey: 0° at 93 ft (28 m). Mud - gel/lime: Weight - 8.8 lb/gal (1.05 kg/L) Viscosity - 50 Bottom hole assembly: 10-in. (25.4-cm) drill collars (2) Shock sub 26-in. (66.0-cm) bit, HTC OSC3
February 16	Drilled in basalt. Added stabilizer and drill collars. Lost circulation at 137 ft (42 m). Mixed lost circulation materials: Plug-it; mica, walnut hulls, Fibertex. Bottom Hole Assembly: 9-in. (22.9-cm) drill collar Stabilizer 10-in. (25.4-cm) drill collars (2) Shock sub 26-in. (66.0-cm) bit, HTC OSC3
February 17	Pumped pill. Drilled with water to 164 ft (50 m).
February 18	Mixed LCM. Pumped pill. Drilled to 169 ft (52 m). Tripped out for bit No. 2. Added stabilizer and drill collars to BHA. Drilled to 248 ft (76 m) in basalt. Bottom hole assembly: 8-in. (20.3-cm) drill collar Stabilizer 9-in. (22.9-cm) drill collars (4) Stabilizer 10-in. (25.4-cm) drill collars (2) Shock sub 26-in. (66.0-cm) bit, HTC OSC3
February 19	Drilled to 311 ft (95 m) with mud, water, and LCM.
February 20	Drilled to 326 ft (99 m). Tripped out for bit No. 3. Added five 8-in. (20.3-cm) drill collars. Pumped pill: no returns.

TABLE A-1 (continued)

February 21	Tripped in with bit No. 3. Drilled with water to 382 ft (116 m). Surveyed hole: 1/2° at 325 ft (99 m). Bottom hole assembly: 8-in. (20.3-cm) drill collars (6) Stabilizer 9-in. (22.9-cm) drill collars (4) 10-in. (25.4-cm) drill collars (2) Shock sub 26-in. (66.0-cm) bit, HTC OSC3
February 22	Reamed hole. Removed stabilizers. Picked up drilling jars. Drilled to 442 ft (135 m). Lost circulation at 392 ft (119 m); got it back at 413 ft (126 m); surveyed hole; 1/4° at 430 ft (131 m).
February 23	Drilled to 537 ft (164 m) with water. Mixed mud. Bottom hole assembly: 8-in. (20.3-cm) drill collars (6) Drilling jars 8-in. (20.3-cm) drill collars (2) 9-in. (22.9-cm) drill collars (4) 10-in. (25.4-cm) drill collars (2) Shock sub 26-in. (66.0-cm) bit, HTC OSC3
February 24	Mixed mud and LCM. Pumped pill. Drilled with 70% returns to 570 ft (174 m). Survey: 1/2° at 561 ft (171 m).
February 25	Drilled with water to 609 ft (186 m). Tripped out for bit No. 4. Serviced rig. Drilled with water to 698 ft (213 m). Twisted off. Top of fish at 498 ft (152 m) at location of drilling jars. Tripped in with overshot, caught fish and landed it. Bottom hole assembly at time of twist-off was 686 ft (209 m) long as follows: Heavy weight drill pipe (7 jts) 8-in. (20.3-cm) drill collars (6) Drilling jars 8-in. (20.3-cm) drill collars (2) 9-in. (22.9-cm) drill collars (4) 10-in. (25.4-cm) drill collars (2) Shock sub 26-in. (66.0-cm) bit, HTC OSCIG

TABLE A-1 (continued)

February 26	Tripped in. Mixed mud. Reamed to bottom. Drilled without returns to 865 ft (264 m).
February 27	Pulled 3 stands and picked up drilling jars. Drilled with water to 933 ft (284 m).
February 28	Drilled to 973 ft (297 m). Tripped out for bit No. 5. Drilled with water to 1067 ft (325 m). Surveyed hole: 3/4° at 985 ft (300 m).
March 1	Drilled with water to 1218 ft (371 m), pumping an occasional pill to clean the hole.
March 2	Drilled with water and occasional pills to 1524 ft (465 m). Surveyed hole: 1/4° at 1290 ft (393 m).
March 3	Tripped out and reamed hole. Rigged up loggers.
March 4	Obtained temperature and caliper logs. Cleaned hole. Tripped in and washed to bottom.
March 5	Conditioned hole for casing. Rigged up casing crew. Found tight hole 5 joints down. Rigged down casing crew. Rigged up TV camera and ran in hole to top of fluid. Tripped out. Tripped in hole with bit No. 4 (rerun).
March 6	Tripped out. Tripped in with reamers. Reamed hole.
March 7	Reamed and cleaned hole.
March 8	Reamed hole. Cleaned out to bottom. Bottom hole assembly: Heavy weight D.P. (7) 8-in. (20.3-cm) drill collars (3) Drilling jars 8-in. (20.3-cm) drill collars (5) 9-in. (20.9-cm) drill collars (4) 10-in. (25.4-cm) drill collars (2) 26-in. (66.0-cm) reamer 26-in. (66.0-cm) bit, HTC OSCIG (No. 4, rerun)
March 9	Rigged up to run casing. Set 20-in. (51-cm) casing at 1511 ft (460 m). Set 24 joints of K-55 and 14 joints of H-40.

TABLE A-1 (continued)

March 10	Rigged down and loaded out casing crew. Rigged up loggers. Ran logs. Rigged up cementing crew. Ran cement. Rigged up loggers. Ran NCTL. Cut drilling line. Ran in 1-in. (2.5-cm) pipe to locate cement. Cement top at 180 ft (55 m).
March 11	Cemented casing in stages in the annulus. Used Class G cement with 20% silica flour, 25 sacks Kolite, 8% Gypseal.
March 12	Cemented final stages. Eight stages were required to complete job. Total volume was 8696 ft3 (246 m3).
March 13	Cut off casing. Welded on well head.
March 14	Nippled up BOP.
March 15	Pressure tested BOP. Obtained state approval to proceed.
March 16	Drilled out cement shoe. Drilled with full returns to 1605 ft (489 m), using gel and water and a 17-1/2-in. (44.5-cm) bit, No. 6. Got full returns. Mud: Weight 8.7 lb/gal (1.04 kg/L) Viscosity 30 Bottom hole assembly: Heavy wall pipe (7) 8-in. (20.3-cm) drill collars (3) Drilling jars 8-in. (20.3-cm) drill collars (5) 9-in. (22.9-cm) drill collars (4) 10-in. (25.4-cm) drill collars (2) 17-1/2-in. (44.5-cm) bit, Reed 21 J
March 17	Survey at 1605 ft (489 m) shows 1/2° deviation. Tripped in hole. Drilled in basalt to 1715 ft (523 m). BHA as before except with shock sub, reamers, and stabilizers just above bit. Mud: Gel/Benex Weight 8.7 lb/gal (1.04 kg/L) Viscosity 40
March 18	Drilled to 1931 ft (589 m). Surveys showed 1/4° deviation. Tripped out for bit No. 7.

TABLE A-1 (continued)

March 19	Drilled to 2144 ft (653 m) with full returns. Mud: Weight 8.9 lb/gal (1.07 kg/L) Viscosity 44
March 20	Drilled to 2339 ft (713 m). Conditioned hole for coring. Tripped out for core barrel.
March 21	Tripped in for core No. 1. Cut 21 ft (6.4 m), recovered 5 ft (1.5 m). Reamed corehole, drilled to 2436 ft (742 m). BHA as before, except bit No. 6 was rerun to ream corehole.
March 22	Drilled to 2507 ft (764 m), survey at 2438 ft (743 m) showed zero-degree deviation. Tripped out for core No. 2. Drilled with core barrel to 2518 ft (767 m). Core barrel jammed. Tripped out with core; cut 11 ft (3.3 m) recovered 8 ft (2.4 m).
March 23	Conditioned hole and rigged up for aquifer test. Ran in 800 ft (244 m) of 1-in. (2.5-cm) pipe. Set submersible pump at 802 ft (245 m). Ran aquifer test.
March 24	Continued test. Pulled pump. Measured water level recovery. Tripped in with bit No. 8. Drilled to 2739 ft (835 m). Survey showed no deviation.
March 25	Drilled to 3143 ft (958 m). Surveyed hole; 1/8° deviation. Mud: Weight 8.9 lb/gal (1.07 kg/L) Viscosity 47
March 26	Drilled to 3551 ft (1082 m). Survey showed 1/4° deviation.
March 27	Drilled to 3564 ft (1086 m). Tripped out for logs. Rigged up loggers. Logged borehole.
March 28	Finished logging. Rigged down loggers. Tripped in hole to circulate. Rigged up casing crew and ran 13-3/8-in. (35.6-cm) casing. Ran 87 joints P110, 72 lb/ft (107 kg/m).

TABLE A-1 (continued)

March 29	Finished running casing, set at 3559 GL. Rigged up loggers. Logged casing. Rigged down loggers. Rigged up cementers. Cemented casing with 4781 ft^3 (135 m^3) Class G cement with one-to-one D72, 40% D66, 3% D20, 0.3% D13.
March 30	Rigged up loggers and ran cement bond log.
March 31	Removed 20-in. (51-cm) BOPE. Rigged up for 12-1/4-in. (31-cm) hole.
April 1	Nippled up BOPE.
April 2	Worked on BOP leak.
April 3	Worked on expansion spool.
April 4	Completed repair of BOP. Ran 1500-psi (10.3-MPa) pressure test. Picked up bottom hole assembly and tripped in with 12-1/4-in. (31.1-cm) bit No. 9; HTC-OWV.
April 5	Drilled cement shoe. Drilled with water to 3661 ft (1116 m). Tripped out for core No. 3.
April 6	Drilled for core to 3713 ft (1132 m). Tripped out with core No. 3. Cut 52 ft (15.8 m), recovered 44 ft (13.4 m). Rigged up for Aquifer Test 2.
April 7	Ran aquifer test.
April 8	Completed aquifer test. Picked up BHA and tripped in with bit No. 10. Bottom hole assembly: Weighted pipe (7) 7-in. (17.8-cm) drill collars (3) Drilling jars 7-in. (17.8-cm) drill collars (4) 8-in. (20.3-cm) drill collars (5) Shock sub Stabilizer, RWP 9-in. (22.9-cm) drill collar Stabilizer 6 pt reamer 12-1/4-in. (31.1-cm) bit, HTC J44
April 9	Reamed out corehole. Drilled to 3955 ft (1205 m).
April 10	Drilled to 4445 ft (1355 m) with water.

TABLE A-1 (continued)

April 11	Drilled to 4796 ft (1462 m).
April 12	Drilled to 4839 ft (1475 m). Circulated and tripped out for core No. 4. Cut and recovered 39 ft (11.9 m).
April 13	Inspected downhole rotating hardware.
	All O.K. Picked up 2-in. (5-cm) pipe and rigged up for aquifer test No. 3. Set pump at 813 ft (248 m) GL. Started testing.
April 14	Aquifer test.
April 15	Completed test. Tripped out. Lost 814 ft (248 m) of 2-in. (5-cm) pipe with elevators and bails. Fished for pipe.
April 16	Caught fish and landed 39 joints of 2-in. (5-cm) pipe. Fished for elevator and bails.
April 17	Fished. Milled on iron. Reamed hole. Tripped in hole and drilled to 4900 ft (1494 m) with bit No. 11, 12-1/4-in. (31.1-cm); HTC J55.
April 18	Drilled to 5266 ft (1605 m) with water.
April 19	Drilled to 5689 ft (1734 m). Deviation at 5465 ft (1666 m) was 1-1/4°.
April 20	Drilled to 5804 ft (1769 m). Ran survey: deviation at 5679 ft (1736 m) was 2°. Tripped out to modify BOPE. Cut drilling line.
April 21	Tripped in with bit No. 12, HTC J55. Drilled with water to 6066 ft (1849 m).
April 22	Drilled to 6400 ft (1951 m). Survey showed 2-1/4° deviation at 6220 ft (1896 m).
April 23	Drilled with water to 6486 ft (1977 m). Deviation 2°. Tripped out for bit change. Rigged up USGS (Denver) loggers. Ran logs, including televiewer.
April 24	Completed logging and rigged down loggers. Tripped in with bit No. 13, HTC J55. Washed to bottom, pumped pill, drilled to 6552 ft (1997 m).
April 25	Drilled to 6860 ft (2091 m). Pumped pill periodically.

TABLE A-1 (continued)

April 26	Drilled to 7107 ft (2166 m). Survey showed 2-1/4° deviation.
April 27	Drilled with water to 7125 ft (2172 m). Tripped out for bit change. Tripped in with bit No. 14, washed to bottom. Drilled to 7245 ft (2208 m).
April 28	Drilled to 7521 ft (2292 m). Deviation 1-3/4°. Serviced rig.
April 29	Drilled to 7760 ft (2365 m). Serviced rig. Deviation 1-1/2°.
April 30	Drilled to 8010 ft (2441 m). Deviation 1-1/4°.
May 1	Drilled to 8295 ft (2528 m).
May 2	Drilled to 8946 ft (2590 m). Tripped out for bit change.
May 3	Cut drilling line. Tripped with bit No. 11 (rerun). Drilled to 8673 ft (2644 m).
May 4	Serviced rig. Drilled to 8934 ft (2723 m).
May 5	Drilled with water to 9177 ft (2797 m). Pumped pills.
May 6	Drilled to 9294 ft (2833 m). Deviation 3°. Serviced rig. Drilled to 9352 ft (2850 m).
May 7	Drilled to 9455 ft (2882 m). Survey showed deviation 2°. Serviced rig. Drilled to 9585 ft (2922 m).
May 8	Drilled to 9773 ft (2979 m).
May 9	Drilled to 9810 ft (2990 m). Circulated to clean hole. Tripped out for core. Tripped in with core barrel.
May 10	Cut core No. 5. Tripped out. Cut 6 ft (1.8 m), recovered 1 ft (0.3 m). Rigged up loggers and logged bore hole.
May 11	Completed logging. Rigged down to loggers. Tripped in with bit No. 13 (rerun). Drilled to 9910 ft (3021 m).
May 12	Drilled to 10,084 ft (3074 m).

TABLE A-1 (continued)

May 13	Drilled to 10,265 ft (3129 m).
May 14	Drilled to 10,324 ft (3147 m). Circulated. Tripped out for core No. 6.
May 15	Tripped out with core barrel. Cut 7 ft (2.1 m), recovered 1.5 ft (0.5 m). Tripped in with bit No. 13 (rerun). Washed to bottom and reamed core hole. Drilled to 10,333 ft (3150 m). Circulated and conditioned hole. Tripped out for water test.
May 16	Tripped in with drill pipe for logging. Rigged up loggers. Logged borehole. Began flow test using nitrogen lift.
May 17	Continued nitrogen lift. Logged the borehole. Completed nitrogen lift test.
May 18	Continued logging.
May 19	Completed logging.
May 20	Tripped in and conditioned hole. Pumped pill at 7100 ft (2164 m). Pulled two stands to 6860 ft (2091 m). Rigged up cementers. Pumped 50-ft (15.2-m) cement plug.
May 21	Tagged cement at 6798 ft (2072 m). Rigged up to run casing. Rigged up lay-down machine. Removed bottom hole assembly. Rigged up casing crew and ran 84 joints of S95 9-5/8-in. (24.4-cm) casing.
May 22	Continued running casing. Made up hanger tool. Hung liner top at 3262 ft (994 m). Cemented bottom of liner at 6796 ft (2071 m) with 251 ft^3 (7.1 m^3) of cement.
May 23	Tripped out with hanger tool. Picked up RTTS packer and tripped in to 3100 ft (945 m). Cemented top of liner with 241 ft^3 (6.8 m^3) Class G cement. Rigged down cementers.
May 24	Drilled out cement. Conditioned hole. Rigged up to log.
May 25	Washed to bottom. Conditioned hole for core No. 7.
May 26	Cut core No. 7 to 10,365 ft (3159 m). Tripped out with core barrel. Cut 32 ft (9.8 m), recovered 8 ft (2.4 m).
May 27	Released rig.

APPENDIX B

BIT RECORD

APPENDIX B

TABLE B-1. BIT RECORD

Bit No.	Size in. (cm)	Make	Type	Depth Out ft (m)	Footage ft (m)	Rotating Time hr
1	26-1/2 (67.3)	Hughes	OSC3AJ	164 (50)	124 (38)	32
2	26-1/2 (67.3)	Hughes	OSC3AJ	326 (99)	162 (49)	15
3	26-1/2 (67.3)	Hughes	OSC3AJ	609 (186)	283 (86)	25
4	26-1/2 (67.3)	Hughes	OSCIGJ	973 (297)	364 (111)	28
5	26-1/2 (67.3)	Hughes	OSCIGJ	1524 (465)	551 (168)	53
6	17-1/2 (44.5)	Reed	21J	1931 (589)	407 (124)	30
7	17-1/2 (44.5)	Reed	21J	2340 (713)	409 (125)	35
6R	17-1/2 (44.5)	Reed	21J	2507 (764)	146 (45)	9
8	17-1/2 (44.5)	Reed	S62J	3561 (1005)	1043 (318)	54
9	12-1/4 (31.1)	Hughes	OWV	3661 (1116)	100 (30)	6
10	12-1/4 (31.1)	Hughes	J44	4839 (1475)	1126 (343)	63
11	12-1/4 (31.1)	Hughes	J55	5804 (1769)	919 (280)	52
12	12-1/4 (31.1)	Hughes	J55	6486 (1977)	682 (208)	46
13	12-1/4 (31.1)	Hughes	J55	7125 (2172)	639 (195)	51
14	12-1/4 (31.1)	Hughes	J55	8496 (2590)	1371 (418)	106
11R	12-1/4 (31.1)	Hughes	J55	9810 (2990)	1320 (402)	122
13R	12-1/4 (31.1)	Hughes	J55	10333 (3149)	517 (158)	67
15	8-3/4 (22.2)	Security	H75GJ	Drilled out cement shoe		

APPENDIX C

CORING SUMMARY

APPENDIX C

TABLE C-1. CORING SUMMARY

Core No.	Date	From ft (m)*	To ft (m)	Cut ft (m)	Recovered ft (m)
1	March 21	2340 (713)	2361 (720)	21 (7)	5 (1.5)
2	March 22	2507 (764)	2518 (767)	11 (3)	8 (2.4)
3	April 06	3661 (1116)	3713 (1132)	52 (16)	44 (13)
4	April 13	4834 (1473)	4878 (1487)	44 (14)	39 (12)
5	May 10	9810 (2990)	9816 (2992)	6 (2)	1 (0.3)
6	May 14	10324 (3147)	10331 (3150)	7 (3)	1.5 (0.5)
7	May 25	10333 (3149)	10365 (3159)	32 (9)	8 (2.4)

*Referenced to kelly bushing (KB).

APPENDIX D

GEOPHYSICAL LOGGING SUMMARY

APPENDIX D

TABLE D-1. GEOPHYSICAL LOGGING SUMMARY

Date (1979)	Log Type	Interval ft (m)*
March 3	Temperature survey	40-1500 (12-457)
	Four-arm caliper	40-1500 (12-457)
	Dual induction-SFL	40-1500 (12-457)
	Compensated neutron formation density	40-1500 (12-457)
March 10	Uncompensated formation density before and after cementation	40-1500 (12-457)
March 27	Temperature survey	500-3500 (152-1067)
	Four-arm caliper	1500-3500 (457-1067)
	Borehole compensated sonic	1500-3500 (457-1067)
	Compensated neutron formation density	1500-3500 (457-1067)
March 28	Dual induction-SFL	1500-3500 (457-1067)
March 29	Uncompensated formation density before and after cementation	22-3500 (7-1067)
May 11	Temperature survey	3500-9700 (1067-2957)
	Borehole compensated sonic	3500-9700 (1067-2957)
	Dual induction-SFL	3500-9700 (1067-2957)
May 16	High-resolution temperature survey	9700-10,200 (2957-3109)
May 18	Dipmeter-fracture identification	9700-10,200 (2957-3109)
	Borehole compensated sonic	9700-10,200 (2957-3109)
	Dual laterolog	8776-10,094 (2675-3077)
	Compensated neutron formation density	8776-10,094 (2675-3077)

TABLE D-1 (continued)

Date (1979)	Log Type	Interval ft (m)*
May 24	Uncompensated formation density before and after cementation	3010-7172 (917-2186)
June 15	Repeat formation tester	3559-10,333 (1085-3149)
August 14	Perforating depth control casing collar	40-6300 (12-1920)
	Perforation record	40-6400 (12-1951)

*Referenced to ground level (GL).